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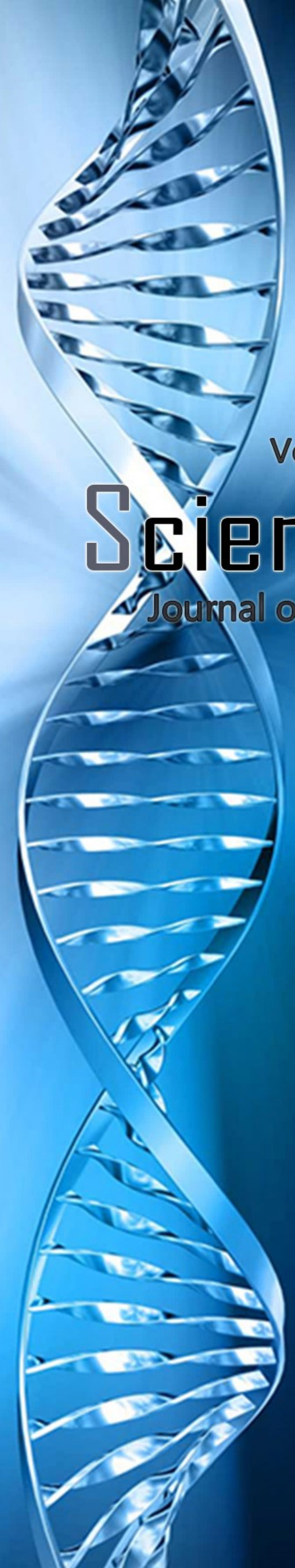

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Idealization, scientific realism, and the improvement model of confirmation

Billy Wheeler*

Abstract

That many of our most successful scientific theories involve one or more idealizations poses a challenge to traditional accounts of theory confirmation. One popular response amongst scientific realists is the "Improvement Model of Confirmation": if tightening up one or more of the idealizations leads to greater predictive accuracy, then this supports the belief that the theory's inaccuracy is a result of its idealizations and not because it is wrong. In this article I argue that the improvement model is deeply flawed and that therefore idealizations continue to undermine "success-to-truth" arguments for scientific realism.

Keywords: idealization; scientific realism; theory confirmation; bootstrapping; the no miracle argument.†

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1 Introduction

Scientific realists contend that the predictive and explanatory success of a scientific theory is a good guide to believing in its truth or approximate truth. However, many of our most successful scientific theories involve laws with one or more idealizations and are therefore known to be false. Famous examples of idealizations include point masses, rigid rods, infinite densities, and perfect vacuums. A common response among realists is that such theories can still be believed to be approximately true because tightening up one or more of the idealizations leads to greater predictive accuracy. This provides evidence—so the account goes—that a non-idealized true theory exists that our best current theory approximates.

This account, which I will dub the "Improvement Model of Confirmation", is most often associated with Ronald Laymon (1980, 1985, 1989, 1995); but other versions of it can be found in Leszek Nowak (1980), Ernan McMullin (1985), James Derden (2003), Michael Weisberg (2007) and Jose Rolleri (2013). That it continues to go unchallenged is surprising, as it seems to me to be deeply flawed. In this short article I assess the Improvement Model of Confirmation and raise what I take to be its most fundamental difficulties. I start by explaining why well-known approaches to confirmation struggle to accommodate scientific theories with idealizations and outline the most essential features of Laymon's version of the improvement model. I then raise a number of objections to it before considering a potential response courtesy of Clark Glymour's condition for bootstrap confirmation. It will be shown that this addition ultimately fails to save the improvement model. As a result, the fact our most successful theories to date involve idealizations undermines "success-to-truth" arguments and poses a serious challenge to scientific realism.

2 The improvement model of confirmation

Traditional models of confirmation do not fare well in explaining how theories that include idealizations are accepted in scientific practice. This can be illustrated by appealing to a well-known idealized theory: the kinetic theory of gases. At the heart of this theory is the Boyle-Charles law, typically written as:

$$PV = nRT$$

Where P is pressure, V is volume, T temperature, n number of moles of gas and R the gas constant. This law is said to hold true only for gases that satisfy certain idealization assumptions, the most important of which include:

I_1 = The particles of gas are small hard spheres that occupy no volume

I_2 = Each particle collision is perfectly elastic and frictionless
I_3 = There are no intermolecular forces between the particles or long-range forces acting on the particles
I_4 = The gas is homogenous and the particles indistinguishable

As none of these assumptions are true for any empirically observed gas, simple inductive confirmation by instances is ruled-out because—strictly-speaking—there are no instances of gas that satisfy these assumptions. Bayesian confirmation theory also struggles to explain how the theory can be supported by observation. According to Bayesians, prior beliefs in a hypothesis ought to be revised consistently with Bayes' Theorem:

$$P(H/E) = P(E/H) \times P(H) / P(E) \text{ if } P(E) > 0$$

In the theorem, P(H) is a measure of the experimenter's prior probability that H is true. However, if H is a prediction based on an idealized theory, then the experimenter already knows for certain that H is false. In other words, that its prior probability is 0. Regardless of whether E occurs the probability of H given E is also 0 and therefore confirmation by E cannot take place.

The hypothetico-deductive method and its derivatives equally fall silent when it comes to idealized theories. In its simplest form it claims that confirmation is the reverse relation of deduction: if a hypothesis H can be deduced from a theory T using background assumptions and initial conditions, then T receives confirmation provided H is empirically observed. But once again we know that our prediction based on an idealized theory will not match that observed. The only time this might happen is if there is a fortunate cancelling out of idealizations that only an unfortunate practitioner would take as confirmation of their theory.

A staple response among realists is that confirmation of idealized theories can be attained using the methods above if we infer not to the truth of the theory but to its "approximate truth". The world is a complicated and messy place, so they argue, and idealization assumptions are needed to make prediction computationally tractable. Provided the experimental observations do not deviate too much from the theory, then we can say it has been confirmed to be approximately true.

The problems with this reply are twofold. Firstly, a measure of approximate truth has been notoriously difficult to pin down and no widely accepted theory exists that allows us to say just how much truth a theory contains. Secondly, even if such a measure were possible, it raises questions about how much approximate truth is needed for rational acceptance. As Chuang Liu (1999) has made clear, a useful idealization need not always be a good approximation: whilst $sin\theta = \theta$ can be assumed for very small angles in a pendulum, larger angles produce unacceptable deviances. There is only a short range of initial conditions that provide "good enough" predictions from idealized theories; but why should these be said to be supporting evidence when other larger error-inducing setups are ignored?

As a remedy to some of these problems several realist philosophers have proposed that idealized theories can be confirmed if the measure of approximate truth is made *relative* to a non-idealized true theory. I will be focussing here on Laymon's account as he has developed it in the most detail over the past three decades; however, I am confident that the problems inherent in his account carry over to all other versions.

The basic strategy goes that if a perfectly true theory exists with no idealizations, then it stands to reason that another theory (which contains systematic deviances from it) is approximately true relative to that theory. For example, in the case of the Boyle-Charles gas law, the final true non-idealized theory is one that allows for things such as the size of the molecules, their intermolecular forces and energy escaping through their collisions. Of course, in practice, scientists are in the dark about the final true theories, but they do have their idealized theories. If it can be shown that these theories are "in-principle improvable", so that when their idealization conditions have been removed, we are left only with a perfectly true theory, then we can infer their approximate truth relative to that final theory.

Laymon sums up this intuition in what we might call his "Improvability Principle":

Improvability Principle: *If a set of fundamental laws is true, then we can make in principle sufficient corrections so as to yield better predictions*. (1989, 359)

The reason why Laymon only calls for "in-principle improvability" is down to the fact that there are limitations to a scientist's computational and practical resources that make it almost impossible for deidealization to be carried out beyond a few steps. Nonetheless, Laymon argues that even though such improvements are possible in only a small number of cases, this provides inductive evidence that they are fully improvable in principle (1985, 156-157; 1989, 359).

From the Improvability Principle Laymon derives two rules, one for confirmation and the other for disconfirmation:

Rule-1: *A scientific theory is confirmed (or receives confirmation) if it can be shown that using more realistic idealizations will lead to more accurate predictions*.

Rule-2: *A scientific theory is disconfirmed if it can be shown that using more realistic idealizations will not lead to more accurate predictions*. (1985, 155.)

Laymon does not intend these rules to stand alone: they are meant to supplement one's preferred method of confirmation for ordinary non-idealized theories. Nevertheless, as I will now argue, these rules cannot help a realist explain how idealized theories are confirmed in scientific practice.

3 A critique of the improvement model

If the Improvability Principle is correct then finding instances from the history of science that satisfy rules 1 and 2 would provide a good case for arguing that our current theories are approximately true vis-a-vis some unknown true non-idealized theory. But why should somebody already sceptical of realism accept the principle in the first place? At present, scientists have never uncovered a fully de-idealized theory, and so there are no complete examples to support its validity. In fact, I suspect that any intuitive appeal the Improvability Principle has comes not from the existence of true theories discovered by scientists but from a much weaker principle which we might call the "Reverse Improvability Principle":

Reverse Improvability Principle: *If we can make in principle sufficient corrections so as to yield better predictions, then a set of fundamental laws is true.*

This principle does not beg the question against the antirealist by already assuming the existence of true scientific theories. It also has strong intuitive appeal: if a theory which is false has been corrected, surely this provides evidence that some true theory about the target phenomena exists to be discovered? Imagine I am playing a game of guessing how many sweets are in a jar and my initial guess is 200. Upon being told that I am wrong, I then guess 250. If I have been told that my new guess is false but more accurate, surely this provides reason for thinking that it is only a matter of time before my correction process arrives at the true figure?

Sadly, for the realist the Reverse Improvability Principle lets in too much and is too weak a foundation for realism. To show why, first consider the fact that any false theory T_f can be in principle corrected for to make it true. Even statements of contradiction can be corrected for by removing the offending conjunct. To find inductive evidence that a false theory can in principle be improved is therefore relatively easy. This means almost all false theories approximate some corrected true theory T_t and are therefore approximately true relative to that theory. As a consequence, this has the unhappy result that one can be a realist about almost any theory—provided it has been corrected a sufficient number of times.

Laymon never specifies just how many corrections are sufficient, but going on the historical cases he cites, it does not seem to be that many. A realist about idealized theories might respond by saying that the problem with the argument above is that it does not start with a scientific theory that we *know on independent grounds* to be one that is idealized away from reality. In other words, rules 1 and 2 are not meant to apply to *all* empirically false theories but only to those that have *known idealization conditions*. For example, background assumptions such as those from atomic theory tell us that nature is not made up of point-sized particles and that therefore any falsity produced by this part of the theory is due to idealization. This gives us independent grounds for thinking that the kinetic theory of gases and the Boyle-Charles law are false because of idealization and not for any other reason. Our background assumptions, therefore, can be used to constrain the number of false theories that rules 1 and 2 are meant to apply to.

The problem with this response is that short of knowledge of the final true theory, we cannot say that our current theory is false because it gets things drastically wrong due to 'brute error' or because it is the result of using an idealization. In fact, even if a clear distinction between these two ways in which a theory can be false exists, the problem still stands. Consider the following amendment to the Boyle-Charles law:

$$PV = nRT + k$$

Where k is some additive constant not significantly different in magnitude from the largest error produced by the idealizations. Then this theory, which is a hybrid containing some idealized falsity and some brute-error falsity, has been corrected or improved by scientists the same number of times as the Boyle-Charles law and therefore takes an equal share of confirmation—even though removal of all the idealization conditions to this law would not lead to some, yet undiscovered, true theory.

4 A bootstrapping response?

Laymon considers whether his original Improvement Model can be strengthened with the addition of a bootstrapping condition along the lines of Glymour (1980). This additional condition provides further reason, he argues, that the improvements are due to deidealization and that therefore the underlying theory approximates a true theory:

> Consider a situation where the relative realism of idealizations I_1 and I_2 is unknown or indeterminate with respect to some existing background

> standard...Say that, with respect to phenomenon P, idealization I_2 produces the better prediction. Therefore, assuming the truth of T, our judgement is that I_2 is the more realistic idealization. Now, let it be the case that T, I_1 and I_2 can be brought to bear on some other phenomenon P'. Then the judgement of the relative superiority of I_2 means that T, if true, will produce a better prediction about P' with I_2 than with I_1. If such a better prediction is not produced, we have reason to believe that T is false. The method is appropriately called bootstrapping because we first use the theory to generate an appraisal of relative realism; then we test the theory using that appraisal.
> (Laymon 1985, 166)

The idea seems to be that we rely on our main theory and any other background assumptions to make a prediction about the relative realism of two idealization assumptions. If that prediction is borne out in the experimental data, then we use that better idealization to confirm the approximate truth of the underlying theory. It is an example of bootstrapping because we are relying on the theory to provide an explanation of why one idealization assumption is more realistic than another.

Can the addition of a bootstrap condition like this resolve some of the worries raised in section 3? Let us return to the Boyle-Charles gas law and the underlying kinetic theory of gases and let us compare two different idealization assumptions I_1 and I_2:

I_1 = The particles of gas are small hard spheres that occupy no volume
I_2 = The particles of gas are small hard spheres that occupy n volume where $n > 0$.

These idealization assumptions cannot both be true: either the particles take up space or they do not. Given some experimental setup and observations, we might make two contrasting predictions about the temperature of the gas. The first H_1 predicts a temperature based on the Boyle-Charles gas law and the second H_2 predicts a temperature using a correction for molecular size (as in the van der Waal's equation). If H_2 is closer in value to the actually measured temperature than H_1, then we can say that we have evidence that the error is caused by a genuine idealization and not for some other fault in the theory of gases.

The problem with Laymon's version of the bootstrap condition is that it is too imprecise to provide warrant for the underlying theory. Even if the relative realism predictions pan out across a wide range of experimental setups, the fact Laymon's account does not require a precise match means it can be too easily explained by other means. For instance, just because the use of I_2 gives us a better prediction (in terms of being closer to the actual observed value), this does not provide much evidence for the truth of the underlying theory. Antirealists could agree that using I_2 produces a theory which is more useful or more empirically adequate—but it is a large jump to go from there to the truth of the underlying explanation.

A bootstrap condition closer to what Glymour originally had in mind might do better. Instead of using the background theory to predict the relative realism of two idealizations, what the realist needs is a prediction of the precise value a law will deviate from the values observed. The odds of the size of deviance matching that predicted when the underlying explanation was at fault seems remote and therefore gives significant reason to believe in the truth of the underlying theory. This is more in keeping with Glymour's original account because it requires the theory, idealizations, and observations to be consistent with one another, not just in terms of *best* fit but *actual* fit.

In practice this would require using our theory and idealizations to make a prediction about what the error size would be between our idealized theory and the actual measurement. Of course, for a theory with multiple idealizations it is going to be difficult to confirm the prediction when the observed value will be affected by other perturbing factors not incorporated into the prediction. And here is where a bootstrapping response ultimately comes unstuck. For it to be successful we would need to do either one of two things: (1) make predictions for the errors of *all* the idealization assumptions or (2) screen-off the effects of other perturbing factors. The first of these is not feasible by assumption because we have already seen that scientists lack the computational resources required to deidealize theories in their entirety. The second is also not possible because, as McMullin (1985, 267) reminds us, not all idealization assumptions can be screened-off through good experimental design. If our idealization is that the light waves are passing through a "perfect vacuum", then although we might be able to approach this, we can never truly replicate it. Experiments designed to screen other idealizations such as "the solar system is a two-bodied system" and "the pendulum is infinitely long" are clearly not feasible.

5 Conclusion

The fact a false theory can be improved in practice gives little reason to support the idea that it approximates a true theory. Many false theories can be improved in this way and if this counts as valid confirmation realists would need to accept as true too many false theories. Attempts to limit the falsity to only those that involve legitimate idealizations fails because there is no practical way of knowing whether the deviances in our theory are caused by idealizations or because our underlying theory just happens to be wrong.

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Insights in how computer science can be a science

Robert W.P. Luk♦

Abstract

Recently, information retrieval is shown to be a science by mapping information retrieval scientific study to scientific study abstracted from physics. The exercise was rather tedious and lengthy. Instead of dealing with the nitty gritty, this paper looks at the insights into how computer science can be made into a science by using that methodology. That is by mapping computer science scientific study to the scientific study abstracted from physics. To show the mapping between computer science and physics, we need to define what is engineering science which computer science belongs to. Some principles and assumptions of engineering science theory are presented. To show computer science is a science, we presented two approaches. Approach 1 considers computer science as simulation of human behaviour similar to the goal of artificial intelligence. Approach 2 is closely related to the actual (scientific) activities in computer science, and this approach considers computer science based on the theory of computation. Finally, we answer some of the common outstanding issues about computer science to convince our reader that computer science is a science.

Keywords: Computer Science, Artificial Intelligence, Theory of Computation, Engineering Science, Science.[1]

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1. Introduction

There are many famous scholars who have directly or indirectly thought that computer science is not a science. For example, Frank Harary (Weinburg, 2001) indicated that any subject that has the name, science, in it is guaranteed to be not a science including the subject, computer science. The Nobel Laurate, Richard Feynman (Dlouhy, 2011), indicated that computer science is engineering. He thought that he slipped into engineering from science (as he was a physicist) because he started to work on quantum computing. Abelson (MIT OpenCourseWare, 2009) of MIT gave a lecture indicating that computer science is not about computer and is not a science. He concluded that computer science is a terrible name. More recently, Krebsbach (2015) wrote a paper specifically to say that computer science is not about computers and is not science (in the ordinary sense of the word).

Another camp of this issue considers that computer science is a science, and members of this camp are just as illustrious as the other camp. Herbert Simon who is a Nobel Laureate in economics and an ACM Turing award recipient advances the notion of the sciences of the artificial (Simon, 1969) in which computer science is one such science. Later, Newell (another ACM Turing award recipient) and Simon (1976) consider that computer science as an empirical science (Polak, 2016) based on empirical enquiry like many natural sciences. Their basic logic is that computer scientists are engaged in the study of phenomena about computers and scientific study is about studying phenomena, so computer science is a kind of (empirical) science. Peter Denning, who was the ACM president, does not just advance computer science as science (Denning, 2005) based on general principles (Denning, 2003) but as natural science (Denning, 2007). According to Denning's view, he considers that in natural sciences (like biology), information processing is abundant and that the study of natural information processing in biological systems for example qualifies computer science to be called a natural science.

It seems that most of the proponents that computer science is science are prominent computer scientists while those that deny computer science is a science include computer scientists as well as scholars of other fields like physics and mathematics. To convince all that computer science is a science, it needs to explain why, and this has been done for information retrieval (Luk, 2020). The underlying explanation that information retrieval is a science is because it is like physics which is a well-known science subject. Similarly, to explain why computer science is a science is to show how computer science is like one science subject, say physics, and then claim computer science is science. Since this has been done for information retrieval, our focus on showing computer science is science will focus on how to map computer science to science instead of answering "why" which has been explained before. Luk

(2020) tried to muster as many pieces of evidence as possible to support the notion that information retrieval is a science and this turned out to be a tedious task as well as sometimes obscuring the objective to show that information retrieval is science. Therefore, we take a slightly different methodology by assuming that the reader is familiar with the paper by Luk (2020) and proceeding to highlight how computer science is a science by discussing some of the controversial issues when mapping some of the computer science aspects to science properties in scientific study (Luk, 2017), which are abstracted from physics. In this way, we can keep a clear track of our objective to show computer science is science, and if the reader is in doubt, (s)he can consult the paper by Luk (2020) to investigate in order to further establish that computer science is science.

The rest of this paper is organized as follows. Sect. 2 presents a short literature review about what is computer science. Sect. 3 delineates how we can show a discipline is science in the general case. This section indicates clearly which principles and assumptions are discussed later and which ones are skipped because they may hold in a self-evident way. Sect. 4 presents what is engineering science because computer science is thought to belong to engineering science. Apart from defining what is engineering science, some principles and assumptions are also provided. Sect. 5 presents the two approaches to show computer science is a(n) (engineering) science. The first approach shows computer science is a science by considering computer science as simulation of human behaviour. Next, we present the second approach which considers how the theory of computation can be used to help in showing that computer science is science. This approach reflects better the (scientific) activities in computer science. Sect. 6 discusses some outstanding issues for example why we prefer the name computer science over computing science. Finally, Sect. 7 provides the concluding remarks.

2. Related work

Wegner (1976) cites four influential definitions of computer science at the time. They are "(1) computer science is the study of phenomena related to computers (Newell, Perlis and Simon, 1967), (2) computer science is the study of algorithms (Knuth, 1968), (3) computer science is the study of information structures (Wegner, 1968) and (4) computer science is the study and management of complexity (attributed to Dijsktra by Wegner, 1976)". Wegner (1976) boils these four definitions down to three traditions of computer science, corresponding to three different periods in computer science. The three traditions are empirical tradition exemplified by definition (1), the mathematical tradition (McCarthy, 1962; Knuth, 1974) exemplified by definitions (2) and (3), and the engineering tradition exemplified by definition (4). Eden (2007) coins these three traditions as paradigms: the rationalist paradigm (corresponding to the mathematical tradition), the technocratic paradigm (corresponding to the engineering tradition) and the science paradigm (corresponding to the science tradition). It is thought that all three paradigms or traditions exist in computer science so that it is difficult to classify computer science into some existing discipline.

Recently, Rapaport (2017) tries to tackle the question, what is computer science, by surveying various ways computer science can be defined or described, as well as trying to develop his own way of defining computer science discipline. This leads him to consider that computer science may belongs to a new type of engineering or a new type of science or an exclusive-or of these two general disciplines. However, the exact nature of this new type of engineering or science is unknown or not described in full by him, even though we are a kind of concur with him as we develop the (new) discipline of engineering science. He concludes that "our exploration of the various answers suggests that there is no simple, one-sentence answer to our question (i.e., what is computer science). Any attempt at one is no better than the celebrated descriptions of an elephant by the blind men" (Rapaport, 2017).

Perhaps, the definition of computer science in the book about algorithms and data structures by Miller and Ranum (2015) is close to our definition of computer science. Miller and Ranum (2015) consider that "computer science is the study of problems, problem-solving, and the solutions that come out of the problem-solving process". However, they do not mention that the problem-solving process involves a programmable device as our definition of computer science requires, and they do not further develop a framework of understanding computer science based on problem solving as in this paper. Also, they quickly turn their attention to algorithms and they proceeded to consider that "computer science can be thought of as the study of algorithms", which concur with one of the influential definitions of computer science. Therefore, even though Miller and Ranum mention that computer science is related to problem solving, they do not develop this idea more fully as in this paper. This is similar to Margolis and her colleagues in 2008 who quote a "spot-on" definition of computer science from a users' guide for Stanford University computer science majors, i.e., computer science was "the science of solving problems with the aid of a computer" (Margolis et al., 2008). Again, there is no further elaboration by Margolis et al. about this definition, so there is no framework for this understanding of computer science as a scientific discipline.

3. Methodology to show a discipline is science

Rapaport (2020) spends about several hundred pages to discuss philosophy of computer science. In here, we cannot spend a similar number of pages to convince people that computer science is science. Instead, we only highlight the important aspects that makes computer science a science and leave out the nitty gritty to the reader to fill in the missing link himself or herself if (s)he is in doubt. Therefore, this paper focuses on the insights that we can gain from making computer science a science rather than showing the evidence to support the claim.

We focus our description of computer science on the computer and programming/computation as these are thought to be the shared aspects in computer science. For example, software engineering is about how programs are written so this is related to our notion of computer science. Another example is in the applications of computer science in which computers are used to solve problems for the user, so this relates to our notion of computer science. Other examples include interests in computational complexity where the efficiency of the programs or algorithms is analysed, which is related to our notion of computer science. However, we do not divert our attention to human-computer interface even though it is related to our notion of computer science as how computers present information to users for effective and efficient communication is important in computer science. This is because interface is not thought to be the core shared part of computer science, which does not affect our claim that computer science is science, so we will not discuss it in here.

Our methodology to show that a discipline is science is based on the work on showing information retrieval is science by Luk (2020). First, we try to define what is the aim of the concerned area of study based on instantiating the aim of scientific study in the context of that study. In this way, we establish that the aims of the various science disciplines are similar to each other and the difference is only that the aim is applied in the context of the particular science discipline. This helps to establish the unity of the different scientific disciplines.

Second, our methodology tries to show that computer science is a mature science (Luk, 2010). Therefore, we need to show that computer science has a framework of theory, model, experiment and physical situation arranged in some kind of hierarchy with inter-connections. This framework is important for mapping the computer science knowledge to knowledge in other scientific disciplines. It is important as these are shared commonalities between different scientific subjects that enable the different subjects to claim that they belong to science.

Third, the principles (Luk, 2017) of scientific study (Table 1) are applied to engineering science and/or computer science. Since some of these principles are obviously applicable, we will not discuss them further in this paper. For example, the principle of immutable laws and principles is applicable to engineering science as the laws and principles are supposed to be unchanged once formulated in engineering science and computer science.

No.	Principle Name	Discussed Here	No.	Assumption Name	Discussed Here
1	Generalization	Sect. 5.1.2 & Sect. 5.2	1	Sufficiently trained	No
2	Modelling accuracy	Sect. 5.1.2 & Sect. 5.2	2	Accurate communication	No
3	Empiricism	Sect. 5.1.2 & Sect. 5.2	3	Unbiased, accurate observation	No
4	Theoretical objectivity	No	4	Adoption of the aim of scientific study	No
5	Theoretical consistency	No	5	Causality of phenomenon	Sect. 5.1.2 & Sect. 5.2
6	Immutable laws and principles	No	6	Explanatory power	No
7	Objective experiment	No	7	No magic	Sect. 5.1.2 & Sect. 5.2
8	Reliability	No			
9	Investigation objectivity	Sect. 5			

Table 1: The principles and assumptions of scientific study (as detailed in [Luk, 2017] and as mentioned in [Luk, 2020]) with the indication on whether they are discussed in this paper about their applicability to computer science.

Fourth, the assumptions (Luk, 2017) of scientific study (Table 1) are assumed to hold for engineering science and computer science. Again, we have indicated in Table 1 which assumptions are obviously applicable and so we will not discuss their applicability in engineering science and computer science. For example, the engineering scientists and computer scientists are obviously assumed to be sufficiently trained to carry out the scientific investigations, so it is not necessary for us to discuss whether assumption 1 (in Table 1) is applicable to engineering science or computer science.

Fifth, when Luk (2020) shows that information retrieval is science, he cited papers relating to the different activities in the interaction model of scientific study (Figure 1 of [Luk, 2020]). In here, we do not make this kind of citations as we feel that it is fairly self-evident that engineering science and computer science follows the interaction model of scientific study. If in doubt, one can consider information retrieval as a sub-discipline of computer science, and the citations made in Luk (2020) can be considered as supporting evidence that computer science and therefore engineering science (because information retrieval is a branch of computer science which in turn is a branch of engineering science) follows the interaction model of scientific study.

4. Engineering science

To answer the question what is engineering science (see [Boon, 2008] for some background), we need to know what engineering is. Engineering can be considered as a problem-solving activity. However, it is not any type of problem-solving activity but that it involves (a) a technical problem and (b) using a device to solve a problem. Therefore, we can describe engineering as using a man-made device to solve a technical problem. So, how can such a discipline or its sub-discipline be considered as a science?

4.1 Engineering science as applied science

One way that engineering can be considered as a science is that in the technical-problem solving activity, it made use of scientific knowledge to solve the problem. Effectively, some aspect of engineering science is considered as an applied science where scientific knowledge is applied to solve technical problems. For example, in mechanical engineering, when Newton's laws of motion are used to solve some technical mechanical problems, then we would consider that this type of problem-solving activity as mechanical engineering science. Another example is in electrical engineering where ohm's law is used to calculate the voltage or current of an electrical device like the light bulb. This kind of problem-solving activity can be considered as electrical engineering science.

4.2 Engineering science as pure science

Another type of engineering science is that it is similar to pure science. What is pure science? Here, we follow Luk's idea (Luk, 2010; 2017) that pure science has a knowledge structure (called a framework) similar to physics with theory, model, experiment and physical situation (in a hierarchy). Therefore, for some engineering science to be a pure science, the knowledge of the engineering science needs to be arranged into a hierarchy of theory, model, experiment and physical situation. The theory would contain the principles which are applied to build models, the predictions of which are measured in experiments. For example, the probability theory of information retrieval (Luk, 2020) has the probability ranking principle (PRP), which is applied to build retrieval models based on TF-IDF term weights, the prediction of which is specified by the PRP (Luk, 2020). The prediction error is the optimal accuracy specified by PRP minus the actual accuracy of the retrieval model. The actual accuracy is measured in terms of the recall and precision of the ranked list produced by the retrieval model. Therefore, we can think of information retrieval as a (pure) engineering science.

In engineering science in general, the prediction is about whether the device can solve the problem in the problem-solving activity. Therefore, the prediction accuracy is about the prediction of solving the problem. Typically, we assume that the device can solve the problem. So, this is the assumption in engineering science which we call the *universal solvability assumption* in engineering science theory. If we make such an assumption, then we predict that the problem is solved (i.e., 100% solvability) by our device. If we can only solve it partially say 25%, then the prediction error is what we predicted minus 25% (i.e., 100% - 25% = 75%). Furthermore, better devices are those that have better prediction errors or those that are closer to the universal solvability assumption. By formulating the prediction in this way, better devices are similar to better scientific models that have better prediction accuracy (or less prediction errors) so that making better devices is similar to building better scientific models, conforming to the aim of scientific study that tries to obtain good quality scientific knowledge (e.g., highly accurate scientific model). Therefore, in this sense, engineering science is like a science.

Engineering science theory contains several general principles. Some of them are related to problem solving activity since engineering science is about problem solving. Specifically, in order to know what the problem is, information needs to be gathered. Gathering information is equivalent to reducing the uncertainty of constructing the device (according to information theory [Shannon, 1948]). So, our most general principle in engineering science is the *minimum uncertainty principle* which states that a problem should be solved with as minimum uncertainty as possible. This principle was identified by Klir (Balsamo et al., 2000) and his co-workers (Klir and Wierman, 1999), but it has not been regarded as the most general principle before. It is rephrased as the above to adapt to engineering science.

While the minimum uncertainty principle guides the gathering of information, it is necessary to know what kind of information to collect. In general, the user has encountered some problem so that the user wants to make use of the device to solve his/her problem. Therefore, the first step is to gather information about the problem. Gathering information about the problem also helps us to gather information about solving the problem. So, the purpose of gathering information is to help us to solve problems, in order to lead to success.

Therefore, our next principle is about the identification of success, as the information gathered tells us how to become successful. The *success identification principle* states that formulating the right problem to be solved by a cost-effective solution is a step towards success. Here, the success of the application is based on solving the problem of the user. Notice that it is not any problem of the user but the "right" problem of the user. The word "right" means that the problem is not related to some superficial problem or epiphenomenon. Instead, this should be a real problem experienced by the user. Because the real problem is not just some superficial problem that can be easily identified, the information gathering process for the problem may need to take some time to find out the real problem of the user, who may not be able to articulate the problem to the engineering scientists. The "real" problem may be some sub-problem of the original problem rather than all the sub-problems, as some of the sub-problems may be insignificant. In this case, identifying the right sub-problem to solve is critical in the problem-solving process. The success identification principle would lead us to the universal solvability assumption since we have a cost-effective solution that can solve the problem, so that the predicted cost-effectiveness is 100%. Given the universal solvability assumption, why do we still want a cost-effective solution? As allured earlier, we are solving the right problem of the user and typically the user is concerned about the cost-effectiveness of the solution as a solved problem that takes a million years to solve is not useful to many users. Therefore, the success identification principle asserts that the predicted cost-effectiveness of the solution should be 100% (if we have the ideal solution for the user).

There is a concern whether the engineering science knowledge is testable since scientific knowledge is testable. For example, it is assumed in the universal solvability assumption that a problem can be solved. For some problems, one can develop an algorithm or solution that guarantees the problem is solved so that the assumption is guaranteed to be fulfilled. Therefore, for some problems, the engineering science theory may not be testable. Note that we have a success identification principle in the engineering science theory. This principle predicts that we can obtain a solution that has 100% cost-effectiveness. This prediction is required because we want to change the prediction accuracy into a predictor of problem-solving ability so that the higher the prediction accuracy the higher the problem-solving ability. Therefore, if we can design our cost-effectiveness measure to be normalized between zero and one, then we can make a man-made device to solve the problem with X% cost-effectiveness. Since the prediction of the cost-effectiveness by the success identification principle is 100%, the prediction error of the man-made device is 100%-X%. Therefore, the higher the cost-effectiveness of the man-made device is, the lower the prediction error and the higher the prediction accuracy of the cost-effectiveness. Why do we focus on predicting the cost-effectiveness instead of the solvability of the device, this is because some device can guarantee to solve a problem but it may take a long time or use an unimaginable amount of resources (e.g., storage). By requiring the solution to be cost-effective, those solutions that guarantee to solve the problems may not have high cost-effectiveness even though their solvability is 100%. In this way, the success identification principle is testable since we need to build the device, measure its cost-effectiveness before we can say that it has 100% cost-effectiveness as predicted by the success identification principle. As a result, the principle of empiricism is upheld (Table 1).

In engineering science theory, we also have the *no-garbage-in principle*. This principle is originated from garbage-in-garbage-out. The idea is that we should not input garbage into our device because it would produce garbage output that would not solve our problem which would contradict the universal solvability assumption. Therefore, we apply the no-garbage-in principle so that we do not feed garbage into our device when solving our technical problem. This principle is universal meaning that it is applied to any device for any problem.

An example of pure engineering science subject is information retrieval (Luk, 2020). Basically, information retrieval is an engineering science discipline (Fuhr, 2012) which makes use of a device to find documents from a collection. It is like a pure engineering science discipline as discussed in the paper by Luk (2020) where the universal solvability assumption predicts the retrieval accuracy is 100% instead of the probability ranking principle. This can ensure even non probabilistic retrieval models can be included in the prediction of retrieval accuracy so that more models can relate retrieval accuracy with prediction accuracy. Consequently, the retrieval performance is related to one aspect (i.e., accuracy) of the scientific knowledge (i.e., the retrieval model). Another example of pure engineering science is computer science which we are going to discuss in Sect. 5.

4.3 The aim of engineering science

What is the aim of engineering science? It should be similar to the aim of science or the aim of scientific study. Therefore, borrowing from the aim of scientific study (Luk, 2017), we state:

> **Definition**: the aim of engineering science is (i) to produce good quality, general, objective, testable, complete scientific knowledge (as defined in [Luk, 2010]) of technical problem-solving using a man-made device (model) to solve the problem, and to (ii) monitor/apply such knowledge.

Note that the man-made device usually has a model. In fact, most engineering science starts with designing the model of the man-made device first before the physical device is built. So, the conceptual problem solving is done using the device model whereas the physical problem solving is done by the physical device. The aim is about the scientific knowledge of technical-problem solving.

Since the device is used to solve the problem, knowledge of problem solving involves in understanding technically the device on how the problem is being solved with it. This scientific knowledge needs to be organized into theory, model, experiment and physical situation similar to a scientific discipline like physics.

The quality of scientific knowledge needs to be measured in terms of accuracy, reliability, consistency, etc. While reliability and consistency are relatively easy to follow for engineering science, getting more accurate results do not directly imply getting better solutions. Therefore, in the previous section, we formulated the universal solvability assumption so that more accurate solution implies more effective solution, thus establishing a direct link between building better models to constructing better devices in solving problems. An engineering science should also look for general, objective scientific knowledge that is testable. Therefore, engineering science should look for general scientific knowledge (like principles) rather than a set of facts. Engineering science should also disseminate its findings so that the scientific knowledge is shared for objectivity. Engineering science should make devices that are testable so that it has some relations to physical reality. Therefore, engineering science has an aim that is similar to the aim of scientific study. Note that this aim belongs to the engineering science theory according to Luk (see Figure 3 in [Luk, 2017]).

Some scientists (e.g., Feynman in [Dlouhy, 2011]) may object that the engineering science is about using a man-made device to solve problems because the study is about the man-made device which is a human artifact instead of natural phenomena. However, if we use such a criterion to demarcate science and non-science, then what usefulness does it serve to demarcate science in this way. Demarcating science in this way does not make the science subjects to be exact science (Luk, 2018), so such demarcation criterion does not have power over the capability of science. Put it in another way, why cannot the study methods of science be applied to study man-made devices? What important reasons that have repercussion on the power of the study are there to prevent the application of scientific study to man-made devices? We feel that there are no strong reasons to stop applying scientific study methods to other seemingly non-science subjects.

5. Computer science as engineering science

In general, we consider computer science to belongs to engineering science. So, computer science is about solving (technical) problems using programmable devices. However, the device for computer science is programmable. Here, programmable means that the device follows a sequence of instructions to execute its actions and this sequence is stored in some (memory or configured) device so that if another sequence of instruction is loaded into the (memory or configured) device, then the overall device will execute a different sequence of instructions. Now, the device can only follow a finite variety of instructions, so that the sequence of instructions must be specified to the instructions that the device can understand. Otherwise, the device cannot turn the instructions into meaningful actions for solving the problem.

Since computer science belongs to engineering science, computer science inherits the principles and assumptions of engineering science. For example, the universal solvability assumption in engineering science is inherited by computer science. Therefore, we expect that the computer [Rapaport, 2018] (a programmable device) can solve the problem either completely or partially. Computer science also inherits the no-garbage-in principle in engineering science so that we expect valid, useful inputs are entered into the programmable device. The aim of computer science can be considered as a specialization of the aim of engineering science as follows:

> **Definition**: The aim of computer science is (i) to produce good quality (measured for example by accuracy, reliability and consistency), objective, general, testable, complete scientific knowledge (as defined in [Luk 2010]) of technical-problem solving using a programmable device (model) to solve the problem, and (ii) to apply/monitor such knowledge. (Adapted from [Luk 2017])

The above definition of the aim of computer science is almost the same as engineering science apart from the fact that man-made device (model) is replaced with a programmable device (model). It is implicitly assumed that the programmable device is man-made, so that the aim of computer science is a specialization of an engineering science. As indicated earlier in a similar way, this definition belongs (Luk, 2017) to the computer science theory. Also, the scientific knowledge is about technical-problem solving that involves the technical understanding of the programmable device on how to solve the problem with it.

Investigations in computer science can be objectively done as computer science papers are published in journals, books and conference proceedings. However, for military applications and for commercial applications, the investigation may be held as a secret so that this hinders the objectivity of the investigation. For commercial applications, the results and knowledge of the investigation may be published in patents so that they are disseminated to the public but protected as intellectual properties. There is also a growing trend to have open data sets like UCI machine learning data sets as well as sharing open-source research software like GitHub to ensure investigation objectivity is being upheld. Overall, we believe that the investigation objectivity principle (Table 1) is applicable to computer science (for approach 1 in Sect 5.1 and for approach 2 in Sect. 5.2).

5.1 Approach 1: Computer science as simulation of human behaviour

While computer science is a way to solve a problem, it is also a model of how a problem is being solved. When we talk about computer science modelling something, that something must correspond to some physical situation. So, the physical situation involves a human agent taking information from a user. The agent tries to solve user's problem by following the instructions given by an instructor. When the problem is solved, the agent gives the solution back to the user. Then, this physical problem-solving activity is complete.

In computer science, we replace the agent by a machine which is a programmable device. The instructor is given a special name called programmer, in computer science. The user remains the same. Effectively, computer science is about using a programmable device to simulate the human agent in following the instructions of the instructor when solving a problem. This perspective of computer science, which is called the agent perspective, is consistent with the view that the Turing machine is simulating a clerk (Anguera et al., 2020) following instructions from a mathematician to solve a mathematical problem like calculating the logarithm of a number before the invention of the calculator. Since simulation is a kind of scientific activity, computing is therefore implicated to relate to science.

5.1.1 Simulation of human behaviour

The science in computer science therefore is in the simulation of human behaviour. If the machine can follow the instructions given by the instructor exactly as the human agent, then we have 100% accuracy of simulation. Therefore, one may be tempted to conclude that computer science is an exact science. However, we have not specified what kind of human instructions we have in mind. For some instructions like writing a symbol on a piece of paper, the machine can simulate the human instructions exactly. For other more high-level instructions like recognizing the human face from a photograph, the machine performing face recognition may not be able to yield 100% simulation accuracy. Therefore, whether the machine can solve a problem with 100% simulation accuracy depends on the kind of instructions that we give to the agent or machine. This perspective ties in with the subject, Artificial Intelligence, in which the goal of Artificial Intelligence can be thought of as the simulation of human behaviour in executing a high-level intelligent instruction. Note that we have to distinguish between simulation accuracy and problem-solving effectiveness as the simulation accuracy can be 100% but the problem solving effectiveness may be as low as 60% with 100% simulation accuracy because human problem solving effectiveness may be limited to 60%.

In computer science, we usually limit the instructions of the programmable device to simple instructions like moving a symbol to a tape or read a symbol from the input. We rarely specify a high-level instruction. Such a high-level instruction is being broken down into a sequence of finer instructions to solve the problem. Finer instructions are further specified into finer instructions until those instructions are simple enough that they can be understood by the programmable device. Such reduction is at the heart of computer science because computer science assumes that all instructions can be reduced into a sequence of simple instructions. We can formulate this as the *reduction assumption*. This reduction assumption is similar to the universal solvability assumption in engineering science because the reduction assumption like the universal solvability assumption may be solved completely or only partially. Because any human behaviour can be considered as a high-level instruction, computer science can be thought of as the simulation of human behaviour in general.

5.1.2 Is simulation science?

One concern is that while simulation is a scientific activity, it is not clear whether doing simulation implies that the subject is science. One can think of simulation as having a model and based on the model we add details to make the simulation to be part of the experiment for making observations. Those details may not be scientific, for example coding certain aspect of the simulation based on some rule of thumb or heuristic. However, usually the model is scientific based on some theory. For computer science, do we have some theory that constructs the model which is used for developing say a program that performs simulation in our experiments as in mature science like physics (i.e., do we have a framework like physics)?

For computer science, we can rely on the theory of engineering science to form the basis of our model for simulation (Figure 1). First, the theory of engineering science has the aim of engineering science which is specialized to the aim of computer science by replacing the man-made device (model) with the programmable device (model). When solving the problem conceptually, it is usually assumed that we use a programmable device model so solve the problem rather than the actual physical device because it is easier to comprehend and apply the device model than the physical device. A specialization of the programmable device model is the human behaviour model (Figure 1) that models the human behaviour following the instructions of some model of the procedure to solve the problem. The model of the procedure or procedure model gets rid of the minor procedure details so that the human behaviour model can focus on the high-level procedure model for solving the problem. Both human behaviour model and the procedure model exist in the (scientific) model realm because they do not contain all the details about solving the problem but only sufficient amount of high-level details on how to solve the problem. For example, some details of the programmable device do not belong to the human behaviour model because they may be heuristics for performing the simulation and these heuristics cannot be explained at the model level so that such heuristics do not have problem solving value or scientific value. The human behaviour model is realized by a physical programmable device to perform the simulation of human behaviour in following the instructions in the procedure model. The procedure model is compiled into a detailed procedure for the physical programmable device to follow directly so that the physical programmable device can be thought of as simulating the human following the high-level instructions in solving the problem. The physical programmable device interacts with the physical situation. On the one hand, the physical programmable device extracts the problem information from the physical problem situation or physical state. On the other hand, the physical programmable device executes actions that may change the physical problem situation or state from one to the other until the physical programmable device halts or the problem is solved (i.e., the goal physical state is reached). This mirrors how the human tries to solve a problem by interacting with reality described by different physical states. Therefore, the simulation of human behaviour that follows the instruction to solve problems can be put in a framework of theory, model, experiment and physical situation as in mature science.

As one aspect of the quality of (scientific) knowledge is reliability, we are concerned about the reliability of the simulation of human behaviour since we are claiming that the simulation is part of science. If the instructions are very simple and easy to simulate, it is supposed that the reliability of the simulation is very high. However, when the instructions involve intelligent human behaviour (such as face recognition), the reliability of simulating following these human instructions may not be necessarily high, so measurement of the reliability of the simulation is necessary. For example, machine learning research (e.g., Krueger et al., 2015) and pattern recognition research typically performs cross-validations, reporting the performance with statistical significance as an indication of the reliability of the results.

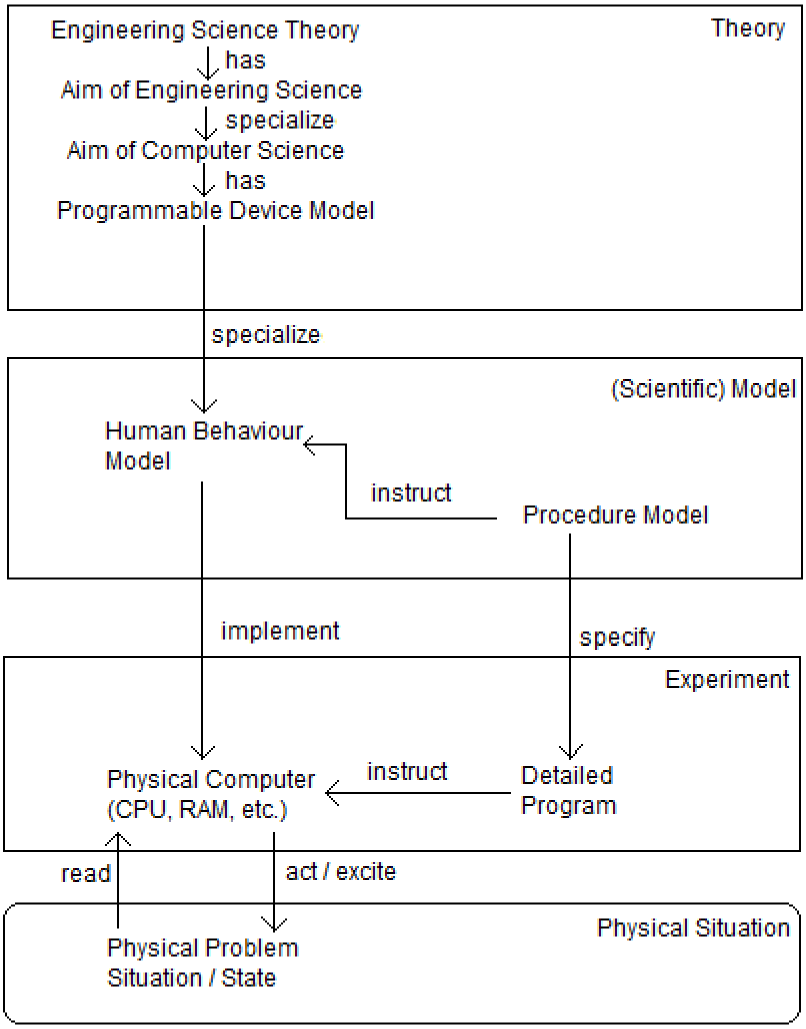

Figure 1: The framework showing theory, model, experiment and physical situation interlinked similar to a mature science like physics (Luk, 2020) for computer science to be simulating human problem solving by following (human) instructions.

Another aspect of the quality of (scientific) knowledge is consistency. According to this approach, it is about the scientific knowledge of the simulation that needs to be consistent. For complex human instructions, their simulations may result in unforeseen inconsistencies in the simulation, which is possible as the simulation is complex. The inconsistencies may not be apparent until the simulation reaches those inconsistencies in the program. As a result, these inconsistencies may be bugs in the program that need to be fixed. Detecting these bugs may not be easy because they may still enable the computer to run, but they may cause the system to crash later, produce incomprehensible results, or output the wrong results (e.g., calculations).

Note that the framework of theory, model, experiment and physical situation is some kind of hierarchy because theory is more general than model, model is more general than experiment, experiment is more general than physical situations. In computer science based on the notion of simulating human behaviour, the framework is also a hierarchy. While we may have the same aim as in the computer science theory, we may have different procedure models for solving different problem types. The procedure model can be implemented in different programming languages in the experiment level. These different programmes may run on different programmable devices (e.g., different CPUs) so that these correspond to different physical situations. Therefore, we may consider that the generalization principle (see Table 1 and [Luk, 2017]) is upheld in computer science.

One problem with this approach is that the simulation accuracy is not linked with the cost-effectiveness of problem solving so that one cannot claim immediately that the modelling accuracy principle (Table 1) is upheld. The reason is that even if the simulation accuracy is 100%, there is no guarantee that the specified procedure model can solve the problem and therefore the cost-effectiveness is decoupled from the simulation accuracy. Having said that, we expect that most procedure models can solve the problems better than random guess as required by the modelling accuracy principle. The fundamental limit of solvability of this approach is the limit set by human following the instructions of the procedure to model to solve the problem. However, this is not the fundamental limit of the cost-effectiveness of the approach since there may be more cost-effective procedure models when the cost of problem solving is taken into account. Therefore, the cost-effectiveness cannot be guaranteed to be 100% and the success identification principle is testable, so the principle of empiricism (Table 1) is applicable to this approach.

The causality of phenomenon assumption (Table 1) is followed by computer science as human behaviour simulation. This is because the phenomenon that is being studied is the human behaviour. This human behaviour follows a causal chain of actions and reading information based on following the procedure model. Therefore, the simulation of human behaviour following the instructions is also following a causal chain of reading information and executing action like the human. For some simulations, the simulation of the human behaviour may cause some non-determinism. For example, the human instruction may throw a dice and execute according to the number shown on the top face of the dice. If the computer follows this instruction, then there is the uncertainty whether the dice thrown will result in the same face as the dice thrown by human. If they are different, then the simulation may be quite different for the machine compared with the human since the instructions followed by the human and machine may be different. We assume that the dice thrown by the human and the machine produces the same result so that both follow the same sequence of instructions for the (exact) simulation to take place. Therefore, the assumption about causality of the phenomenon is followed.

The no magic assumption (Table 1) states that if identical or similar situation occurs, then identical or similar distributions of outcome are produced. For this approach, the simulation of human behaviour is the same as the human behaviour if the simulation started with the same initial state and the same input is given to the computer as the human. Therefore, we would expect that the same result state would be arrived. Note that as indicated earlier, there are some complications when the human instructions follow the result of throwing a dice or using a random number in which case the simulation may not result in the same outcome. Therefore, it is assumed in the simulation that the dice outcome or random number outcome of the simulation is the same as that of the human instruction of throwing a dice or using a random number. Hence, we believe that the no magic assumption is followed in computer science as human behaviour simulation.

5.2 Approach 2: Computer science with the theory of computation

In the theory of computation, the instructions are required to be specified in definite ways. Therefore, the concept of "effective procedure" was raised so that we are not talking any kind of instructions that can be performed by human. In this way of thinking, the instructions must be definite and simple enough to be executed by a machine that simulates the human, effectively guaranteeing that the simulation accuracy is 100%. In this light, an algorithm can be thought of as follows:

> **Definition**: An algorithm is a model of a procedure, the high-level instructions (or their equivalent) of which are definite enough to be implementable by a machine (to possibly guarantee 100% accuracy for simulating a human that follows these instructions to solve a problem).

Some prominent computer scientists (e.g., Knuth, 1968) claim that computer science is about algorithms. According to our definition of algorithm, if we concur with this claim about computer science, it implies that we must place some restrictions on the kind of instructions that the problem-solving activity can have. In other words, a procedure or its abstraction is an algorithm as long as we are certain that the high-level instructions (or their equivalent) can be implemented in a machine (which can simulate the human being following such instructions). The advantage of complying with this definition of algorithm is that we can now import the theory of computation as a focused theory of the engineering science theory.

According to the aim of computer science, we are using a programmable device called a computer to solve the problem (see Figure 2). This device has a finite set of instructions that we can specify. These instructions in turn specify the instructions that can appear in the algorithm. Note that an instruction in an algorithm can be a sequence of instructions of the computer so that an algorithm can be any abstraction of an effective procedure that can be implementable on the computer as sequences of computer instructions. Therefore, the engineering science theory specifies a computer, the allowable instructions of which specify the kind of algorithm that we can design. Now, according to the theory of computation, the Turing machine or Turing computer (Rapaport, 2018) is the most powerful among other computing machines (e.g., push down automaton or finite state automaton). In fact, what is conjectured is that what is computable is accomplishable by a Turing computer according to the Church-Turing thesis. Although this thesis was regarded by some as a hypothesis, the Church's thesis is being axiomatized (Gurevich, 2000; Dershowitz and Gurevich, 2008), and the thesis can be derived from four postulates now. If we assume that the postulates for the Church's thesis and the Turing's thesis (Dershowitz and Gurevich, 2008) to hold, then the Church's thesis and the Turing's thesis are logical consequences (i.e., theorems) and the Turing computers can compute computable functions. Turing computers are used to solve problems because they are the most powerful, so our inability to solve a problem is not limited by the capability of the machine or programmable device. Since lambda-calculus is equivalent to Turing computer, one can write algorithms in lambda-calculus to solve problems, and then translate it to run on a Turing machine. However, modern computer scientists do not use lambda-calculus for specifying algorithms. Instead, some high-level specifications are used where the instructions are thought to be implementable in some high-level programming language like Pascal or modulo 2, because these high-level programming languages are like natural languages which are easier for the programmer to write and understand. This can be done because the high-level programming languages are usually Turing complete (i.e., as powerful as the Turing computer) so that programs in these high-level languages can be implemented in some Turing computers for solving problems. These high-level programming languages typically form the basis to specify the equivalent instructions that appear in an algorithm because the programmer or instructor does not want to get into the details of the program that may side-track the problem-solving activity.

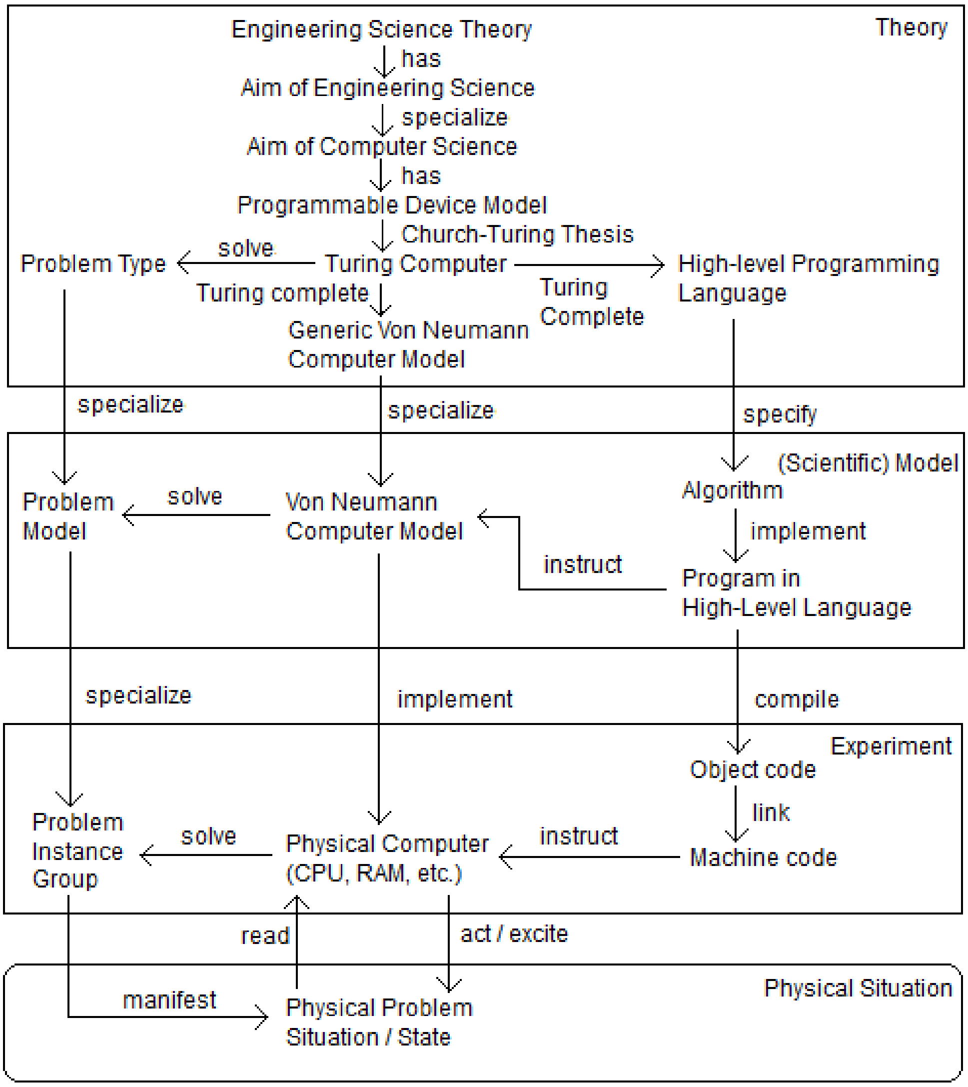

Figure 2: A framework of theory, model, experiment and physical situation applied to computer science with the theory of computation, as problem solving activities. Note that there are other connections between the theory, model and experiment realms. For example, the (engineering science) theory has the success identification principle (not shown) which is applied to the solution (in the model realm) consisting of the von Neumann computer model and the program written in high-level programming language. The solution model then predicts that the physical solution has 100% cost-effectiveness performance according to the success identification principle. The reason why these are not shown in the figure is that it would complicate the figure and make it hard to discern. Instead of showing all the connections, we have selected the ones that show the knowledge can be arranged in a hierarchy framework for illustration purposes.

For those programmers who need to implement the system, they convert the algorithm into programs specified in the high-level programming language. Because the high-level programming language is more or less independent of the programmable device, we regard these high-level programs to be models. When these programs in high-level programming language are compiled into object codes, such object codes are considered to belong to the experiment as these object codes are typically machine dependent. The object codes are still general in the sense for example that the actual addresses of the program need to be recalculated as parameters of the program. When the machine code is generated from the object code, it can be used to execute the physical computer which is usually an implementation of a von Neumann computer model (with some extra functions). Such a model is a derivative of a general von Neumann computer which is found to be Turing complete (Moore, 2014). This is necessary because we need to make sure that the (Turing complete) algorithm that we specify is implementable on a Turing complete machine so that we would not find for some instructions, we cannot specify them for the physical computers.

According to this approach, computer science is scientific in two senses. In one sense, computer science is the simulation of human behaviour similar to Approach 1. However, the instructions in this approach are so simple that the simulation accuracy of the human behaviour following the instructions is 100%. Since we have discussed the simulation of human behaviour in Approach 1, this sense of computer science being a science is not elaborated further in here.

Another sense that computer science is science in this approach (i.e., Approach 2) is that the problem-solving activity is scientific. The problem-solving activity is placed in a framework similar to mature science (Luk, 2010) as in Figure 2. In mature science, we expect that the principles in the theory are applied to build the models which predict the outcome with certain performance in the experiment (Luk, 2010; 2017). Similarly, in computer science (Figure 2), the engineering science theory has the success identification principle which is applied to build the problem model and the solution model consisting of the von Neumann computer model and the program in high level programming language. The solution model predicts the outcome in the experiment and the prediction of the cost-effectiveness performance is 100%. Therefore, the prediction error of the cost-effectiveness is 100% minus the actual cost-effectiveness of the physical solution model. In Figure 2, we have not shown the details of these connections to avoid complicating the figure, which may make it hard to discern the hierarchy framework for illustration purposes.

The problem-solving activity (Figure 2) is being modelled with an algorithm solving a problem model which is a general description of the physical problem. For example, the problem model may specify the problem size as a variable, but the particular problem specifies the problem size with a definite number. The problem-solving model is implemented in the experiment as a specific instance group of problem solving using a machine running machine codes for a particular problem instance group at hand. The particular problem instance group is manifested in the physical problem situation or state in the physical situation realm. The physical computer (or machine) interacts with the physical problem situation and turns it into a physical goal state that satisfies the user. This corresponds to the physical problem-solving activity that is being modelled by the problem-solving model in the framework. Therefore, the specialization of the aim of computer science produces a problem-solving generic model in the theory realm specifying the problem type that the Turing machine solves. This generic model is then specialized into a problem-solving activity model with specific problem model solved by a von Neuman computer model running some algorithm or high-level language program in the (scientific) model realm. This problem-solving activity model is then specialized to a particular problem instance group solved by a machine running machine codes in the experiment realm. Finally, the computer or machine solves the problem by interacting with the reality to execute the problem-solving process in the physical situation realm. Hence, the generalization principle (Table 1) of scientific study, applied to problem solving activity is upheld by Approach 2. In the remaining part of this section, we will focus on the sense that computer science is science is a problem-solving activity rather than human behaviour simulation. This sense of computer science is science has direct linkage with the engineering science theory which is about problem-solving with a man-made device put into a scientific framework.

Apart from generalization, the quality of the scientific knowledge in the aim of scientific study is also important. One aspect of the quality is the accuracy of the scientific knowledge. In the case of computer science interpreted as a problem-solving activity as in Approach 2, the success identification principle in the engineering science theory is inherited by the computer science theory. According to this principle, it predicts that the cost-effectiveness of the problem-solving activity is 100%. This is similar to the Probability Ranking Principle in information retrieval (Luk, 2020) which predicts that the accuracy is optimal. As the machines are the most powerful, the only thing that can change in the problem-solving activity is the algorithm or the program. Therefore, the prediction of the cost-effectiveness applies to the algorithm. The cost-effectiveness is measured by two aspects: one on how effective, E, is the problem solved, which we can give a percentage, and the (normalized) cost, NC, which is another percentage. Thus, one cost-effectiveness measure, CE, is E – NC which can range from 1 to -1. For algorithms that guarantees to solve the problem, E is 100%, as for many combinatorial problems. However, the algorithms compete with each other by having the smallest NC so that the overall CE is the largest. That is why some computer scientists work on papers that focuses on the computational complexity (i.e., the cost) and has the proof that the problem is solved (i.e., the effectiveness). The prediction accuracy of the problem-solving activity is the prediction accuracy of the cost-effectiveness. This would encourage algorithms with higher CEs so that the prediction error of the problem-solving ability is less, because the error is 100% - CE achieved. In this way, the more cost-effective the algorithm is the more accurate the cost-effectiveness prediction and so the knowledge in the algorithm is better in a scientific sense as accuracy is a quality of the scientific knowledge. Note that since we do not know beforehand whether the E measure of the algorithm will be 100%, the success identification principle is testable, and therefore the principle of empiricism (Table 1) in scientific study is upheld. Also, the modelling accuracy is based on randomly guessing the answer to a problem of the solution. Therefore, we expect that most computer solutions or applications have better Es than the E by random guess. We will discuss this in more details in Sect. 6. In summary, we expect that the modelling accuracy principle (Table 1) is upheld.

Another quality of scientific knowledge is reliability. For some problems, we have a proof for solving them based on the algorithm so that E is 100% and this can be absolutely reliable. However, the measure of the accuracy of the scientific knowledge in computer science is based on cost-effectiveness. Therefore, we need to consider whether the prediction of NC is reliable or not. This means that we have to deal with computational complexity (CC). CC is typically measured in terms of time-cost and space-cost. Moreover, computer scientists are usually not concerned with the actual time-cost and space-cost, which may depend on a number factors (like what CPUs are used) but on the (upper) bounds of the time-cost and space-cost. The reason is that if the computer scientists feel that the bounds of the time-cost and space-cost are small enough for the problem size that they are interested in, then they think the solution is good enough. Therefore, NC is measured in terms of the (upper) bounds of costs for the specific problem sizes that the scientists are interested in. Because NC is dependent on the problem size, so is E dependent on the problem size. In this case, the reliability of E may be specified by some bounds on E rather than some exact figure of E.

The final aspect of the quality of (scientific) knowledge is consistency. According to this approach, it is about the scientific knowledge of the problem-solving activity that needs to be consistent. Because central processing units (CPUs) are very complicated circuitries, it is not unheard of that there are bugs or inconsistencies in the circuitries (e.g., Pentium FDIV bug). So, it is possible that the CPU circuit model that generates the physical circuitry may have inconsistencies. For complex programs, they may also have (semantic) bugs (Nuseibeh, 1996) in problem-solving that need to be fixed. Detecting these bugs may be very difficult because the tools (e.g., compilers) may not be able to pick up these bugs. This subject is more in the domain of software engineering (as this may depend on the specification and requirements of the system) which we will not elaborate any further. In general, computer science is concerned with the consistencies of the computers and programs in order to solve the problems correctly.

The phenomenon of computer science can be considered as the state of the physical problem. The problem-solving activity starts at an initial physical state and based on actions of the physical computers the physical state was caused to change. The physical computer reads information from the physical state which is caused to be changed further by further actions of the physical computers. This cycle of physical state changes can be thought of as a casual chain reaching the final physical goal state. Therefore, the desired phenomenon that we want is for the physical computer to arrive at the physical goal state (i.e., our desired phenomenon to be achieved). Thus, the assumption of the causality of phenomenon (Table 1) is upheld.

The no magic assumption (Table 1) states that if identical or similar situation occurs, then identical or similar distributions of outcome are produced. This assumption may not be exactly followed for some types of programs (like randomized algorithms). Instead of solving the problem exactly, these types of programs may solve the problems probabilistically so that on average, the problem is solved better than solving the problem by random guess. The repeatability of the problem-solving ability may be called into question, but we believe that the distribution of the problem-solving ability outcome remains the same after repeated trials. Therefore, we believe that the no magic assumption still holds for these types of programs or algorithms.

6. Common outstanding issues

Why do we have computer science and not computing science? The reason is that computing science focuses on the algorithm (e.g., Knuth, 1968; Shapiro, 2001) to define computing science. While it is true that most computer scientists are concerned with designing algorithms and implementing high level language programs, the set of instructions of the algorithms and the high-level programming language are defined by the programmable device (i.e., computer). Now, not all instructions can be implemented in a computer, but all computer instructions can be used by the algorithms and high-level programs. Therefore, computers specify the allowable instruction sets used by the algorithms and high-level programs. Thus, computers are more fundamental than the algorithms or high-level programs. It is because of this dependency, computer science as a name is preferred over the name computing science. If computing science is used, we may be emphasizing computer science as

Approach 1 over Approach 2 where some (human) instructions may not be realisable by computers. In this case, our hierarchy framework of theory, model, experiment and physical situation is broken as the experiment may not have a realisable computer to execute the program, and this affects our claim that computer science is science.

Some computer scientists are only concerned with computational complexity of an algorithm like the time-space complexity. They seem to forget whether they are solving a problem or not, or what programmable device they use. Usually, these computer scientists are focused on a problem that can be solved. So, the solvability of the problem is 100% for the algorithm. Therefore, the computer scientists are no longer concerned about the solvability issue of the algorithm. Instead, they are concerned with how fast the problem can be solved and how little resources does the algorithm need to solve the problem. Therefore, these computer scientists appeared to be more concerned with the computational complexity of the algorithm. For some scientists, they are concerned with the computational complexity of the problem which may place some limit to the efficiency in solving the problem by whatever algorithms that can be designed. This kind of issues may be involved mathematically, and they may deserve special attention from the computer scientists. That is why their papers are focused on time-space complexity without touching on the other aspects of computer science.

One concern is that computer scientists rarely do experiments. This is, however, not true in general, as this depends on the kind of problem the computer scientists are trying to solve. For many combinatorial problems, computer scientists are mostly interested in the computational complexity because there are simple algorithms that can enumerate the solutions and guarantee to solve the problem with 100% solvability but with poor computational complexity. These computer scientists are usually not concerned with the real-time cost or exact space-cost because they are trying to solve the problem efficiently when the problem size is large, and because improvement of computer technology may mean that real-time cost or space cost may become obsolete as technology advances, so that we are only interested in the general form of the complexity (e.g., whether it is polynomial or exponential cost) rather than the exact form. Therefore, computer scientists rarely perform experiments to measure the time-cost or space cost. Having said that, some computer scientists are concerned with the real-time cost and space cost. These may be computer scientists specialized in real-time systems or control systems where real-time response is required. For those computer scientists, they may look at the real-time cost and space-cost efficiency of the algorithms. In these cases, experiments may be carried out to take actual measurements of efficiency. For other problems where the solvability of the problem cannot guarantee 100%, experiments are done to benchmark the performance of the algorithms or models. For example, information retrieval as a sub-discipline of computer science is concerned with the accuracy of the retrieval, which is usually not 100%. Therefore, information retrieval has published many papers with experimental results (Luk, 2020). Other sub-disciplines of computer science like neural network, computer vision, pattern recognition and machine learning have many papers that report experiments on performance. Therefore, there is a large class of computer science works that involve experiments.

One concern of the modelling accuracy principle is that random guess is used to define the lower bound performance. In computer science, some algorithms (like randomized algorithms) may solve a problem by making random guess, so it may appear that some problems in computer science can never surpass the performance of random guess. It should be noted that the algorithms that make use of random guess do not just guess the solution without any knowledge or structure. Instead, these algorithms may employ certain knowledge or structure in the solution, and only in certain part, random guess is made to help solving the problem. Therefore, such algorithms should not be considered as pure random guess algorithms which are used to define the lower bound modelling accuracy performance. Thus, the algorithms in computer science involving random guess may perform better than the pure random guess algorithm used to define the lower bound modelling accuracy, so that the modelling accuracy principle (Table 1) is upheld.

Is computability still a central question in computer science? For both approaches, this question is indeed central. The reason is that this question probes the limit of computer science because it asks the questions what problems can be solved by the methodology that solves a problem by following a sequence of instructions. This limit depends on whether the instruction is implementable in a machine, which set some limits for Approach 1. This limit also depends on whether the most powerful computer ever devised cannot solve what problem, which sets the limit of Approach 2.

7. Conclusion

In this paper, we have defined computer science as a problem-solving activity involving a programmable device (model). We explain why the field is called computer science and not computing science because all instructions in the algorithm are realizable by a computer (or a programmable device). We have also highlighted how computer science correspond to science based on two approaches. The first approach considers computer science as simulation of human behaviour which is similar to the goal of artificial intelligence. However, this approach decouples the simulation accuracy from the cost-effectiveness of problem solving as a result this decouples the approach from some of the principles of computer science and scientific study in general, so this approach is less preferred. The second approach considers computer science based on the theory of computation. It guarantees that the simulation accuracy of human behaviour is 100% for Turing computers since the instructions can be carried out by a human being. Based on the theory of computation, computer science guarantees that the algorithms can be executed in a programmable device that can be realized. Using the programmable device, algorithms are defined as sequences of high-level instructions that are realizable in programmable devices. This definition makes clear the vague notion of an algorithm before.

One major insight in this paper is that computer science is about using a programmable device to solve technical problems. While it is not a surprise that a programmable device is used, what is surprising is that computer science is regarded as problem solving. This is different from past influential definitions of computer science which is related to algorithms or information. Regarding computer science as problem solving enables computer science to be related to engineering science, as well as enabling the success identification principle to be directly applied to the problem-solving instances so that there is a prediction of the cost-effectiveness of the solution. In turn, this prediction is related to the accuracy of the scientific knowledge which consists of the problem model and the algorithm. As a result, this problem-solving perspective of computer science unifies the various aspects of computing into a framework of theory, model, experiment and physical situation, enabling us to claim computer science is science. This insight also concurs with the informal definition of computer science as “solving problems with the aid of a computer” (Margolis et al., 2008).

Another major insight in this paper is that computer science can be regarded as simulation of human behaviour for both Approaches 1 and 2. Effectively, the computer is simulating an agent who follows the given instructions to solve a problem. This simulation can be made to relate to artificial intelligence, where complex instructions are allowed to specify in the procedure to solve the problem. In the case that the instructions are limited to those executable by a von Neumann machine, the simulation of the agent has an accuracy of 100% since the instructions of the von Neumann machine are simple ones that a human and a machine can both follow without difficulty. In this sense, Approach 2 is doubly scientific as the computer simulates human doing the problem solving, and the problem-solving activity is a scientific one.

The final major insight in this paper is that there is a scientific discipline called engineering science. It can be divided into applied science sub-disciplines (like mechanical engineering science) and pure science sub-disciplines, in which computer science is an example. Engineering science has its own assumptions and principles. One can even develop a framework of theory, model, experiment and physical situation for engineering science. Specifically, the theory contains the aim, assumptions and principles mentioned in engineering science plus the problem type and the man-made device. In the scientific model realm, the man-made device is specialized into a device model and the problem type is specialized into a problem model. The device model is then realized as a physical device in the experiment realm and the problem model is specialized into a problem instance group, which is manifested in the physical problem situation or physical state in the physical situation realm. The device will change this physical problem state into a physical goal state that solved the problem in the physical situation realm. This is very similar to the framework (Figure 2) mentioned for Approach 2 in computer science as this is a problem-solving activity in engineering science and in computer science. The minor difference between computer science and engineering science in general is that computer science specify that a von Neumann/Turing machine is used, but the engineering science may be a von Neumann/Turing machine or some other device that the engineering scientist creates, as well as the freedom of not requiring the Church-Turing thesis to justify the use of the Turing machine in engineering science theory so there is no necessity to develop an algorithm/program to solve problems.

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Agent-based modelling in environmental policy analysis

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Abstract

This paper is a summary of the research developed in the author's Ph.D. programme. The case study deals with the implementation of Energy Efficiency policies in the Building sector of the Lazio Region and carries out an ABM analysis of the impacts of training on the social actors involved. Its purpose is to reproduce the social mechanisms through the study of the actors' actions with ABM in order to evaluate socio-economic impacts by interconnecting the social and economic variables by means of the Social Accounting Matrix (SAM).

Keywords: ABM, interconnection, social action, environment - energy policy, social influence, training.[2]

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1 Introduction

Over the years, man has increasingly pursued achievement of energy independence through the use of forms of alternative energy sources permitting autonomous consumption capable of satisfying demand. This pursuit has led to environmental, economic and social problems brought about by different actors adopting different strategies according to their interests. The behaviour and actions of these actors move the system by generating impacts which can be analyzed by means of the Agent Based Model – ABM. Agent Based Models (ABMs) are in fact useful tools for the study of mechanisms leading to the achievement of Energy Independence. The case study focuses on Energy Efficiency policy implementation[3] in the Building sector[4] of the Lazio Region[5], in particular through ABM analysis of the impact of training on the social actors studied [1]. The aim was to reproduce the social mechanisms through a study of the subjects' actions with ABM, and then assess the socio-economic impacts by inter-connecting social and economic variables by means of the Social Accounting Matrix (SAM). The ABM was created by following Boudon's [2] and Coleman's [3] Macro-Micro-Macro mechanical theory. The research activity falls within the methodological branch of local development analysis as it seeks to discern how a policy can lead to growth and development. The study aims to examine the social behaviour of individuals, social influence and social proximity in order to study the interests and decisions of local actors, the way in which influence occurs, and by what means it is transmitted, while at the same time considering the theoretical and methodological plane. An analysis of the local context, the conditions of the area chosen for study and its component network made it possible to define the features to be investigated and subsequently assess their effects [4] [5]. By reproducing the ABM model [6] it was also possible to observe the integration of local analysis in the evaluation of public policy. The model was built first with R and then with NetLogo software. The former makes it possible to describe the model in its mathematical context showing the mathematical equation; in addition, it is a useful support for interconnection with the Social Accounting Matrix (SAM) which shows mainly the economic impacts

[3] Energy Efficiency constitutes a new energy source fundamental both for the reduction of fuel poverty and socio-economic growth.
[4] The building sector is analyzed because it seems to be the one with the greatest likelihood of implementing the different policy measures as well as the sector which because of the economic crisis exploits all its opportunities. At the same time, this sector makes it possible to study how training can be the driver and facilitator in the diffusion of innovative systems of Energy Efficiency and in stimulating the creation of new jobs.
[5] The Lazio Region was chosen because of its proximity and geographic potential to facilitate travelling, and because it is simpler to gather data in one's own region.

and the consequent social impacts. NetLogo is the ideal software for agent-based simulation because it makes it possible to show the movement of the social actors.

2 The research[6]

In measuring Energy Efficiency, the behaviour and choices of citizens are fundamental since growth and development is possible only when EE measures are put into effect. Training is considered to be the important variable in implementing the measures, starting from the consideration that training is fundamental for social and economic growth and development since it provides the driving force towards change [7].

In order to analyze training within the social model, questionnaires were administered and interviews and direct observations carried out.

The operative field research phase was preceded by an analysis of the sector, defining its production chain and actors, in order to facilitate the construction of the model.

The social model was built with the following actors: 1. Business; 2. Government; 3. Trainers; and 4. Families.

The first actor analyzed was the business sector which with its decisions implements and changes the mentality of the sector. The entrepreneur has the greatest pull [8] since every choice he makes not only affects his own firm but also other actors, the market, the sector and society. In aiming to meet the needs of his business, the entrepreneur, according to Weber [8], acts in accordance with the dictates of a rational action in relation to an objective: growth of wellbeing and increased earnings.

The second actor is Government which with its actions and decisions affects those of entrepreneurs. Policy implementation aimed at increasing social well-being involves development and increased choice in investments for Energy Efficiency measures as well. In addition, in the case under consideration, the Public Administration must respect the 2020 agreements, create incentivizing activities capable of developing the entire sector and lead it to the established objectives.

Trainers are the third actors useful for the realization of Energy Efficiency. Training makes growth and development possible, and continuing education is a

[6] Presented at the 11th Conference of Environmental Sociologists. Acts in the process of being printed with the proposed title: *Training as Driver in Social Decisions for the Application of a Policy. Case Study on Energy Efficiency in the Building Sector in the Lazio Region*. The study has its origins in the author's doctoral research titled *Integration between Social and Economic Models. Development Policies in Energy Efficiency in the Lazio Region*, PhD in *Educational and Social Theory and Research,* Università Roma Tre in co-supervision with Enea Research Board. Presented at Roma Tre on 27 March 2018 and completed in October 2017.

resource because it permits continual evolution which brings growth. The fourth and last actor consists of families which intervene both indirectly and directly since their decisions can stimulate the sector and force businesses to innovate by following social and economic trends.

The research hypothesizes that the greater the demand for measures on the part of families, the greater will be business investment and incentives by Public Administrations.

With the theoretical study based on the actions of social agents and their behaviour, the social actors were defined and a sample was selected, utilizing available databanks, contacts with different professional sectors, organizations, authorities[7] and trainers.

The sample of business firms was extracted in different ways and through different procedures. A database of all Italian businesses updated to 2015 was found: AIDA (Analisi Informatizzata delle Aziende Italiane), which is a database of Italian Businesses of the Università Cattolica di Roma. After obtaining the various authorizations necessary, it was possible to compile a complete list of the construction firms in the Lazio Region across its five provinces. The sample was reduced from 197,597 businesses to 543 with a specific filter selected on the basis of the Ateco code, choosing the codes with their respective *subcodes*[8] *and selecting active businesses with over 20 employees.*

To these 543 businesses were added sustainable building and social housing construction firms, whose names were furnished, after a request via email, by the Enti Ance of Rome, Latina, Viterbo and Rieti and Ance Lazio; Confartigianato di Latina; Confindustria Lazio; Fillea (Italian Federation of Construction Workers and Carpenters) both at provincial and national level; Acer; Acer Lazio; Cefmectp; Formedil and CNA (National Confederation of Craft Trades and Small and Medium Businesses)[9] and businesses in the Unindustria registry, for a total of 731 businesses contacted.

The final Sample consisted of the 27 businesses that responded to the questionnaire.

The firms were contacted both by email and telephone. The material was sent through the University webmail with a letterhead attachment describing the research[10]. The letter asked the firms to actively participate in the research by

[7]These included: Ance, Acea, Enea, Enel, Confartigianato, CNA, Fillea, Lazio Region, Professional Associations and the National Council of Land and Building Surveyors.

[8]41.2 (Construction of residential and non-residential buildings), 43.2 (Installation of plumbing systems and other construction and installation work), 43.3 (Building completion and finishing) and 43.9 (Other works by construction specialists).

[9] Acer Roma and Acer Lazio provided greatest support.

[10] The study was supported with the collaboration of Università Roma Tre and the Enea Research Institute. The letterheads of the two organizations were used to give official status to the research and reassure the firms of its authenticity.

responding to the questionnaire either in person or by email. Only three firms decided to respond online, while the questionnaire was administered to the others *face to face*. Emails were sent requesting confirmation of both receipt and reading. When no such confirmation was received, the firms were also contacted by telephone in order to speed up the process.

The sample of trainers was even smaller than the firms sample; in the Lazio Region 13 questionnaires were distributed. The construction sector has its own training schools through which it seeks to provide its students with a good skills level.

The most important public ones include: Fomedil, Cfmecdp, Ente bilaterale paritetico territoriale for training and construction safety in the Province of Latina, Ente Scuola Edile Frosinone (ESEF), Ente Scuola Edile Viterbo (ESEV) and Lazio Region. Private schools include Lazio Deiconsulting.

The trainers sample was selected from the list of Training Institutions released by the Lazio Region and Cefmectp. Thirty-one Training Institutes and Agencies for businesses and technicians in the building sector were contacted by email following the same procedure used for the building firms.

Twenty training centres responded and of these 16 consented to be interviewed, but ultimately it was actually possible to interview only 13.

Within the government sector, officials from the Lazio Region and the Ministry for Economic Development were interviewed. There were 3 respondents from the Lazio Region and one from the Ministry. The four respondents carry out different tasks and have different political affiliations. The functionaries from the Lazio Region made it possible to study how the Regional system was organized, developed and orientated towards innovation.

2.1 Research tools

Business Firm Questionnaire

A questionnaire consisting of 37 questions was administered to the 27 business firms. Each question had the aim of constructing the interconnection between the social and economic models. Most of the questions analyzed the opinions of the firms, their rational decisions and the actual state of facts. The questionnaire was sub-divided into four parts which made it possible to study both policy impacts and limitations and the actions of the agents:

I. Impacts of the Energy Efficiency measures (from 1 to 6)[11];

[11]The first part or area of the questionnaire, as indicated by questions 1 to 6, studies the impacts of Energy Efficiency measures, focussing on self-evaluation and implementation of imminent measures established by law.

II. Investments (from 7 to 16)[12];
III. Policy limitations (from 17 to 21)[13];
IV. Business, Participation and Communication (from 22 to 37)[14].

The four parts were structured to identify the actions chosen by businesses. The questions were designed to investigate how decisions and motivation of the business sector may influence the implementation of Energy Efficiency measures and at the same time how external actions may modify agents' decision-making. The questions were formulated on the basis of the indicators of the company's development and vitality. The fields analyzed as indices of development and growth included: Training, Participation, Investment (Willingness to Invest), Limitations, Employment and Opportunity. The questionnaire aimed to furnish a complete picture of all three dimensions to be analyzed: political, economic and social; but included questions with social variables which would then feature in the construction of the social model and the SAM.

Trainer Interviews

A questionnaire consisting of 21 questions was administered to the trainers, who were fewer in number than the other agents. The interview was divided into three parts:

I. Opinions regarding Energy Efficiency policy (questions 1 to 4);
II. Specific questions on training, administrative orders and courses offered by the trainer's institution (questions 5 to 15);
III. Questions focussing on the information-participation relation and training.

It is important to consider the trainers' opinions since it is training which permits the implementation and diffusion of energy policy measures. By analyzing the relation between trainers, businesses and technicians, it is possible to study how, on the basis of their opinion of the Energy Efficiency policy, trainers are able to convince firms that it is a good investment in the mid and long term. For the part related to Government[15] comments and opinions were collected of

[12]The second part, *Investments*, consists of questions 7 to 16 investigating all the areas of investment carried out by the businesses and those proposed to them. The questions deal with investments – both actual and potential -, and training. In this area it is possible to observe what relation exists between training and implementation of the measures.
[13]The third part, *Policy Limitations*, questions 17 to 21, studies the limitations of non-diffusion both of Energy Efficiency measures and construction of new sources.
[14]The fourth part, *Business/Participation/Communication*, questions 22 to 37, investigates the relations between business and the sector and government as well as the participation of business in decisions and implementation.
[15]For the Government part, the following people were contacted: for the Ministry for Economic Development (MiSE) Mauro Mallone, and for the Lazio Region 7 political representatives,

political representatives in the environmental, energy and development fields of the Lazio Region, of the director of Division VII "*Energy Efficiency and Energy Savings*" in the Ministry for Economic Development (MiSE), and finally of administrative personnel responsible for different departments in the Lazio Region. The officials contacted were in charge of the following departments: Regional Directorate for Economic Development and Productive Activities; Programmes and Projects for Sustainable Development; Regional Directorate for Infrastructure and Housing Policy – Planning and Public Housing Projects; and Regional Directorate for Training, Research and Innovation, Schools and Universities, Right to Education – Planning Area for Training and Orientation. Political representatives were interviewed in depth in order to analyze the role of the Energy Efficiency policy and training for policy development.

3 Model Description

The model, as mentioned above, was constructed on the behaviour of three agents (Businesses, Trainers and Families), which in practical terms implement the policies emanated by the fourth subject – the political class.

To construct the model the political decision-making processes were translated into numbers: one example of a translation of actions into a numerical measurement is the increase of a defined X percentage of the number of energy upgrading interventions in domestic dwellings within a given geographical region.

The model was built upon the sufficiently detailed description of the behaviour of the actors considered, by selecting the questions from the interviews

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including: 1. The Governor of the Lazio Region Nicola Zingaretti; 2. Fabio Refrigeri, Committee Chairman for Infrastructure, Housing Policies, Local Authorities; 3. Councillor Porrello Devid member of Commission for Environment, Public Works, Transport, Housing and Urban Planning Policies, member of Social and Health Policy Commission; 4. Enrico Forte Vice-president of the Commission for Environment, Public Works, Transport, Housing and Urban Planning policy; 5. Councillor Silvia Blasi, member of the Commission for Environment, Public Works, Transport, Housing and Urban Planning Policy, Commission Member for Agriculture, Artisanal Workers, Commerce, Professional Training, Innovation, Labour, Small and Medium Businesses, Research and Economic Development; ; 6. Enrico Panunzi, President of the Commission for Environment, Public Works, Transport, Housing and Urban Planning Policy, and 7. Adriano Pallozzi, Vice president of the Commission for Environment, Public Works, Transport, Housing and Urban Planning Policy. Governor Zingaretti was contacted but replied that he was not available for interview at the time because of the elections and delegated Councillor Refigeri, but said that if necessary he would be available for interview. Councillor Refrigeri's secretary guaranteed that the Councillor had already been informed that he could be interviewed and assured his availability. The councillors interviewed were Porrello, President Panunzi, Councillor Forte and Committee Chairman Lo Cascio, in lieu of Prof. Fabiani.

and questionnaires relating to training (number of training courses followed in the current year; participation in courses, motivation and the return on investment in training courses over time); policy implementation, both in the application of technology and for motivation; Participation; Investment and Opportunity.

Families were the only agent-group not interviewed. Their data were taken from the Enea database on the number of incentives applied for and from the data of the Ministry for Economic Development, available from 2007 to 2013.

The model was constructed with two software products: R and NetLogo, both with programming language that enables the realization of social models with two different interfaces. The former makes it possible to observe the evolution of the process mathematically; the latter shows the movement of the social agents and their influence. R was used because it more easily permits integration with the economic accounting matrix and also shows social impact. NetLogo makes it possible to observe the movement of social agents and their role during the social influence phase.

Structure of the model built in R[16]

The model is influenced by a research model on social dynamics and collective behaviour and social influence by Nowak, Szamrej and Latanè [9]. In the model, the Energy Efficiency Policy will be indicated with EE.

Four individual factors operate in this model:

1. individual **attitude** in the population, translated into binary terms [0-1 or YES-NO] with a division into two opposite opinions about an issue (in this case whether to do EE or not);
2. **persuasion power** with regard to agents with contrary opinions (variable between 0% e 100%) placed into dynamic relation with attitude, hypothesizing that its intensity would increase with the persistence of an attitude over time;
3. power of external support with respect to agents with similar opinions, structured like the preceding one, with a random attribution to each change in attitude;
4. **social proximity**, given by the spatial localization within the social structure, with a distribution of the agents characterized by a space of 40 x 40 cells.

With regard to maintenance/change of attitude, the basic assumption is that attitude changes according to the power of impact groups. If persuasion P of group y is greater than the power of support S of group x to which the agent belongs it means that if $P_y/S_x > 1$, then the agent's attitude will change. In the

[16] R is a free software program with programming language and specific development ambient for the statistical analysis of data.

work in question, the results show that the dynamics of polarization and resistance often depend on the initial conditions.

The basic equations of the model are:

Equation 1 – Impact of Power of Persuasion (P) in Latanè (1990)

$$\hat{\imath}_p = N_0^{1/2}\left[\sum \left(p_i/d_i^2\right)/N_0\right]$$

Where:

$\hat{\imath}_p$ = impact of the power of Persuasion
N_0 = number of individuals carrying out the persuasion action
d_t = distance between source and recipient

Equation 2 – Impact of Support (S) Power in Latanè (1990)

$$\hat{\imath}_s = N_s^{1/2}\left[\sum \left(s_i/d_i^2\right)/N_s\right]$$

Where:

$\hat{\imath}_s$ = impact of Support power
N_s = number of individuals effecting the Support action
s_i^2 = distance between source and recipient

Equation 1 shows that a group's persuasion impact is the average force exercised by it (persuasion impact / distance squared) multiplied by the square root of the number of members in the group itself. The persuasion of a social group impacts on the actions and behaviour of the individuals.

Following the theoretical model of reference, implementations were carried out to enable the construction of the social model proposed for this study.

Firstly, individual attitude within the population, translated into binary terms [0-1 or YES-NO], with a division into two opposing opinions regarding an issue (in this case, whether to do EE or not) is translated with respect to our problem into the form of "YES, I will implement Energy Efficiency (EE) from this moment)" or "NO, I will not implement EE" and is calculated according to equation 4) shown below. Secondly, the persuasive power regarding agents with opposing opinions (varying between 0% and 100%) produced both internally and externally (all the various subjects urging the realization of EE interventions, which can also be located *within* the family), is placed within a dynamic relation with attitude assuming that its intensity will increase with the persistence of an attitude over time as in Latanè's model. Thirdly, the element of Rational Calculation (RC) has been posited as equal to the Probability of New EE Training by Businesses (PNTB) according to the hypothesis that training is directly correlated with the price indications furnished by the businesses, and this variable is therefore the connecting link between the training policies and the model constructed [10]. In addition, the power of external support, with regard to agents with similar opinions, is set up like the preceding one, with random attribution to each change in attitude (but varying between 0% and 100%). Finally, social proximity, given from spatial localization within the social structure, is not considered in this simplified model. This is an important point: the model did not make use of spatial metrics to examine the diffusion of the phenomena (in this case attitudes towards EE interventions). This is a possible future development. However, in this experiment, the *Persuasion Driver* is also examined within the family nucleus (the atomic element of the Family agent), with a different approach from Latanè's (in which pressure is always exercised from outside the peer group and the support of the group itself). This would be mathematically equivalent to placing $d_i^2 = 0$ into equation 1), with the effect of annulling it completely. The modified functional form of the model proposed is presented below in equation 3. It is assumed that the Political actor has the aim of increasing interventions of energy upgrading in homes and desires to verify the effects of a possible additional intervention to the established one which provides upgrading incentives in the form of tax deductions (the so-called 55% - 65% formula), that is to say the percentages deducted from the value of the investment. In analyzing the role of *Training* in the process of translating Policies into social and economic effects on the system, the training tool is examined with reference to a work previously carried out on the relation between the subjects examined, in which the effect of a training action in Businesses was estimated in terms of price effects [11]. It is assumed that a training action can convince Firms to invest in Energy Efficiency and drive them to lower the prices of goods and services offered to families to create efficiency (a firm convinced of the future of Energy Efficiency can, for example, apply prices lower than the regional or municipal average for window and door fixtures sold to families within its market segment). Two policies are then taken into consideration: *Policy 1* and *Policy 2*, characterized by different costs and results, and the data furnished by the above-mentioned study limited to the PNTB parameter (41% in hypothesis 1, High Skills Training; 23% in hypothesis 2, Low Skills Training, which are the two extreme cases in the work cited).

To summarize the model proposed, the analysis focuses on:

- Government, which enacts/passes regulations;
- Trainers who facilitate awareness in Firms operating in the market;
- Businesses, which it is assumed are competitive within the market in terms of Training;
- Families that respond to the signals of Businesses and integrate them into their decision-making models.

Families are seen not only as actors that give importance to the rational element – represented by the cost of interventions – but also as actors in which two further drivers act: the Persuasion effected both externally and internally on the members of the i-th family nucleus interested in acting in any capacity[17] by investing in interventions; and the Support Force which the external environment, in the form of other subjects with the same orientation as the i-th nucleus, can offer.

As far as the price of interventions is concerned, it is assumed that this is correlated to the level of confidence the firms have in the potential of their market: this level can be rationally correlated directly to their level of training in the potential of the sector technology and is thus identified (posited in proportional relation), with the likelihood of new training.

Since in this context it would have been complicated to carry out precise statistical research on average prices in the entire region, it was decided to use the research results in the work of Cubeddu, Rao [12], published by Enea, on the probability of new training for the firms according to a simplified logic of the YES/NO type: it was assumed that the firms receiving most training would apply lower prices, and in the model effectively developed, the input utilized is a percentage value of new training by the firms, which is used in calculating the product of other factors. The level of persuasion and support was allowed to vary from 0% to 100%, in keeping with the model of Nowak, Szamrej, Latanè. The equation which expresses the number of interventions for the i-th policy considered is:

Equation 3 – Impact of Persuasion Power (P) in Cubeddu (2017)

$$\hat{\imath}_p = PNTB_i * N_0^{1/2} * (P_i/S_i)/N_0$$

[17]Valid in one-person households as well, if we consider the decision-making process of a person as resulting from a composite evaluation system..

From this formula can be obtained the number of interventions desired from the model for the link with the Social Accountability Matrix.

Equation 4 – Equation of Action (number of new interventions) in Cubeddu (2017)

$$nint_i = \overline{N_0} * \overline{\hat{\iota}_p}$$

where:

$\hat{\iota}_p$ = Persuasion Power Impact

$PNTB_i$ = Probability of New Training by Businesses in the i-th policy

P_i = level of persuasion external to one's family nucleus

S_i = level of support external to the family nucleus

N_0 = number of people interested in change[18]

$\overline{N_0}$ = average number of people interested in change

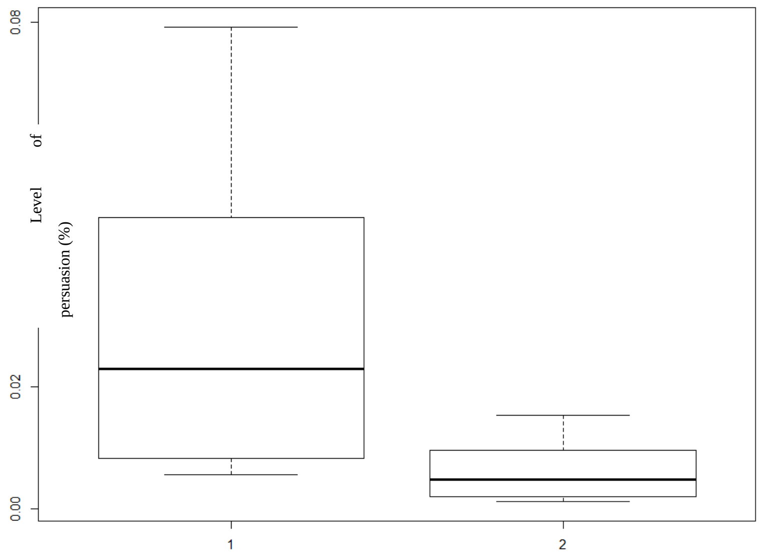
$\overline{\hat{\iota}_p}$ = average pressure resulting from the simulation

The sample not being large, it was decided to carry out a *bootstrap* simulation based on 10,000 repetitions of the model itself. The simulation resulted in an average value of the pressure indicator equalling 8.9% and 4.9% respectively for the two policies of Low and High Training. Multiplying the value of this indicator by the historical average of the number of the Families considered (equal to 14.217 in the period 2007-2013) 1260 and 695 new implementations of the policy

[18] Hypothesized as equal to the historical average of subjects which carried out EE interventions in the period 2007-2013 indicated in the ENEA report [13].

were obtained. In figure 1 a box plot shows the value of the impact of the social pressure expressed in the simulation.

Figure 1- Logical Synthesis of the social experiment carried out simulation



Impact of social pressure

The *box-plot* summarizes the model written in R, presented below. It will be observed that in the model realized the most trained subjects are also those who start up the training. Social pressure involves a spread of training and thus a greater start-up of interventions in Energy Efficiency. The agents affect one another; social persuasion involves an increase in the spread of training.

Policy 1, with greater investments in training, shows that the greater the increase in training the greater the spread of technologies and the more rapid the implementation. As a result, there is an increase in interventions.

Construction of the Social Model in NetLogo

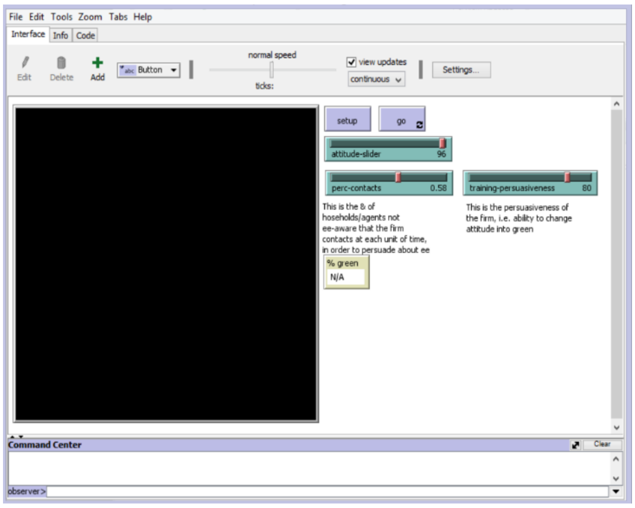
The model analyzed above with R does not permit observation of the movement of the social actors and thus does not graphically effect micro reproduction of the actions.

The ABMs follow Boudon and Coleman's Micro-Macro-Micro process, but in order to be able to observe it, Netlogo software [14], whose settings permits such a representation, was used.

NetLogo reproduces the simulation of the real system showing: the movements of the social agents (Business, Government, Trainers and Families), how the spread of Energy Efficiency policy measures (ee in this graphic representation) occurs, and what happens when investments in training are made.

The Nowak, Szamrej, Latanè Model [15] is represented with the ABM in NetLogo, showing that training carried out in the firms has effects on the families: 100 firms correspond to 1000 families which as a result of persuasion and influence are in their turn trained. NetLogo, as shown in Figure 2, appears with an interface consisting of: *Setup*, *Go* and three *Sliders* which are: *attitude*, *perc-contacts* and *training-persuasiveness*. The *green %* button shows the percentage of the agents/families that have an *attitude* towards implementing Energy Efficiency measures.

Figure 2 – Interface of Cubeddu NetLogo Social Model



The settings were chosen and created to permit the movement of agents: specifically, the *attitude slider* makes it possible to see the decision of families to adopt energy efficiency systems; the *perc-contacts slider* represents the number of subjects/families that have not been influenced and on which the firms apply persuasion, and *training-persuasiveness* is the persuasion carried out both by the firms and subjects in proximity which have the capacity to change *attitude* (to implement energy efficiency measures) in relation to training.

First of all, on the basis of the social model shown above, a *code* is written in which the functions of the actors and their actions are made explicit, permitting representation of the simulation. The functions written in the code simulate the movements of the agents in the software.

From this point all the actions shown are referred to the graphic simulation. In fact, it will also be necessary to graphically illustrate the software interface in order to show the reproduction of the ABM, theoretically the Macro-Micro approach that in its representation becomes Micro-Macro.

Going back to the theoretical model, the opinion on the application of tools in Energy Efficiency is observed with *attitude*, based on both the persuasion and support variables.

The model indicating *attitude = 1 (green)* shows that the agent decides to implement Energy Efficiency interventions. Families are influenced by *neighbours*, as in the Nowak, Szamrej and Latanè model. In addition, it can be observed that the effect of persuasion and support is determined by the firms and the training exercised on the firms:

1. one (or more) firms that train and persuade the agents to change their minds about Energy Efficiency;
2. the power of persuasion, given by the training of the firms.

In the model the firms come into contact as a result of proximity with a variable number of non-trained agents who do not have any knowledge about Energy Efficiency (*perc-contacts slider*) and to which the process of persuasion is applied. In other words, the firms exercise on the subjects a force given by the relation of persuasion and support on the subjects in their vicinity

$$(\hat{\imath}_p = PNTB_i * N_0^{1/2} * (P_i/S_i)/N_0).$$

The agents near both the firms and the agent/family exercise a capacity of persuasion (which is variable, can be defined with the *training-persuasiveness slider* and has a distance of zero). In addition, it can be stated that, as a result of contact with the firms (which have clearly explained all the advantages of ee to the other agents), the people who come into contact and exchange influence about the implementation of Energy Efficiency systems (*ee-friendly*) inherit the firm's power. Their capacity of persuasion and support increases significantly, because they have been more informed. Therefore, their capacity to contribute to the diffusion of the policy becomes greater and greater.

The effects of training, persuasion and spatial vicinity among all the agents makes it possible to observe that if we start from the original model (launched with Setup) from a situation of low green (if no training has been exercised on the firm and thus there is no knowledge of the policy), the result will be that the greens, the agents trained, are forced to disappear – as though a culture of anti-development, anti-investment and anti-efficiency were being spread in society (Figures 3a and 3b).When the level of persuasion of the firms is introduced into the model with the *perc-contacts slider* the opposite effect is observed – that is, the firms contribute to inverting the tendency thanks to the action of influence practised on the agents and families. This influence generates agent spreaders with a high persuasion capacity. The result is evident: starting from the same situation, green energy spreads (Figures 4a and 4b).

Figure 3a – Cubeddu Setup Model with low level of persuasion and presence of agents with knowledge of EE measures.

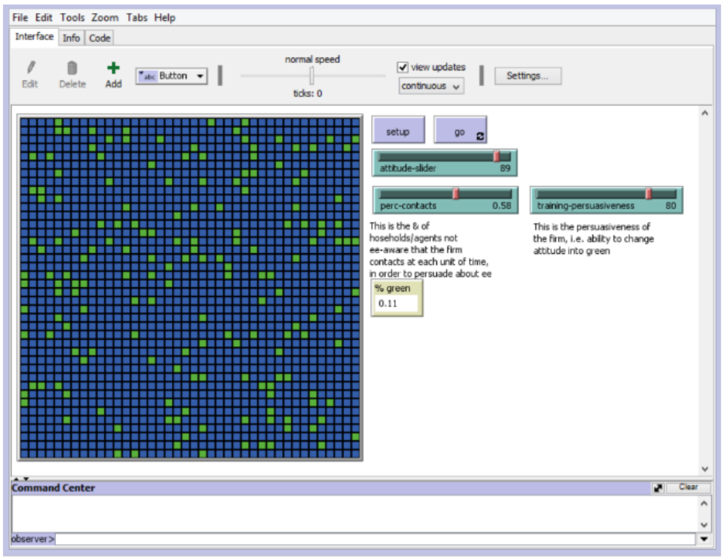


Figure 3b – Cubeddu Go Model movement of agents with low level of persuasion and training; the agents increasingly have no knowledge of EE and measures and do not put them into practice.

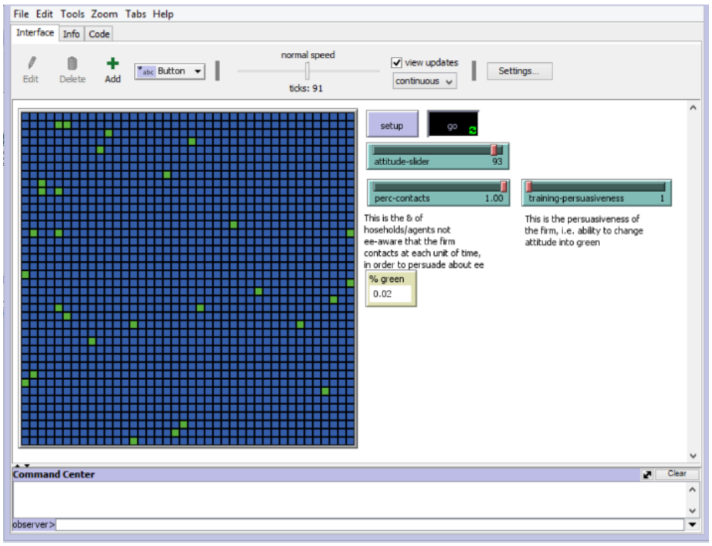


Figure 4a – Cubeddu Setup Model with high level of persuasion and training and agents who have knowledge of EE measures.

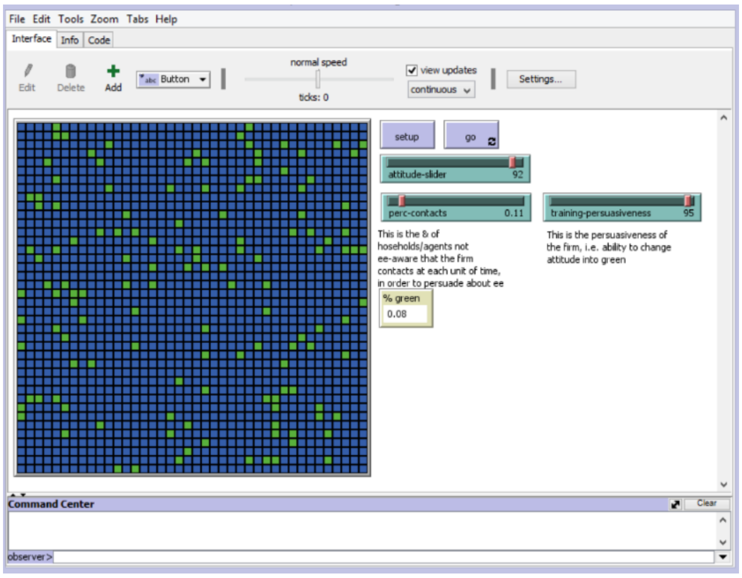
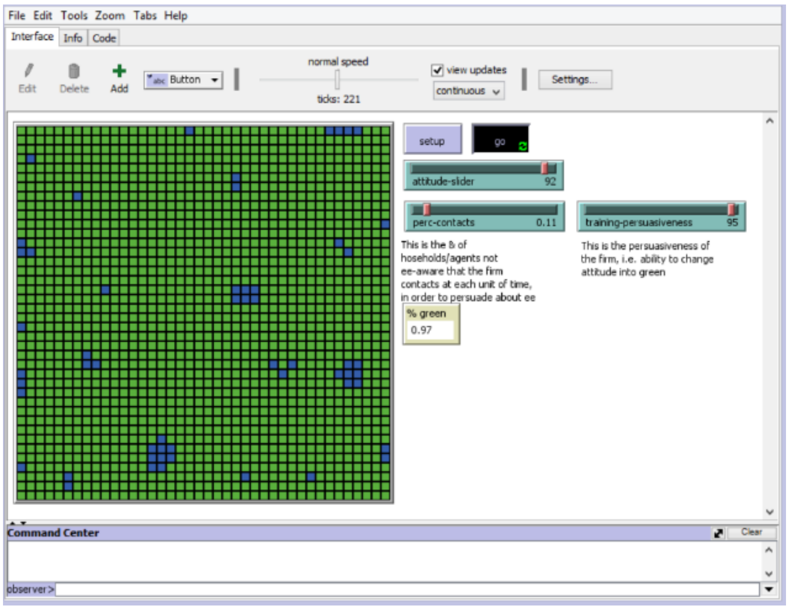


Figure 4b – Cubeddu Go Model movement of the agents who with a high level of persuasion and training increasingly have knowledge of EE measures, put them into practice and spread knowledge.



The model shows that once a critical level is reached, the policy spreads itself, through the persuasion of the agents who live in close proximity.

With training, the firms exercise a stimulation force leading to activation of the process.

The ABM model presented in NetLogo makes it possible to see what impacts a training policy has in the spread of – in this case – Energy Efficiency measures[19].

The true model is not so much the one represented with the software but the one outlined in the theoretical part, since only by studying the network, the actors and their movements over the territory is it possible to generate opinions and functions that are translatable mathematically and graphically.

In the social model it is clearly shown that training involves the diffusion of the policy, with the application of its mechanisms, only if there is a real interest in investment in training. Social persuasion is thus exercised on the families and support comes into play. Investments in training are among the tools used to incentivize policy implementation and diffusion, which is fundamental because it brings the economic dimension into social behaviour. In fact, a concrete method to illustrate how the adoption of Energy Efficiency policy comes about is to observe the number of interventions carried out and participation in training courses.

The results of the case study integrated into the SAM[20]

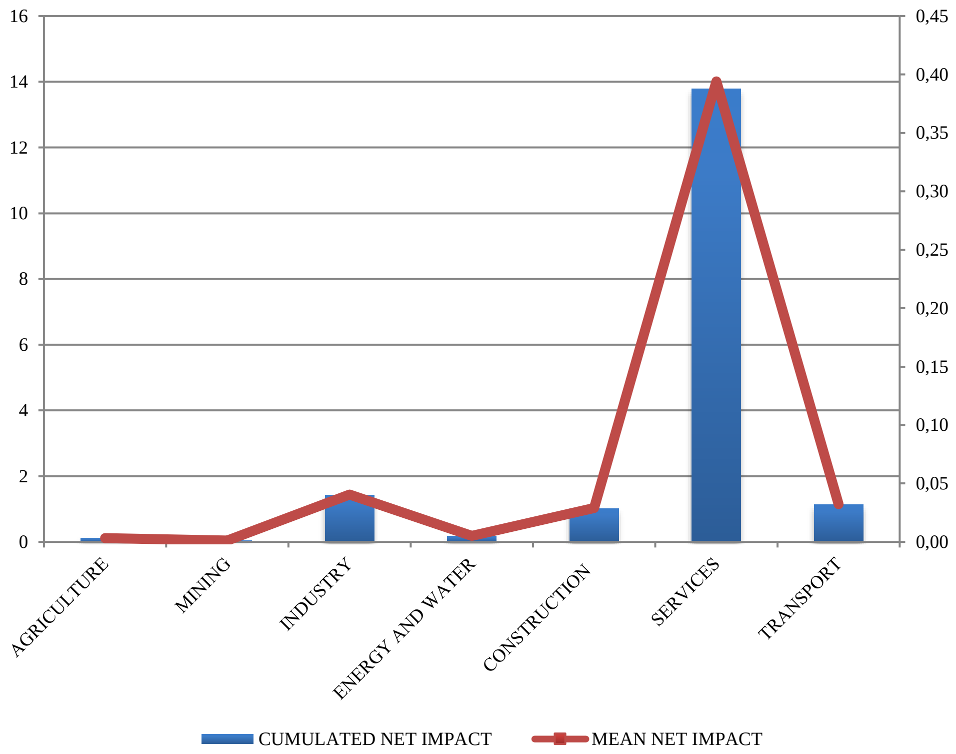
Once the social model was built and realized with the two types of software, it was possible to go on to the second phase of the research: the insertion of the social variables into the Social Accounting Matrix.

The Social Accounting Matrix – SAM from now on – [16] permits observation of all the social impacts deriving from the social model. The data of the social model examined are fed into the Matrix constructed in Excel. The data on training and investment in incentivizing activities for the Energy Efficiency measures show that with increased information and education there is an increase in human capital employed, in addition to the economic capital possessed by the subjects. Figure 5 shows average annual effects on added value and employment deriving from the adoption of the Policy (of training) simulated in the Social Model. The effects are clear, since the values calculated for the Policy scenario have been subtracted from those relating to the contra-factual scenario. This

[19] The effects of Training can be analyzed and studied according to different themes and policies.
[20] Matrix used at Enea, designed and patented with Tor Vergata University.

makes it possible to have a realistic and concise picture of the effects derived from investments in training.

Figure 5 – Net results of the evaluation of macroeconomic impact of the scenarios under consideration (Policy - contra-factual– annual average – data in millions of euros (added value) and thousands (JC).



The SAM results confirm that an aggressive policy on training would (if the result furnished by the Social Model created is accepted as a given) produce a positive effect both in terms of added value and number of jobs. The complete results expressed by macro-sector are contained in Table 1. The table shows the impacts in the macro-sectors of economic activity. Closer examination of the data makes it possible to observe some characteristics of the type of impact considered, relating to the nature of the activities connected with interventions of building upgrading.

Table 1- Complete evaluation results of the Policy and contra-factual scenarios by means of SAM – data in millions of euros (added value) and thousands (number of jobs)

	POLICY 1		**POLICY 2**		**NET**	
ADDED VALUE	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**
EMPLOYMENT	2,34	0,07	1,87	0,05	0,47	0,01
CAPITAL	2,89	0,08	2,31	0,07	0,58	0,02
FAMILIES	6,08	0,17	4,86	0,14	1,22	0,03
ENTERPRISE	1,39	0,04	1,11	0,03	0,28	0,01
AGRICULTURE	0,15	0,00	0,12	0,00	0,03	0,00
MINING	0,14	0,00	0,11	0,00	0,03	0,00
INDUSTRY	2,28	0,07	1,84	0,05	0,45	0,01
ENERGY AND WATER	0,40	0,01	0,32	0,01	0,08	0,00
CONSTRUCTION	0,72	0,02	0,58	0,02	0,13	0,00
SERVICES	5,15	0,15	4,12	0,12	1,03	0,03
TRANSPORT	0,61	0,02	0,49	0,01	0,12	0,00
GOVERNMENT	1,12	0,03	0,89	0,03	0,22	0,01

	POLICY 1		**POLICY 2**		**NET**	
JOBS CREATED	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**
AGRICULTURE	1	0	1	0	0	0,01
MINING	0	0	0	0	0	0,00
INDUSTRY	13	0	11	0	3	0,07
ENERGY AND WATER	1	0	1	0	0	0,01
CONSTRUCTION	5	0	4	0	1	0,03
SERVICES	45	1	36	1	9	0,26
TRASPORT	4	0	3	0	1	0,02
GOVERNMENT	0	0	0	0	0	0,00

The data are grouped according to macro categories thus providing a summary of the effects of the two policies and the resources necessary for their implementation. The table shows that there is an impact on all sectors; however, it is greater on productive activities. The effects of the policy produced by the difference between added value generated in the case of the Policy scenario and added value generated in the contra-factual scenario, lending support to the hypothesis that investment in training can pay off in positive effects on the entire system: activation of upgrading interventions and direct and indirect movement of the economy. It moreover very clearly illustrates that the sectors in question (when only the productive and not institutional sectors are considered) can be divided into two groups where most of the effects of the interventions are concentrated: energy, construction and services.

This is understandable since these are the sectors most involved in carrying out upgrading procedures (ranging from construction firms to the various professionals involved in different ways in the operations). There are other effects – not analyzed here – relating to the structure of the SAM matrix multipliers, showing that the indirect effects can also be significant in sectors which are not, naturally, directly linked to the investments made (such as health care, for example, in the graph). When a policy of investment in training is implemented permitting the diffusion and application of Energy Efficiency measures, there is an impact over the entire socio-economic context since Social Well-being increases. The benefits of the Energy Efficiency policy appear only if other kinds of policies which validate and promote development policies are implemented.

Only an increase in employment, generated by increased demand for interventions, will have a cascading effect, as follows:

1. Dual effect – that is, physical and mental – on subjects' health;
2. income;
3. GDP growth;
4. increased consumption;
5. increase in savings;
6. environmental wellness;
7. decreased fuel poverty;
8. decrease in CO2;
9. increase in social security.

These nine impacts are only some of the possible benefits, since there are multiple effects on social well-being. The theoretical and methodological aspects permit us to state that the actions triggered even by a single social agent can modify the entire social system, above all if the action implemented brings with it determined logical behaviour aimed at well-being. The pursuit of well-being by a single individual involves all social behaviour, because the collective social consciousness of well-being moves with each subject.

4 Discussion

The research aimed to observe the role of Training in the use of and investment in Energy Efficiency measures. More specifically, it analyzed how training, promoted by the policies addressed to firms, is spread to other agents in the social system.

The effect of training spreads with social proximity, persuasion, support and individual attitudes. These categories were borrowed from the 1990 model of Nowak, Szamrej and Latané and the study's equation was specifically re-formulated according to the superstructure of the phenomenon under consideration. The Cubeddu model studies the role that firms play in relation to the subjects within their area, a power given from the relation between persuasion and support:

($\hat{\iota}_p = PNTB_i * N_0^{1/2} * (P_i/S_i)/N_0$)[21].

The analysis is applied to the Lazio Region and is based on the behaviour of three main subjects (Family, Trainers and Businesses), which put into practice and respond to the policies proposed by the fourth (Government). The study of the Lazio Region permitted the collection of primary data – albeit not statistically important – on which the social model and integration was then constructed.

Training entails social influence, shown by the persuasion which is reinforced by incentivizing subjects' well-being. With training courses, trainers provide support to the persuasion of the subjects because they believe, as is evident from the answers to the questionnaire, that training brings impacts of short, medium and long duration. They maintain that by modifying the technological approach, an improvement in individual and collective well-being occurs.

The model presented with ABM shows that training carried out by businesses has effects on the families: 100 business firms trained correspond to 1000 families which as a result of persuasion and influence are in their turn trained.

The agent-based model created with NetLogo shows that the probability of implementing Energy Efficiency activities grows in relation to the level of training the subjects have, to the level of external persuasion exercised by the

[21] Impact of Persuasion Power (P) in Cubeddu (2017), mentioned above where:
$\hat{\iota}_p$ = Persuasion Power Impact
$PNTB_i$ = Probability of New Training in the i-th policy
P_i = level of persuasion outside one's family nucleus
S_i = level of support outside the family nucleus
N_0 = number of people interested in change
$\overline{N_0}$ = average number of people interested in change
$\overline{\hat{\iota}_p}$ = average pressure resulting from simulation.

businesses and the residents themselves and to the level of support, thanks also to the number of subjects who changed attitude. The social model shows that training entails policy diffusion with the application if its mechanisms, but only if there is real investment in training. In this process social persuasion exercised on the families and support is activated.
Investment in training is one of the incentive tools for policy implementation and diffusion. Incentives are fundamental because they bring the economic sphere into social behaviour. Concretely, the adoption of Energy Efficiency policy is ascertained through the number of interventions carried out, as well as participation in the training courses.
In order to obtain the socio-economic impacts of such investments the social model data was inserted into the Social Accountability Matrix (SAM), which shows that with an increase in information and training there is an immediate increase in human capital employed, in addition to the economic capital in the subjects' possession. There are immediate impacts, for example in the building sector, real estate and professional activity (employment); cascading impacts follow, first of all on health and social services, then on electrical energy, gas and steam and ultimately on commerce. These impacts produce immediate benefits observable in the short, medium and long term. One of these is employment, which naturally occurs, as a result of training as well, because it becomes clear that there is the need to create new job positions.
In analyzing local dynamics, it becomes important to explain the phenomena according to an integrated model. In this analysis, it was possible to exploit this approach in order to be able to observe its impacts. The study of the local dimension makes it possible to integrate different systems and to formulate a new integrated paradigm. The figure of the social actor moving over the territory and acting to achieve his goals connects the social with the economic aspect. In fact, only with a paradigm of interconnection is it possible to interpret the social system in its entirety.

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The logical perception of the pure consciousness

Yosef Joseph Segman[1]

Abstract

Does pure consciousness exist without being incarnated to a physical mechanism (e.g. physical body)? Can such claim be proven logically? The magnitude of asking this sort of question is similar to asking: Is it logical that matter exists out of the total void? The answer to both questions is yes. The aim of this paper is to show that, the existence of pure consciousness is a logical state, it is not energy, and it exists timelessly and can be experienced beyond the physical body. Furthermore, we show that pure consciousness (the soul) is a virtual junction on the metaphysical virtual net where each junction incorporates a set of cords of consciousness. The set can be limited, unlimited or uncountable. Cords of consciousness is treated as brain neural patterns and as such the brain can easily be manipulated by an external device which may transmit neural patterns in order to generate artificial scenes. A computation example was provided to elaborate the neural patterns and cords of consciousness. Finally, we discuss the opportunity rather than the possibility to visit the metaphysical virtual space. In that sense, since it is possible, should we grab the opportunity and expend our science beyond physics, into the metaphysics?

Keywords: Consciousness, pure consciousness, Void, Void Complementary, Metaphysics, Logic, Brain, Neural Network, Synchronization, Synchronized Groups, Order, Disorder, Linear Schrödinger Representation, Frequency, Phase, Hologram Surfaces, Virtual,[2].

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1. Introduction

Throughout history, humans have been making efforts to understand, define and study consciousness, since understanding our consciousness is so central to understanding anything else. Unfortunately, so far, no distinct answer has been found for this question [2-24]. What is distinctive about how modern scientists and scholars are approaching this issue is that they are treating it as a scientific problem rather than a spiritual one and they approach the neuroscience for answers [4-14]. On the other hand, consciousness cannot be faced using only the scientific approach saying that consciousness is a physical state, as it sounds like saying software is a laptop. Looking for consciousness solely in the brain would be similar to looking for the radio broadcaster inside the radio itself. William James, for instance, remarked that a purely cognitive description of it would leave consciousness dry and without purpose, a situation corrected by appreciating the importance of emotion to consciousness [3]. Furthermore, trees do not have any nervous system or brain, but they have consciousness. Whether a single living cell has a mind or intelligence may raise disputes, but it undoubtedly possesses consciousness. Therefore, a different, logical approach should be used in order to finally crack the enigma of consciousness.

The scientific exploration of phenomena and experience relating to consciousness has long been hampered by two obstacles. One is that subjective experience does not meet the commonly accepted criteria for data in a scientific analysis, in that it is not public, objective, and replicable. The other is that many consciousness-related phenomena do not appear to fit comfortably into the accepted scientific worldview. For instance, the common-sense assumption that conscious volition is causal — that my desire can cause things to happen — conflicts with the assumption of mainstream science that the universe operates according to causal laws which can be objectively known.

The purpose of this paper is to show the logical perception of the existence of consciousness without necessarily incarnated to a physical body, the "***pure consciousness***".

2. The Void and its Complementary

The understanding of the timeless existence of pure consciousness starts with understanding that the natural state of existence is total void Segman 2020[1]. The existence of matter out of the total void is discussed in Segman [1] and it is summarised as follows.

The void is the only logical state, and due to the existence of the void, the void has complementary. What would be the void complementary? It is shown that the void complementary cannot be the universe, i.e. substance, and it is concluded that the void complementary represents the total information about all potential scenarios, i.e. stories. A story can be our life time story, a planet story, a sun story, a universe story up to any space time universe. In that sense the void complementary represents the story of any potential event.

Yet, stories are realized within universes, and the question remains how a universe exists if the void complementary incorporates virtual possibilities but not substance?

Substance is a logical state within the void complementary, wherein a universe has a complementary universe such that the total matter of the universe and its complementary collapses timelessly into zero matter i.e. null matter [1]. This can be presented in the following equation:

$$(1)\ [+U] + [-U] = 0$$

[+U] represents the "positive" universe and [-U] represents the complementary universe (please notice that the complementary of the void and the complementary universe are two different things). The differences between the "positive" universe and its complementary are detailed in Segman 2020 [1]. The important understanding for the current explanation of physical matter existence lays within the above equation. The right side of the equation, represents null physical sensation i.e. no sort of any physical force. But, each part of the left side of the equation, represents physical sensation i.e. real physical force. For example: (+2) +(-2) =0, the right side equal to zero indicates zero matter, resulting in no physical sensation, while (+2) of the left side, represents real physical force, e.g. gravitation or attraction at level 2 and (-2) represents the opposite force, e.g. opposite gravitation, in that sense rejection at level (-2). Therefore, the existence of the physical forces and matter is a virtual logical state in the void complementary which is realized timelessly [1]. A potential story is realized in an applicable spacetime universe, such as [+U].

3. The Metaphysical Space

The Metaphysical virtual space is defined to be the void and the void complementary [1].

The metaphysical space incorporates all information about any potential scenario, including the null scenario or the null story. The metaphysical space is a unique complete virtual space [1]. It does not evolve, and it has no reason or desire to evolve. Yet, within our own story, we evolve and our evolution reflects intention.

A good example of the completeness of the metaphysical space is the human brain that may generate images that were not encountered during the specific life, and yet, it was generated by the brain. In that sense, the brain incorporates all potential stories and one may or may not rediscover it. All scenarios are existing in the metaphysical space, and by the power of our pure consciousness (as defined below) intention we may rediscover new metaphysical events.

Due to the above-described characteristics of the metaphysical space it can be also described as GOD. A particular example is of Exodus 33: Moses asks GOD, show me thy Glory.

20 ….And said, Thou cannot see my face: for there shall no man see me, and live.
21 And the Lord said, Behold, there is a place by me, and thou shall stand upon a cliff:
22 And it shall come to pass, while my Glory pass by, that I will put thee on the cliff, and your eyes be covered until passing:
23 And your eyes be uncovered, and thou shalt see my rear as my face cannot be seen.

Pursuant the definition of the Metaphysical space, the Lord face is the void and the Lord rear is the void complementary. As it seems, the definition of GOD in the old testimony is a logical mathematical definition.

While writing these words, Moses is standing on the cliff in his time, experiencing a timeless moment of our time and other times of the void complementary.

4. Realization of stories within the universe

4.1 Time and Lack of Time:

The concept of time exists only in the physical universes, also called spacetime universes. In the metaphysical space, the concept of time does not exist and therefore one can simultaneously observe a story that happened, for example, thousands of years BC and a story that happened a few thousand years "in the future". Similarly, we experience linear time throughout our lives, but if we look at this life from a metaphysical point of view, we will realize that the beginning and endpoints of our lives reflect the same state - a state without time. Figure 1 elaborates on this idea.

Based on the above, it can also be concluded that our life story and the life trajectory we are experiencing now is the realization of the metaphysical story that exists timelessly. On the other hand, in the linear timeline, we are currently experiencing within a physical state, every decision and every situation we experience determines the story, so now we determine what exists timelessly forever. This situation creates an infinite and uncountable number of potential routes. Each potential trajectory has a suitable spacetime universe realizing the particular trajectory decision branches, including trajectories of situations of other entities associated with the same trajectory as can be seen in the following figure 2, where each colour represents different life trajectories created as a result of different decisions made during a trajectory with a shared starting point

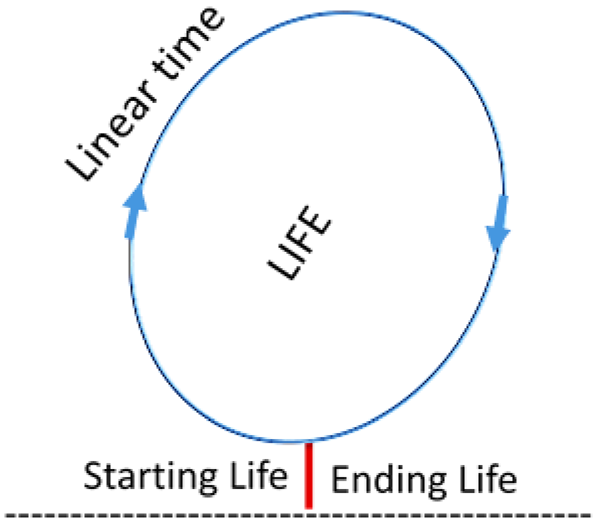
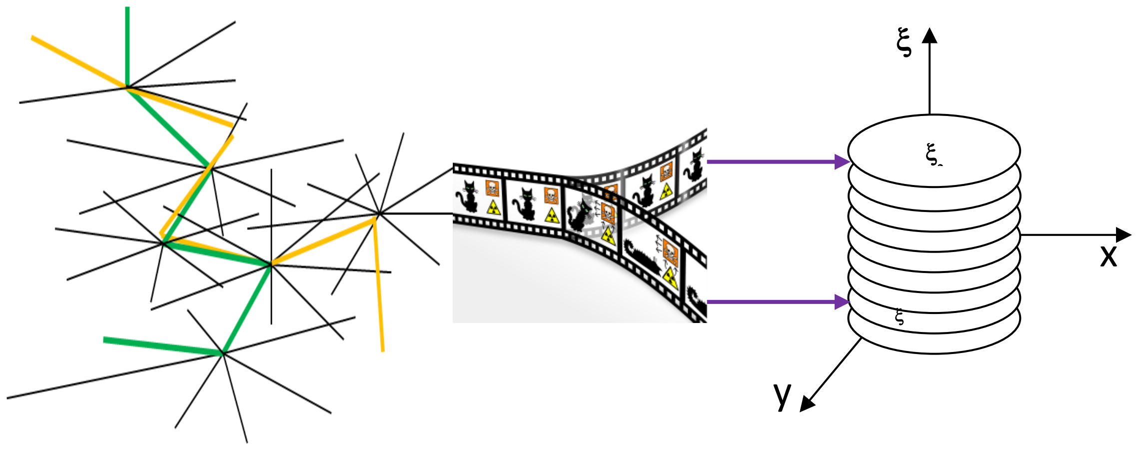


Figure 1: From the metaphysical perception starting and ending life reflects timeless event.



A **B**

Figure 2: A: Two possible stories differ from each other by certain decision made at specific point, making the two stories to separate from this point on. B: Each story is realized in an applicable space-time universe virtually located over distinct phase hologram surface [1].

4.2 Realization of stories

In order to understand the idea of what is the pure consciousness, let's understand first, how stories are realized from possibility into a realized story.

In order to do that, let's assume that there are two buckets. An a-priori bucket incorporating all potential scenarios (i.e. events, stories) that have not been realized yet in suitable universes and a post-priori bucket, incorporating all realized stories in suitable universes. A story can be the story of a planet, star, galaxy, universe and of every living creature. A story of a living creature would reflect the story of every biological cell, every thought, desire, wish, love, hate, anger, appearance, intention, etc. If a story was realized it changes its virtual logical status from not realized into realized e.g. from {0} to {1}. That is to say, the story is shifted virtually from the a-priori bucket into the post-priori bucket. However, due to lack of time, all stories have been realized timelessly and the a-priori and post-priori buckets are in fact one single bucket, i.e. huge archive representing infinite uncountable events or stories that have been realized in applicable universes. Once a potential story/event exists, it is realized timelessly. Currently, at this moment, each one of us is executing his/her timeless story.

Figure 3 below elaborates that all potential stories are realized timelessly.

Possibility is being realized in a {+U} Universe

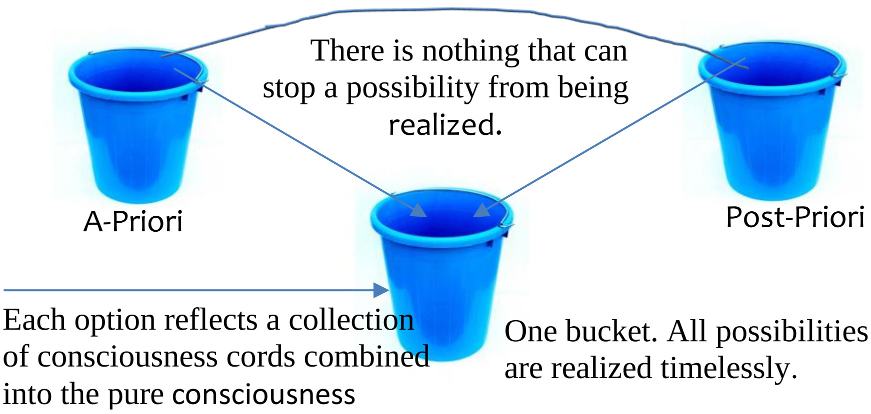


Figure 3: All stories are realized timelessly.

To summarize the above, if a scenario exists, then what stops its realization? In fact, nothing. Every story is being realized in a suitable universe, just because of its potential existence in the void complementary. We, in the current situation, realizing our own story. We do not know the end of the story but we are walking in the path of the story. While the story exists timelessly, it is us determining and experiencing the story right now. Within the story, we sense linear time. Yet from the perspective of the void complementary, before birth and after death represent lack of time.

In order to better understand the relationship between the timeless metaphysical virtual space and the actual realization, consider the current brain memory. All memories are potentially in the brain, yet, they are not there unless the brain is triggered to remember. Furthermore, we can remember in any order, for example, age 10 then 5 then 15. Although memories are accumulated in a linear order, however, once accumulated, the retrieving process may be in a disordered manner or an ordered manner or various combinations, it depends on our wish to retrieve memories.

We can also consider the metaphysical space as a huge, infinite, uncountable archive of video clips, in which any story has its clip presenting the story. A metaphysical observer can watch a video describing a story from the year 2020 and then year 1900 or both simultaneously or in any order that the observer intends to or of any spacetime universe.

But who is this metaphysical observer? A metaphysical observer is a pure consciousness and it can be more than just an observer.

5. Brain neural network and cords of consciousness

The last puzzle particle before we can define the pure consciousness is the way a realized story is connected to the physical body- neuron synchronization in the brain.

As described by the neuroscience, basic neural operation would be one of the following states: idle, receiving charge, transmitting (firing) charge. In the same way, computer memory is composed by zeros and ones coded in bits and bytes. But what information these zeros and ones give us without executing a dedicated decoding software to interpret these zeros and ones into harmonic information?

Similar to the case of computer decoding bits into information, the brain "decodes" neural activity into neural patterns. A neural pattern reflects metaphysical information. Information is a metaphysical state, piece of information in the story puzzle e.g. emotions, intentions, etc. For example, the scene observed by the human eyes reflects certain images, these images are transmitted and decoded into neural brain patterns. When the brain regenerates the neural patterns, these images are recreated out of the metaphysical virtual space.

5.1 Order vs. Disorder:

In order to understand the neural network synchronization, let's look first at the factors influencing order vs. disorder.

Figure 4A demonstrates matches thrown randomly on a table. Order is achieved by setting groups of matches according to their common angle. Matches at identical angle form a synchronized group with a synchronization angle element. The group intensity is considered as the total matches within each group.

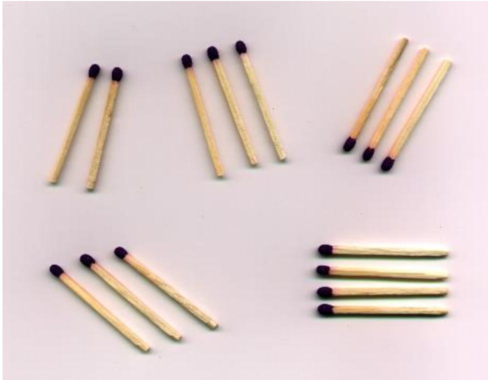


Figure 4: A: Disordered Matches reflecting neurons.

B: The order within disorder. Each group is represented by the angle and the group intensity by the number of matches.

As shown in the above figure, the matches are synchronized into patterns, each pattern is identified by its synchronization angle element. Now, let's consider neurons instead of matches, where the synchronized reaction of a group of neurons determines neural pattern. The pattern is identified by its synchronization element, i.e. angle, by the group intensity represented by the total neurons participated in the group and by the group topology.

The group topology, for example, could be neurons having identical synchronization element and are sufficiently close one to each other. Other topologies can be association rather than distance. Association means having certain similar characteristics such as similar inner frequency or mutual reaction to certain stimulus. For example, in daily life, the closest neighbour may not be the best friend, the best friend may live far. Similarly, the closest neuron may or may not be part of the synchronized group.

It is important to note that single neurons may synchronize with various groups of neurons depending on the momentary stimulus. This characteristic enables a large variation of synchronized groups of neurons.

Pictures 5 presents the general idea of synchronized temporal groups of neurons based on different fish school examples.

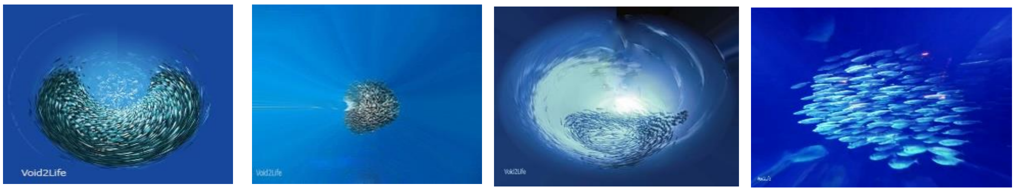


Figure 5: Each picture represents a different synchronized school of fish. Considering each fish as a single neuron associated to its current synchronized group. Each synchronized group has its pattern.

5.2 How do we "download" information?

The retrieving process is achieved by a linear combination of groups of synchronized neurons [1, 23-27]. That is to say, a virtual linear combination over various neural patterns retrieves the desired timeless metaphysical information. What is information? It reflects a story, a scene, an image, a sequence of images, a voice, a feeling, desire, a story of an atom, planet, galaxy, the universe, etc. This means, that the process of remembering is a recreation of the neural patterns associated with the specific historical events.

Although memory depends on the existence of neural patterns, i.e. synchronized groups of neurons, unexperienced sensation such as images, voices, smells, tastes and feelings can be created by synchronizing new groups of neurons without experiencing real sensation. This may occur in dreams, whether a random or intended dreams, wherein neural patterns are created without being experienced in reality.

Whenever existing neural patterns are recreated, it is treated as memory, otherwise, it is considered as new learning, imagination, ideas, dreams, illusion and so on as described in the below figure.

The intention is the key to downloading metaphysical information. The intention may trigger the neurons to synchronize in such a way that it provides the desired metaphysical sensation by forming the desired physical neural patterns.

"Downloading" information

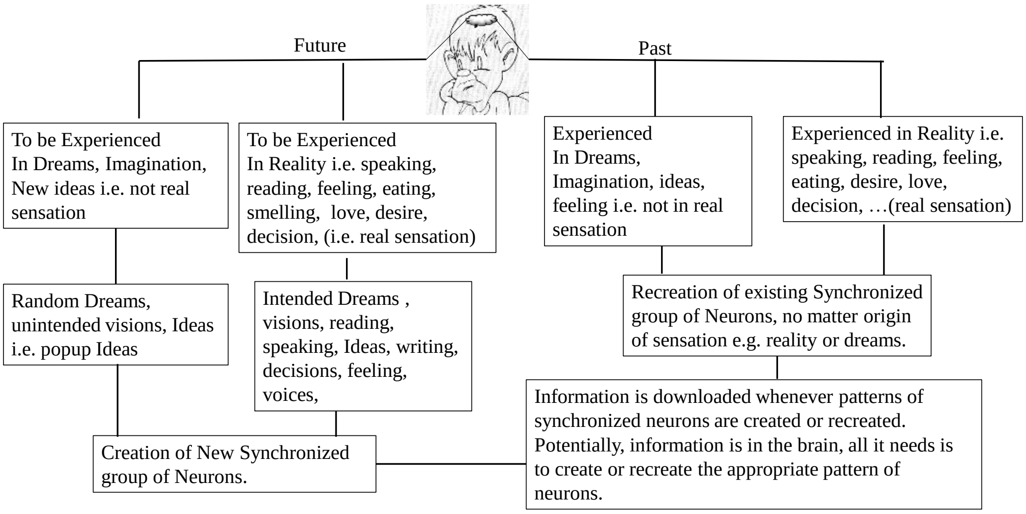


Figure 6: Past memories depend on the recreation of neural patterns acquired during life. These patterns may have been acquired by real experience or by other sensations like dreams or imagination. Future is the potential to create new patterns of groups of synchronized neurons either by real sensation or virtual sensations such as in dreams or imagination whether randomly or by intention. Whenever a neural pattern is created, the sensation is established, no matter the source (real life experience, popup idea, dreams, imagination, etc.). Memory can fade if not being used or if there is certain biological "hardware" problem in the brain like blood supply.

5.3 Why don't we remember all of our experiences all the time?

Although all memories are potentially existing within the brain neural network up to the current moment, we do not experience the entire memory every moment, unless the brain is triggered to remember i.e. to recreate or re-stimulate the neural patterns associated with a specific event.

Why does the computer not play its entire memory all the time unless there is a request? The simplest answer would be minimal energy spending. There is no need to overload the system if there is no request for specific information, otherwise, the system (biological as well as electronical) may result in a crash. We remember when we need to remember, when the brain is triggered to retrieve information. We can remember in disordered manner, age 20 then age 5 then age 10 and so on. Once stories are stored as brain neural patterns, time is irrelevant.

Considering the metaphysical virtual space, the total potential information is there, once the brain creates synchronized neural patterns information is retrieved in that sense it is being "downloaded" from the metaphysical space. Retrieving order is irrelevant just as retrieving order of brain memories is irrelevant. Potentially everything is there and we just need to trigger the brain to download the information in order or disorder.

6. The pure consciousnesses

Based on the above we can now proceed to the definition of the pure consciousness:

6.1 Cord of Consciousness:

A neural pattern is considered to be cord of consciousness and vice versa, i.e. cord of consciences defines neural pattern. A neural pattern matches certain cord of consciousness reflects certain information, sensation, feeling, etc. On the other side, a cord of consciousness reflecting a sensation, vision, image, etc., matches specific brain neural patterns.

Cord of consciousness is a metaphysical logical event and whenever the brain create/recreate neural patterns there is a virtual match with certain cords of consciousness. Yet, the issue is not really the information, rather the intention within the information i.e. the story.

6.2 The metaphysical virtual net of pure consciousnesses

A virtual net of infinite, uncountable junctions, where each junction incorporates cords of consciousness, represents a pure consciousness i.e. a soul.

Due to the completeness of the metaphysical space, the net represents order and disorder and any potential scenario. It has no space, no distance, no first, no last, no direction, no history and yet idioms of time, history, order, disorder can be found in the net as the perception of the pure consciousnesses.

Pure consciousness may incorporate one, two, finite and infinite junctions up to the entire net representing the entire metaphysical net. We are now, in the present time, experiencing junctions of the virtual net of cords of consciousness.

6.3 Pure Consciousness, soul and reincarnation:

Pure consciousness is a virtual set of cords of consciousnesses. The set can be finite, infinite and/or uncountable cords of consciousness which can be incorporated into one or multiple junctions of the metaphysical virtual net up to the whole net. The vividness, e.g. richness of the pure consciousness is determined by its cords of consciousness, reflecting memories, knowledge, emotions, intelligence, talent, wishes, desires, loves, hate, anger, intentions, etc. It is the virtually story or stories of a junction or multiple junctions.

It is upon each one of us to define the level of his/her consciousness, to be a single junction or multiple junctions. Each junction may represent life in a certain space time universe. Therefore, single junction means a consciousness incorporates only “me”, it is my virtual replica of the current life. It exists due to its logical existence in the void complementary i.e. in the metaphysical space. It carries virtual eyes, ears, brain up to the entire body, it carries the sensation of me of this life. Multiple junctions mean “my” consciousness incorporates this current lifetime story together with additional lifetime stories as much as my pure consciousness has experienced up to the totality of the whole metaphysical net.

A pure consciousness with a capacity to incorporate multiple virtual junctions represents multi metaphysical timeless life stories, in that sense all stories have being realized. However, from the physical perception while experiencing a specific life story, i.e., living the actual story, we get the sensation of order where “reincarnation“ is a sequence of life story, executed one after the other.

The metaphysical space is one complete virtual space wherein all sort of information is potentially accessible to any pure consciousness. Potential accessibility means we are virtually connected. Yet, there are pure consciousnesses who may have the knowledge to isolate themselves in the virtual metaphysical net.

Furthermore, the metaphysical virtual space would be experienced as the pure consciousness vividness. That is to say, the boundaries of a personal metaphysical space are the boundaries of the pure consciousness capacity to incorporates various life stories and its beliefs. A pure consciousness which is willing to explore the metaphysical space would experience scenes and knowledge beyond imagination.

6.4 Random and Intended dreams, Awareness, Remote Viewing and Out of body experience:

Majority of the population are experiencing random dreams. The scenes appear as random brain neural patterns. In addition, in most of the dreams, the dreamer is an observer, in some cases the dreamer will observe himself participating in the scene, in some cases the dreamer will observe himself as a different individual. So, who is the individual, the observer, the observed or both? As discussed above, pure consciousness may represent multi individuals in contradiction to the perception provided in [25] where consciousness represents single unique individual defined by certain constraints. Nonetheless, during the execution of the story in an applicable spacetime universe, while being aware to a single body, gives us the sensation of uniqueness, i.e. of a single individual. However, the outcome of the neural patterns are cords of consciousness and as such they are *not* 1-1 connected to a single individual. In that sense, a dream can be dreamed by several individuals from different space time universes. That is to say, cords of consciousness can be matched by several individuals independent of their space time universe. The neural activity of each individual matches these cords of consciousness representing identical dreams or ideas or vision, etc. For better understanding this issue considering the following example:

Let N(X,t) be a neuron positioned in the brain at X = (x,y,z) brain coordinate system. "t" represents the response (firing) time. Every neuron N(X,t) has its own internal spatial-temporal frequency:

$$(2)\quad N(X,t) = p \cdot e^{j(\Omega X + \omega t)}$$

Where p is the response amplitude, $\Omega X = (\alpha \cdot x + \beta \cdot y + \gamma \cdot z)$ is a vector dot product, $\Omega = (\alpha, \beta, \gamma)$ is the frequencies vector related to the spatial neural vector X and ω is the temporal frequency related to the neural temporal group synchronization determining the momentary neural patterns.

A stimulus of the Mona Liza image is projected onto the retina sensors and further transmitted into the cortical visual section. The neural activity responded to the image generates set of neural connections Δ_k where

$$(3)\ \Delta_k = N(X_k, t_{MonaLiza}) \cdot Signal(t_{MonaLiza}),$$

X_k represents the spatial neurons that participated in the response and all share for example identical momentary temporal wavelength ω_M resulting from viewing the Mona Liza picture.

From the brain perception the Mona Liza is decoded into the sequence Δ_k. So, the Mona Liza is not in the brain instead it is a sequence of connections Δ_k that reacted synchronously and form neural patterns that matched cords of consciousness of the Mona Liza sensation.

Following the basic fundamental claim that the void complementary incorporates all potential information, it follows that in order to download the Mona Liza image i.e. to remember, a linear combination of the spatial frequencies of the neural patterns representing the Mona Liza i.e. that have formed the synchronized neural patterns of the Mona Liza stimulus should be recreated in order to recover the Mona Liza sensation. Of note*: usually the recovery would not be identical to the original sensation due to certain change in the original groups of neurons that participated in the historical event.* The recovery is presented as follows:

$$(4)\ \text{Mona Liza Sensation} = \sum \Delta_k \cdot \overline{N}(X_n, t_{MonaLiza})$$

The left side of Eq. (4) represents the metaphysical sensation of the Mona Liza resulting from the right side of the actual neural activity. $\overline{N}$ represents the conjugate to N. The right side is internal neural search mechanism in order to match the neural patterns Δ_k. In that sense the variables in the exponent of Eq. (2) will be chosen such that, whenever $k \neq n$, the outcome is zero otherwise one. This orthogonality is achievable since there are finite number of neurons per each summation. Eq. (4) and (5) are pseudo formulation of the general concept. Assuming that instead of Δ_k new neural patterns $\emptyset_m$ that previously was not experienced in the brain is now forming:

$$\text{(5) Wow I got a wonderful idea} = \sum \emptyset_m \cdot N(X_n, t)$$

Or maybe not, someone else already downloaded this idea from the Metaphysical virtual space! In that sense, the neural patterns $\emptyset_m$ are not unique to a single individual as noted above. The left side of Eq. (4) and (5) represents the metaphysical cords of consciousness sensation resulting from brain neural patterns of the right side. The sensation of the Mona Liza is not in the brain, it is a metaphysical sensation, kind of hologram projection, resulting from the brain neural activity. In that sense, the neural patterns Δ_k have matched certain cords of consciousness representing the sensation of the Mona Liza. Vice versa the cords of consciousness of the Mona Liza sensation have been matched with certain individual neural patterns Δ_k.

In terms of mathematics, the pseudo formulation may represent unique code to certain metaphysical sensation e.g. The Mona Liza. The neural restoration does not have to be in the form of a 1-1 mathematical operator inversion such as Matrix inversion i.e. if Ax = y and A is regular then y = A^{-1}x. The reason is that metaphysical information exists timelessly and the outcome of the brain neural patterns (right side of Eq. (4), (5)) match certain cords of consciousness (left side of Eq. (4), (5)). Similar neural patterns shall result in similar metaphysical sensation.

It is important to note that the right side provides certain time reference indicating on the physical momentary occurrence, while the left side is not unique to the current time reference.

Cords of consciousness are not unique to single individual and may experience by several individuals. Pure Consciousness may not be unique to single individual and it may experience several individuals where each individual has unique single physical body.

Intended dreams are controlled by the dreamer. The dreamer can stop the dream or change the scene and the actors. Furthermore, if the dreamer is capable to instruct to watch his pure consciousness or to watch his body during a dream, most likely he is *out of his body*.

Remote Viewing. A simple effective way to describe *remote viewing* sensation is like staying at home and watching videos or pictures of other places or individuals. In that sense, the pure consciousness stays "home" i.e. does not detach the body (i.e. still incarnated in the body) and it is intending to view certain scene over the metaphysical space. Intending means, to order the target scene to be viewed remotely.

Out of body experience is a sensation of the pure consciousness disengaged from the physical body. The sensation reflects sort of nonphysical awareness i.e. with a null body. Yet, the pure consciousness may construct a virtual body. The virtual body can be duplication of the actual real body or any sort of body or other physical structure.

From the physical perception, the sensation of *out of body experience* will be reflected as brain neural activity although the sensation is out *of the body, the brain is never shutdown*. In that sense, the pure consciousness can be in the kitchen or in other dimensions and the brain will continue to show neural activity*, although the metaphysical spatial location is not where the body is laydown*.

Does the Pure Consciousness exist without incarnated into physical body? *Does the left side of Eq. (4) or (5) exists without having the right side?*

The answer is provided in the fundamental claim that the void has void complementary which represent all potential stories of any scenario. This means that the information representing the left side of Eq. (4) or (5) exists timelessly representing the sensation of the pure consciousness and whenever there is neural activity it will always match certain information, or sensation or idea or memory, etc.

The outcome of an image (Eq. (4), (5) left side) resulting from brain neural patterns (Eq. (4), (5) right side) reflects sort of hologram projection or hologram sensation which is pure metaphysical event.

Out of body sensation, will always be decoded into neural patterns in the form of the right side of Eq. (4) and (5) representing the virtual replica as cords of consciousness, while the virtual replica is a logical timeless metaphysical state that matches a neural pattern in the form of the left side of Eq. (4), (5).

Some people may experience spontaneous *out of body experiences*. Others, would to willingly initiate a dedicated technique. There are various techniques to experience out of body experience. The simplest way and without any guarantee to its success is when going to sleep, to instruct yourself to see the body while sleeping. If you succeed, then you are out of your body. Next, look at your virtual body and most likely you will see nothing, i.e. pure consciousness. In time, you will manage to build virtual body. Stay in your home, go visit the kitchen. Return to your body. Next time give clear instructions what is it you wish to do when you are out of your body. If you reach this stage, it is suggested to be guided.

Out of body experience should be part of the education system and taught starting from early age. It may sound unrealistic, particularly the existence of pure consciousness detached from a body, but that is just pure logic, not physical energy, the existence of the pure consciousness is a virtual logical existence.

Expending the pure consciousness boundaries requires new educational system. A system that teach reality and beyond reality, into the metaphysical virtual space. Children would be thought how to control their virtual body. This should be part of our lives, of our educational system, this is the future of mankind. Telepathies, traveling, visiting other dimensions and other entities should be part of our lives.

7. Conclusions

The story of pure consciousness is the story of the void complementary. The void complementary is a logical state. It exists due to the existence of the void.

The metaphysical space was defined as the void and the void complementary. It is unique, complete virtual space, incorporating all potential scenarios, including the void itself. It does not, however, incorporate matter nor energy. Yet, it incorporates a logical scenario of the existence of matter out of null matter, i.e. zero matter. In that sense, the matter, representing the universe, incorporates complementary universe so that the total matter of both universes collapses timelessly into the null matter, e.g. into zero matter.

A potential story, such as a human being story, is realized in a suitable spacetime universe. From the metaphysical perception the story is timeless, logical metaphysical event, representing the pure consciousness. It is not energy, it is a virtual logical copy of the actual life story, it carries virtual eyes, ears, brain, body, wishes, love, hate, desire, intentions, in that sense it represents a virtual biological body and all the spiritual characteristic of the story. A story cannot be vanished due to its existence in the void complementary. A piece of information carrying the story characteristics. The virtual replica represents the pure consciousness and it can be experienced during a specific life time as an out of body experience. Having out of body experience open a new field of exploration, beyond physics into the metaphysics.

Pure consciousness may also be considered as virtual junction over the metaphysical virtual net. A junction of the metaphysical virtual net incorporates set of metaphysical cords of consciousness. From the physical perception cords of consciousness represents neural patterns.

The cords of consciousness represent visions, voices, tastes, feelings, desires, body parts, intentions and all characteristics experienced in the current life, although from the metaphysical perception the life story exists timelessly.

Pure consciousness may be bounded to a single virtual junction, representing the current life story or may incorporates multi virtual junctions, representing multiple lives or other forms.

Some of us feel my pure consciousness is only this “me”; others may feel and experience beyond “I am only this life story”. Their pure consciousness experience more than single entity, i.e. multiple entities. They may experience other stories of animals, entities, trees, etc. They are metaphysical actors; one story they experience hamlet, other story, fiddler on the roof, other stories birds and so on. They wander timelessly between different figures.

Such pure consciousness is not bounded only to this life. Such pure consciousness understands the order and disorder of the metaphysical virtual net, that a story is not about “me”, it is about experiencing different metaphysical stories induced from the void complementary. It is about the pure consciousness ability to wander timelessly from story to story and to recreate or rediscover new worlds. It is upon each one capacity to define his/her pure consciousness boundaries.

It is the moment of mankind to evolve into the spiritual metaphysical world. Spiritual is metaphysical, meaning a virtual logical space, a space of scenes, a space where we communicate by images, where we speak words without speaking words. The deeper and wider our imagination of the metaphysical space, the deeper and wider we will explore it. It is time to wander across the metaphysical space and communicate with other entities, it is time mankind understand the pure consciousness is a virtual logical event carrying the characteristic of life. It is time to learn how to explore beyond physics into the endless uncountable fascinating metaphysical possibilities. It is time to move on into the spiritual abundance.

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A mathematical assessment on the ontology of time♣

Jorge Julian Sanchez Martinez♦

Abstract

In this work, we develop and propose an ontological formal definition of time, based on a topological analysis of the formal mathematical description of time, coming from approaches to both quantum theories and Relativity; thus, being compatible with all physical epistemological theories. We find out a mathematical topological invariability, thus establishing a rigorous definition of time, as fundamental generic magnitude. Very preliminary analysis of physical epistemology is provided; likely highlighting a path towards a final common vision between Quantum and Cosmology ontology and human feeling of time.

Keywords: Time essence, topology, parameterization, metaphysics, science.[1]

♣ The author would like to acknowledge this analysis to the first scientist in the Modern Age who studied “machines to measure time” systematically, through his scientific method, *Galileo.*

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1. Introduction

In Epistemology of Physics, the problem of time is a conceptual conflict between "general relativity" and "quantum mechanics" theories. In the latter, flow of time is regarded as universal and absolute, whereas general relativity regards the flow of time as malleable and relative [1]. This problem raises the question of what time really is in a physical sense and whether it is truly a real, distinct phenomenon. It also involves the related question of why time seems to flow in a single direction [2], [3], [4]. Though, it is recognized for macroscopic systems the directionality of time is directly linked to "first principles" such as the Second law of Thermodynamics, thus Universe concerned [5].

In classical mechanics, a special status is assigned to time in the sense that it is treated as a classical background parameter, external to the system itself. This special role is seen in the standard formulation of quantum mechanics. It is regarded as part of an a priori given classical background with a well defined value. In fact, the classical treatment of time is deeply intertwined with the "Copenhagen interpretation" (V Solvay Conference) of quantum mechanics, and, thus, with the conceptual foundations of quantum theory: all measurements of observables are made at certain instants of time and probabilities are only assigned to such measurements [6]. Special relativity has modified the notion of time. But from a fixed Lorentz observer's viewpoint, time still remains a distinguished, absolute, external, global parameter [7]. In consequence, the Newtonian notion of time essentially carries over to special relativistic systems, hidden in the space-time structure. The last is a consequence of the pure geometric nature of the essence of the Relativity theory. Nevertheless, there is a substantially different nuance: the imaginary magnitude of quantitative time description. This, as we will see later, is the initial key point to identify a common ontological definition of time, since the mathematical essential source of the magnitude has drastically changed. In Relativity, since Geometry is an intrinsic physical feature of the system, time cannot be observed as external to the system, as Quantum (and thus, classical) approximations consider. The last has been basically, the root of the "problem of time": the ontological discrepancies for time definition.

Attempts to define "time" as an observable parameter in a Quantum approach (external approximation to define "time") have fundamental limitations: Pauli's theorem [8]. This theorem imposes a serious limitation to define time as an observable due to Heisenberg's uncertainty relation between $[\hat{H}, \hat{T}]$, being $\hat{H}$ energy of the system and $\hat{T}$ operator related to observable "time".[9]. Basically, the limitation comes from the fact that values that observable energy could take are unlimited, which obviously has no physical meaning, [10] [11]. The initiatives to find novel approaches to overcome this major limitation haven't achieved to relevant successful results, to the best of our knowledge, from the Epistemological point of view, being one of the most relevant approaches the so called "Positive Operator-Valued Measure." (POVM) approach [12].

A third intermediate approach (neither internal nor external ones), the so called "covariant theories", does not have a notion of a distinguished physical time with respect to which everything evolves [13], [14]. However, it is not needed for the full formulation and interpretation of the theory. The dynamical laws are determined by correlations which are sufficient to make predictions. But then a mechanism is needed which explains how the familiar notion of time eventually emerges from the timeless structure to become such an important ingredient of the macroscopic world we live in as well as of our conscious experience. The "thermal time hypothesis" has been put forward as a possible solution. It postulates that physical time flow is not an a priori given fundamental property of the theory, but is a macroscopic feature of thermodynamical origin [15].

In the following section, a unique and mathematical consistent definition of time is shown. From a topological approach to the different conceptions of time, we will propose a generalized mathematical definition; thus including "quantum mechanics" (classical theory as a limit of this is, in consequence, concerned) and cosmological existing approaches. The success is achieved by distinguishing parameterization of the magnitude time, including the "time thermal hypotheses" as the natural flow of time, with definition of the nature of time as a physical magnitude mathematical modeling. Preliminary consequences following this definition for the mathematical configurational space for time are finally provided, including for Metaphysics of Science.

2. The difference between time as magnitude and its parameterization

The purpose here is to highlight the difference between a magnitude itself and its formal mathematical representation under a parameterization including a continuous function, consequence of its mathematical definition. Effectively, for the trivial case of time as external parameter (quantum vision and in the limit, classical approaches), this parameterization is naturally provided by the human feeling of time as a continuous succession of ordered events. The natural parameterization then could preliminary be conceived as [0, a], being “a” $\subset \mathbb{R}$, “a”>0. This parameterization is induced naturally for whatever system is considered when time is external to the system identified. One then could identify the parametric function as the identity one, which is inaccurate. Reason comes from historic quantum consideration about the well-known “the problem of the measure”, inducing a perturbation in all physical systems during the observational stage in the measurement fact [16], [17]. Effectively, under these recognized assumptions, we can consider that system itself comes back after the measurement to the unperturbed original point in its essence: the initial point in time is equivalent to the final one, thus defining in the set of magnitude set of time a quotient space [0, a)/ $\mathcal{R}$. Being “$\mathcal{R}$” the equivalence relation induced by the quantum-based “problem of the measure”. This quotient space becomes to [0,a), mathematically modeled.

Now, we will see that Cosmology will also accept the same parameterization as the above quotient space [0, a)/ $\mathcal{R}$, both with the topology induced in the set by the continuous function, projection *“p”*:

$$\text{“}p\text{”}: [0,a] \subset \mathbb{R} \longrightarrow [0, a]/\mathcal{R} = [0, a).$$

In Cosmology, there is consensus that the beginning of time is localized behind us in a finite steps of time [4], and coincides with the beginning of space according to Einstein’s Relativity [18]; in fact, we definitively date the origin of the universe into temporal units, according to established methodology [19]. So it makes sense to assign and include in our parameterization a beginning, zero. In principle, this is the well-known *“problem of initial conditions”* for Cosmology [4].

As far as the other edge of the interval is concerned, there are, in principle, two possibilities; either, there is an end of the Universe in a finite sequence or this ending is in a series of infinite number of steps: it will always be, *eternal universe*. For this last case, taking into account the previous paragraph, the parameterization is in consequence, [0, ∞).

This parameterization form has a natural homeomorphism "*f*" (biyective, "*f*" "f^{-1}" continuous) well identified:

$$f: [0,\infty) \rightarrow [0,a)$$

$$f(x) \rightarrow \begin{cases} \frac{x}{2}, & x \in [0,a) \\ \frac{a(2x-a)}{2x}, & x \in [a,\infty) \end{cases}$$

This homeomorphism preserves the topological properties between the two intervals, being able to analyze each other interchangeably. Thus, it is shown that the parameterization of time in this case can be described as [0, a). "a" finite.

On the other hand, if Universe ends in a future finite moment, this last step, where space-time disappears will be equivalent (and here is the key, again) at the beginning mathematically speaking; "nothing can be said of it". Thus, the beginning and end are again equivalent under this statement inducing once more an equivalence relation between the edges of the interval. Directly, then, the parameterization of time is again the quotient space [0,a).

Therefore, under the proper formal definition of the so called "problem of initial conditions" in Cosmology, time parameterization is mathematically expressed by $[0, a]/ \mathcal{R} = [0, a)$.

Summarizing the above, we propose to reformulate the so-called "problem of initial conditions" to "problem of boundary conditions" by mathematical formal arguments characterizing the parameterization of the physical magnitude of time. As a consequence, a single equivalent parameterization of time is achieved given by the *quotient spaces* $[0, a]/ \mathcal{R} =[0,a) \subset \mathbb{R}$. Being $\mathcal{R}$ *the equivalence relations* provided above by this reformulation in each approximation. Order inside the parameterization set is complete ($t_n<t_{n+1}$), provided by the human existence, which orders naturally cognitive events related to itself. This natural auto induced order is also supported and justified by Second Law of Thermodynamics principle also proposed valid in both Cosmology [5] and in the covariant theories (*thermal time hypothesis*). If Second Law is cosmologically valid everywhere, we provide evidences of mathematical coherence with human natural experience of time flow order induced by its existence; thus, this thermal hypothesis is consistent and provides a natural flow-time in its parameterization set $\subset\mathbb{R}$.

Finally, mathematically, under all circumstances and for the whole Physics Epistemology , we can define the parameterization of time as:

$$T = \{t \in \mathbb{R}: t \geq 0\} => [0, a)$$

Here, a concise comment is worth. The equivalent relation pointed out between "0" and "a" does not imply we argue an approach physically to the origin for the universe at the end. We rather assess that, mathematically, both points are equivalent to accurate define the mathematical configurational space: nothing can be said on them because space time configuration has no sense either before the beginning, at "0" or in the epilogue of Cosmos, "a".

3. Comments on time as physical fundamental magnitude

Is the purpose of this part to demonstrate that the above definition of time fully ordered is perfectly consistent with time defined in Relativity.

Cosmological time under Einstein's Relativity is mathematically defined as:

$$\tau=\{x\in\mathbb{C}:Re(x)=0,Im(x)\geq 0\},\ \ x=Re(x)+iIm(x)\quad Re(x)\ \wedge Im(x)\in\mathbb{R}$$

That is, a pure imaginary number, a subset of the well known "complex numbers".

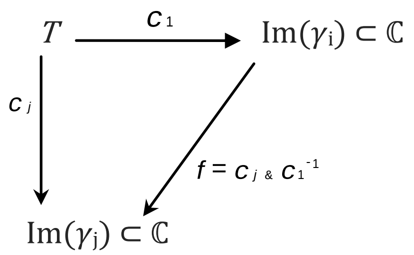
Mathematically, this definition is a particularization of a subset Im(γ) $\subset\mathbb{C}$, under the generic homeomorphism (γ biyective, γ and γ^{-1} continuous):

$$\gamma(s):I\rightarrow C,\text{with } I \subset\mathbb{R},\text{interval } [0,a)$$

Where the flow of the parameterization is given directly by the homeomorphism condition of the function, which in fact is a mathematical parameterization of 1-d manifold, subset of $\mathbb{C}$ (equivalent $\mathbb{R}^2$). More precisely, the above definition is always consistent with time in Quantum theories and classical ones IF we consider the interval [0,a) previously commented as another particular subset of $\mathbb{C}$ (equivalent $\mathbb{R}^2$). The particularity for the latest is that the homeomorphism γ here is the identity function, "*I*".

As a direct consequence, it can be observed that there is a mathematical topological (in consecuence,ontological) equivalence between all parameterizations of magnitude time in Physics Epistemology: all are 1-dimension varieties, topological subspaces of the topological space ($\mathbb{C}$, *Tu*), where "*Tu*" is the Euclidean usual topology induced by Euclidean distances. Being $\mathbb{C}$ isomorphic to $\mathbb{R}^2$ as euclidean metric spaces.

What is more, taking into account that given a specific parameterization "T", defines a specific relationship "*f*" between the different varieties 1-dimensional as follows ($i \neq j$):



Being "*f*", in consequence, homeomorphism. This homeomorphism identified induces a further equivalence relationship among the different $\mathrm{Im}(\gamma_i) \subset \mathbb{C}$, thus inducing an additional quotient space defined as:

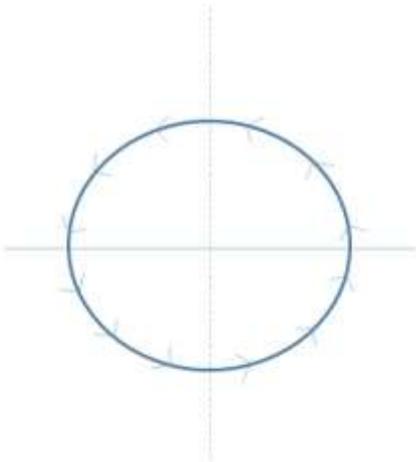
Be $\mathcal{P}(\mathrm{Im}(\gamma_i))$ set incluiding all $\mathrm{Im}(\gamma_i) \subset \mathbb{C}$, with γ_i homeomorphism as describe above *(i*=1,2,3….). The defined equivalent relationship, $\mathcal{R}^*$, as "defining a *f* homeomorphism under the composition of $\gamma_{i,j}$ above shown" induces the following quotient space,

$$\mathcal{P}(\mathrm{Im}(\gamma_i))/\mathcal{R}^*$$

In particular, at this point, we will point out that there is an specific $\mathrm{Im}(\Upsilon) \subset \mathbb{C}$ defined as the homeomorphism, representing the whole space (canonical representative):

$$S^1(s): I \rightarrow \exp(i\, 2\pi/a\, s) \subset \mathbb{C},\ I \subset \mathbb{R} \text{ interval } [0,a)$$

Whose $\mathrm{Im}(S^1) \subset \mathbb{C}$ can be geometrical represented as, taking into account the preliminary arguments concerning human feeling naturally providing an standarised parameterization of time with its natural and unique flow, by "thermal time mathematical consistent hypothesis":



Im(S^1)⊂ℂ geometrical representation, as defined as 1-d oriented manifold with boundary and flow-time induced by natural human feeling of-time.

This provides, in consequence, a mathematical ontological-based definition of time: this unique and solely canonical element, valid and mathematically consistent with Physics Epistemology.

Linguistically speaking, this definition can be expressed as:

"Ontology of magnitude of time is represented as a 1-dimensional manifold (with boundary) in the $\mathbb{R}^2$ plane (or equivalent $\mathbb{C}$ body set), oriented and embedded with respect to natural human parameterization".

The author points out that this definition is not equivalent to the cyclic S^1 circumference, as the circumference can be identified as a closed-loop in its parameterization. Thus, not injective as our identified 1-dimensional manifold. The mathematical difference between the circumference S^1 and 1-d manifold S^1 can be seen elsewhere in any undergraduate topology handbook [20]. Just we briefly point out here that is well recognized that only two types of 1 dimension manifolds exit for connected 1d spaces: the numerical line $\mathbb{R}$ -or interval- and the circumference S^1. For interval sets in $\mathbb{R}$ as the ones shown in this paper, 1d manifold with boundary (the S^1 manifold proposed) appears coming from deconstructionist topological arguments in the identified quotient spaces [0,a). S^1 manifold with boundary is a topological set completely different (non homeomorphic) to the circumference S^1. Being the main difference already pointed out: the circumference is a closed-loop (not injective) and

S^1 is homeomorphic to [0,a) as quotient space, topological deconstruction under equivalence relations expressed.

Following to this argument, Nielsen et al. [5] had already rejected the S^1 circumference as mathematical expression of time, but with a mathematical inconsistence in the arguments provided by its definition of time as the whole set $\mathbb{R} = (-\infty, \infty)$. Topologically, this set, as defined is not homeomorphic (thus, not topologically equivalent) to the following 1-d manifold: [0,a) we have defined. In fact, we remind here that $\mathbb{R}$ is a connected space, being homeomorphic to $(0,\infty)$, mathematically inconsistent to Nielsen et al. decomposition shown: $(-\infty,0)$ and $[0,\infty)$. Consequence of this, we disagree with the authors in their artificial mathematical description of thermodynamics as a sum of entropy magnitudes running across $(-\infty,0)$ and $[0,\infty)$. On the other hand, we can agree in their second conclusion about Second Law of Thermodynamics, but with a more simple (and realistic) argument: the natural feeling for humans of time while ordering chronological events justifying the "Thermal time hypothesis" giving a natural induced flow time through the flow induced in the parameterization while ordering the human events. Briefing our comments to Nielsen et al.: topologically, we demonstrate time configurational mathematical space and its flow is unique; in consequence, allusions and comments about the lack of anthropic principle in Cosmology are unfounded.

4. Epistemological implications of time definition

Let us brief at this point now the implications and consequences achieved and derived up to now:

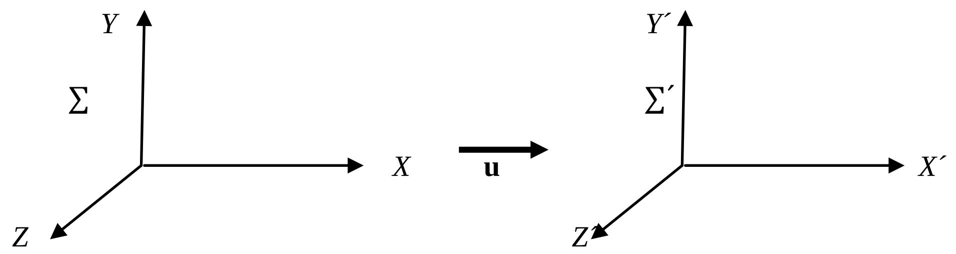
- The thermal time hypothesis is consistently sustained by the human induced feeling of time parameterization, thus giving sense a unique coherent flow of time.
- Consistent with all cosmological theories where there is a final for the Universe either in a finite or infinite steps. In any case, there is a mathematically equivalence of time as a physical fundamental magnitude under an identified quotient metric space, subset of the topological space ($\mathbb{C}$, *Tu*), where "*Tu*" is the Euclidean usual topology induced by Euclidean distances. Being $\mathbb{C}$ isomorphic to $\mathbb{R}^2$ as euclidean metric spaces. It is worth pointing out that even Conformal Cyclic Cosmology approach is compatible by this mathematical space configuration of the ontology of time [23], [24]. Cyclic periods of expansions and contractions of Cosmos are not excluded by this mathematical expression of time because equivalence relations identified only refers to circumstances when space-time has no

epistemological sense: before Cosmos existence and, if ever, beyond the end of Cosmos.

- The definition is unequivocally unique, taken into account the equivalency between the identified homeomorphisms, and the subsequence quotient space identified. The canonical element of this second quotient space identified provides us with the mathematical model of the magnitude "time" valid for all epistemological approaches in Science in general.

Now, let us consider the orthogonal group of the Lorentz Poincaré transformation of the Relativity. The so called semiorthogonal group, $O(3,1)$, subgroup of the general group $GL(4;\mathbb{R}^4)$ of all invertible 4x4 matrixes. As a reminder, be $A\in O(3,1)\leftrightarrow A^T\mathcal{E}A=A\mathcal{E}A^T=\mathcal{E}$. Where $\mathcal{E}$ in this case is diag(1,1,1,-1).

Be two reference systems ∑ y ∑′, with relative movement one to the other with uniform speed **u** in the x direction as shown in the schema below:



Schema of the movement proposed to facilitate comprehension of the analysis shown: a general u speed provides the same result complicating the mathematical formalism.

From generic algebraic undergraduate texts for Relativity [21], one can check that metrics satisfies:

$$ds^2=(dt)^2[c^2-(dx/dt)^2-(dy/dt)^2-(dz/dt)^2]=\text{const.}$$

The above expression for each reference system corresponds to:

$$(dt)^2[c^2-\sum_j\left(\frac{dx^j}{dt}\right)^2]=(dt')^2[c^2-\sum_j\left(\frac{dx'^j}{dt}\right)^2]$$

Suppose the system at rest is ∑ , as described in the schema above. Then,

$$(dt)^2c^2 = (dt')^2[c^2 - \boldsymbol{u}^2]$$

Thus, finally giving the famous expression of relativity of time, belonging always to S^1:

$$dt' = \frac{dt}{\sqrt{1-\beta^2}} \qquad \beta = \frac{|\boldsymbol{u}|}{c}$$

$$dt = \left|\left|dS^1(s)\right|\right|, being \left|\left|*\right|\right| \, modulus \, of \, dS^1(s) \, in \, \textstyle\sum \text{reference system.}$$

Thus, evidencing that our time definition is also consistent with relativistic semiorthogonal group, $O(3,1)$ for Lorentz Poincaré transformations.

In Epistemology, all the above immediately leads us to affirm:

- It does not matter what mathematical representation you are describing; Physics will be the same according to Lorentz-Poincaré transformation checked. This directly implies no sense for travels between different times. ALL ontologically are the same in the Universe: the one described by the identified quotient metric space, whose canonical element is proposed for simplicity the S^1 manifold.
- Direct implication is that Universe is unique. Physically, no travels between different Universes. According to thermal time hypothesis, consistent with our time definition, there is only a valid time flow. So, loops of time and travels between different times are non sense epistemology taking into account the consistency between the above hypothesis and our definition of "time".
- It is indeed consistent with the cosmological concept of "Time of Planck"[22], defined as "time from which the universe can exist as we know, with the current epistemology of Physics being applied. Mathematically, the parametric topological space is dense; in consequence, in the neighbourdhood of zero, $\varepsilon \underset{lim}{\longrightarrow} 0$, whatever the manifold 1-d is, we can identify the corresponding Planck Time. Also consistent with current theories about Cosmology description [3], [23], [24] based on Relativity background. For those, consistency is immediate due to geometrical arguments based on the homemorphism-based argumentation previously identified.
- Consistent with Heisenberg's uncertainty principle $\Delta t \Delta E \sim h$, being "t" parameter of time as 1-d manifold. This comes directly from the fact that γ_i^{-1}, for all i, provides directly "the operator time" $\hat{T} = \gamma_i^{-1}: Im(\gamma_i) \subset \mathbb{C} \rightarrow [0, \mathrm{a}) \subset \mathbb{R}$, where directly if we assume the set metrical space-time as defined in $\mathbb{R}^3 \oplus S^1$ (as

canonical element of the quotient space defined for time above), directly induced the definition of the eigenvector and the corresponding eigenvalue of "operator time", in Pauli's notation, as:

$$\hat{T}|Im(\gamma_i)>=t|Im(\gamma_i)>, t \text{ as parameter value in } [a,b).$$

Where $\| Im(\gamma_i)>\|$ is defined as 1s.

This last point directly could open the door to the mathematical consistency of Relativity with Quantum Theory axioms from first and fundamental principles; thus, providing further support to research towards the "Single Field Theory" in Physics.

5. Conclusions

This work has shown a mathematical assessment, by topological analysis, of the ontological definition of the fundamental magnitude of time, being part of the mathematical configurational space of Cosmos in general. A formal definition unique and consistent with all epistemological fields in Science has been provided. The last eliminates the hypotheses of travels in time, thus eliminating definitively loops, by thermodynamics considerations supported by natural parameterization of time induced by human existence (ordering continuously facts related to existence). Additionally, a confirmation of compatibility with semiorthogonal group $O(3,1)$ of Lorentz-Poincaré transformations for Relativity has been checked. The universe, both finite and infinite based models for time description, can be mathematically conceived as unique with a single ontological definition of flow time. Finally, Cosmology could also assume the Axioms of Quantum Theories; thus, providing a further support towards "Single Field Theory" in Physics. Consequences in the theoretical limit of Physics Epistemology is in progress, though we have considered, keeping in mind the potential impact of this novel approximation to the ontology of time, to publish now our results up to now. Finally, by clearly splitting mathematical character of time, as a 1-d manifold (with boundary), and its natural parameterization provided by human feeling of time, we clearly indicate the way in Philosophy to fully understand the entity "space-time" in Science; thus, eliminating all cognitive misunderstandings among the various approaches to time entity human knowledge can do.

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Trust and ethics: ambivalent foundations of relationship and sui generis forms of gift

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Abstract[1]

Is there a circular relationship between trust and ethics? Is it possible to alter their relationship, changing the perception that social actors have of them? How has trust changed in the transition from modernity to post-modernity and how does it change in times of crisis? Starting from the epistemological assumption that progress in the social sciences is determined by the change in the theoretical horizon produced by "a reformulation of metaphysical assumptions"[2] and combining this path with the relational perspective, according to which "not the facts, but the relationship between the facts is what requires analysis"[3], we will examine definitions, meanings, functions and relationships between trust and ethics. Following the theoretical logical method, we will understand that trust and ethical behaviour are particular forms of gift[4] that co-own each other.

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2 See J. Alexander's strong program in Segre, 2019; 12. It is not enough to observe reality, it is necessary to interpret it, taking into account theories and traditions whose foundations have a metaphysical character.

3 Ferrarotti, F. (2018). *La sociologia come analisi critica della società.* in Cipriani, R. (a cura di). *Nuovo Manuale di Sociologia.* Sant'Arcangelo di Romagna: Maggioli, p. 24.

4 The classical meaning in M. Mauss, *Essai sur le don. Forme et raison de l'échange dans les sociétés archaïques*, 1ª ed. 1925, revisited by G. Satta, 2011.

As such, they are ambivalent in nature and their circle can also produce dysfunctional outcomes that depend on the ability of social systems to modify collective perceptions through forms of communication, in the awareness that distrust constitutes an ineliminable and, paradoxically, preparatory element for the restoration of the trust circle. The relational circle between gift, trust, collective ethics and personal morality does not end with distrust, but changes in a contingent way, determining perverse effects: correct behavior could produce, unintentionally, a disaster; incorrect actions could generate unforeseen positive effects. The perverse effects cannot be defined as exceptional - as is believed in the theory of rational choice - but recurrent because daily practices are marked by an intuitive, emotional and moralistic trust circle that prevails over logical reasoning, as ascertained by both relational theory and behavioral economics. Functionalist paradigms cannot engineer and optimize the performance of trust.
Keywords: Relational theory, trust, ethics, gift, perception, perverse effect, System 1, System 2.

1. Sociality and trust: circular but ambiguous relationship

Trust is at the Centre of our daily life and our life in common and it is impossible to erase it, otherwise we risk erasing social action (Fanciullacci, 2012, 280). Trust belongs structurally to human relationships, but it enjoys a fragile harmony. It is an eventual, contingent phenomenon; it is created and destroyed frequently, in different contexts and circumstances.

It is not univocally perceived, nor unanimously shared.

However, its weakness on the level of social practices can prove to be a strength on the evolutionary level. If, in fact, it is true that trust brings the person closer to the other, it is equally true that mistrust sets limits, preventing human behaviour from taking for granted that the reliability of a given subject, in a given circumstance, recurs in subsequent interactions with the same subject. It follows that trust is a factor that must always be reconstructed or, at least, renegotiated when entering into a relationship, in order to avoid a return to distrust. The construction of trust relies on relationships that are repeated over time and evolve into recurring links. Therefore, it requires a long time and consistency in the way it is placed.

Trust can also be broken through the falsification of the last relational exchange: a single element of incoherence, compared to previous exchanges, could undermine its foundations.

As a result, distrust takes root quickly and spreads like a virus: its meme is contagious, fast and pervasive. Certainly, it is possible to restore trust where it has been lost, but this implies a strong motivational leverage and an ability to scale down what has happened before. It is possible to restore trust, because the human being needs to believe that each of us should have new opportunities, because at any moment what the subject has suffered could make another suffer.

For this reason, the circle of trust is not completely suppressed, otherwise the minimum conditions for the survival of a social system would not be created[5].

However, an organization where the circulation of trust is often interrupted and restored is fundamentally blocked: it welcomes new things very carefully, except to stop at the first obstacle, to return to the previous belief system or to give confidence to other groups.

The transition from a modern era to a post-modern society, characterized by precarious and fragile relationships, has increased interruptions and misalignments between personal and systemic trust, as we will see in the following paragraphs.

In the collective imagination, the concept of trust takes on multiple denotations and connotations: it means trusting, but also hoping that the other does not disappoint our expectations, or trusting in the experience and/or abilities of others. Each of us interprets the term according to our level of education, values and past experience, as such it is a multi-dimensional concept and, as such, requires several indicators to be examined[6].

Since its foundation, sociology has directed its most important research towards the analysis of trust.

Simmel, one of the pioneers of the discipline, maintained that when we ask for and obtain trust, we only mediate between what we know and what we ignore[7].

Moellering, continuing the Simmelian perspective, defines trust as a weak form of inductive knowledge that leads to a suspension of judgement[8].

Giving trust means reducing the complexity of decision-making processes, decreasing the cognitive load that would arise if we were to research the

5 On the systemic circle of trust see Luhmann, N. (1979). *Trust and Power*. Chichester West Sussex: John Wiley&Sons Ltd.

6 On the multidimensionality of trust: Bianchi, L.; Liani, S. (2017). Fidarsi della fiducia? Uno studio sull'intensione del concetto. *Quaderni di Sociologia*, V. LXI, n. 74**,** p. 127.

7 Simmel, G. (1988). *Sociologia*. Milano: Edizioni di Comunità. p. 299.

8 Moellering, G. (2001). The Nature of Trust: From Georg Simmel to a Theory of Expectation, Interpretation and Suspension. *Sociology,* 35, 2, pp. 414-415.

credibility of any person (or organization) with whom we establish relationships.

Giving trust means saving time, money and energy that can be used in other contexts or for other opportunities.

However, if on the one hand trust speeds up the processes of socialization and decision making, on the other it exposes us to the risk of not having made the right choice.

Trust has also evolved over the ages. In traditional societies, giving personal trust was a more habitual behavior than giving trust to an organization; on the contrary, in modern societies, the occasions have multiplied in which an individual must suddenly trust formal institutions and organizations.

Contemporary society is subject to greater risks related to trust[9], because globalization on the one hand has considerably weakened emotional and kinship ties - through these ties it is easier to ascertain or test people's reliability - on the other hand it has forced each social actor to make quick choices with other unfamiliar subjects, coming from worlds and cultures dissonant with their own.

Consequently, in the contemporary world, relying on trust has become a compelling and more necessary necessity than before modernity and pre-modernity: a recurring and fast practice.

Following the definitions of sociological and economic thought, trust can be strategic or moralistic: in the first case we trust a person, making a decision based on the information we have available and our attitude to risk (although many schools of thought they consider this concept of trust spurious, because it is substantially guided by rationality, awareness and interest, as we will see in the following paragraphs).

In the second case we decide to trust the other even in the absence of information, following a value or moral imperative (We could define it deontological and universalistic. We will return to this theme in the third paragraph) which leads us to consider people worthy of trust, in the belief (intuitive, but not statistical[10]) that most of them share our values.

Strategic trust reflects our expectations about how people will behave, based on the data available to us, while moralistic trust is determined by our beliefs about how people should behave. Strategic trust implies a greater cognitive load:

9 Beck, U. (1992). *Risk society towards a new modernity*. London: Sage.

10 On this dichotomy see: Kahneman, D. (2012). *Pensieri lenti e veloci.* Milano: Mondadori, p. 25-28. The author calls System 1 the fast thinking and System 2 the slow thinking. Both are present in our cognitive process. The former is intuitive, operates quickly and automatically, with little or no effort and no sense of voluntary control. The second directs attention to challenging mental activities that require focus, such as complex calculations. Giving confidence unconditionally and without having taken information is typical of system 1: trust is generally intuitive because man prefers to orient himself towards choices that imply a cognitive saving of attention and concentration.

only after we have worked on the information, we decide to give confidence. Moralistic trust is a shortcut in the decision-making process and comes into play more frequently, as the human being always opts for load-reducing choices. Strategic trust is preparatory to rational, purpose-oriented action; moral trust is guided by value-oriented action.

Following the theory of rational choice, it may be difficult to establish whether a subject has granted trust simply on the basis of strategic or moralistic criteria[11]; but if we observe from a relational perspective and take into account recent evidence of behavioural economics and social neuroscience, we can deduce that the trust process is mainly intuitive-emotional-moralistic, because every day the person selects information about the other that is neither exhaustive nor decisive for the final decision: in most cases credulity - as well as distrust - relies on personal intuition. In this case, the person falls into errors of assessment due to the well-known ‘halo effect’.

As Kahneman demonstrates, in his psychological experiments on decision-making processes under conditions of uncertainty, the human being relies on his intuition - defined by the author System 1 - when he decides to believe unconditionally and quickly, based on his convictions. Subsequently, he is able to make his thought coherent *a posteriori*, in order to justify the final choice.

On the contrary, the human being is diffident or slow in granting trust, when he concentrates on the criteria to be adopted - in this case we refer to System 2 which is rational and statistically oriented[12].

When we are confident or suspicious with reason, the risk of making mistakes is minimized, without prejudice to the unpredictability and uncertainty about the choice we have made a priori and which we will only verify after the other (to whom we have given confidence) does not betray our expectations.

But when we decide to trust on the basis of intuition, we are guided by what we have already experienced in previous experiences, looking for familiarity, associations and consonances with current experience.

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11 The theory of rational choice aims to explain the action, individual or collective, as the result of the orientation of individual actors towards the efficient achievement of an objective. Those who follow this perspective consider intentions as the only cause of behaviour actually and deliberately followed by the actors. But this perspective is reductionist in that it excludes most behaviours and sudden changes, determined by impulses, self-deception or lack of clarity in determining objectives. The theory of rational choice is insufficient, because it reduces choices to the paradigm of methodological individualism (applied by influential sociologists such as Elster, Boudon, Coleman, Hedstroem) and analyses perverse effects as phenomena determined unintentionally because of the misalignment of individual rational intentions, excluding the perverse effects produced by other voluntary or involuntary phenomena of an irrational nature that make the failure of the set objectives much more frequent than one would think.

12 On this topic Kahneman 2012, 109.

If a person we met for the first time reminds us of negative experiences in the past, the trust pact is broken. This way of proceeding is not rational, but intuitive. When we have no references from the past, we tend to fall into the trap of the halo effect. The tendency to appreciate or detest everything about a person, including things that have not been observed, is called the halo effect[13].

If trust is granted in a strategic way, based on data-driven reasoning to establish reliability, we can say that our expectations are guided by knowledge of the context. But if trust is granted intuitively, it means that we need to believe and look for the person who is most like us, avoiding selective attention to signs of inconsistency with what we are really looking for. We want to rely on and decide to do so, rationalizing *a posteriori* the decision we would have taken anyway, finding useful arguments for such self-deception.

This is why trust proper is intuitive or moralistic (we will describe the concept better in the next paragraphs). From a sociological point of view, collective trust should generally be intuitive, because all processes concerning recurrent collective behaviour cannot be taken slowly or on the basis of accurate research of information, otherwise we would complicate our daily habits.

The social behaviour of each of us happens with recurring daily automatisms, without adequate reflection, in the hope that expectations will not be disregarded.

Unconditional trust allows us not to withdraw money from the bank even when a serious economic crisis breaks out; or to entrust our children to teachers every day, trusting that their behaviour will continue to be reliable.

During the Covid-19 emergency, trust allowed the populations of many nations to stay at home, strictly following the indications of the institutions (institutions which, in other circumstances, are criticized).

Those who execute without discussing the rules assume that those who have established them know what they are doing.

We therefore trust the skills of others, even though we do not know the curricula of those who order us to follow the rules.

This trust agreement is also quickly determined by anxiety and risk communication. If there were not this unconditional and quickly agreed trust, no crisis could be managed by any system[14].

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13 On Halo Effect: Kahneman 2012, 110.

14 The first Italian study conducted on trust at the time of Covid19 was carried out in collaboration between the "Trust, Theory and Technology group" and "Evaluation Research group" of the Institute of Science and Technology of Cognition of the National Research Council (CNR). The study was aimed at Italian citizens who had reached the age of majority. In particular, 4,260 people were interviewed between 9 March (beginning of the survey) and 14 March 2020 (end of the survey). The study basically confirmed that the population has confidence in the measures adopted by the government and trusts that those who make decisions know what they are doing. See: Falcone, Castelfranchi, Colì, *Corona Virus and Trust*,

It follows that trust is a necessary relational asset in any age, even more so in times characterized by greater complexity and speed of decision-making processes. Trust is a proactive attitude that transfers one's hopes to someone or something. In particular, the trust we place in collective processes is guided by our perceptions, the halo effect, intuition, values, emotions and is an integral part of social capital.

According to the pioneers of sociology, it is one of the basic pre-contractual elements for the construction of social cohesion[15]. According to the research conducted by the author of this paper, trust should be defined as a particular form of gift without which the triggering of solidarity practices is not possible.

Sociologists, according to paradigmatic affiliations, have classified trust with different terms which, however, confirm the foundations of the discourse established so far. Giddens, for example, distinguishes personal trust from that of abstract or symbolic systems.

Personal trust usually develops between individuals who know each other, because they have built a relationship that repeats itself over time (Giddens, 1990, 88), but the fact that it is repeated over time, creating more familiarity, does not represent a rational criterion for continuing to trust.

On the contrary, trust in abstract systems does not presuppose any prolonged interaction over time, but grows through relationships with those responsible for these systems, both human and technological: in this case there is no indisputable reason to continue to trust in successive times.

For Giddens, therefore, granting and obtaining trust in relationships means reducing complexity and maintaining a balance between knowledge and ignorance, allowing us to act where there is not full knowledge of the problem we have. To the words of Giddens are the statements of Niklas Luhmann, systemic sociologist, who shows that in the absence of trust an individual could not even get out of bed in the morning, because he would be assaulted by an indeterminate fear and a paralyzing panic[16]. Trust is an attitude that allows us to make decisions that involve risks. So, paradoxically, there is a systemic logic in the 'crazy decision to intuitively rely on the other'.

Luhmann identifies two types of trust: personal and systemic. According to the scholar, in post-modernity the use of personal trust has decreased, while systemic trust has grown.

For the author, in order to develop trust, some conditions are necessary: a) familiarity with an alter; b) acting based on motivations recognizable by the

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2020.www.cnr.it/sites/default/files/public/media/rassegna_stampa/cnr%20istc_nota_coronavirus%20e%20fiducia_una%20ricerca%20esplorativa-2.pdf

15 On the relationship between personal trust and organic solidarity: Durkheim, E. (1971). *La divisione del lavoro sociale*. Milano: Edizioni di Comunità.

16 Luhmann, N. (1979). *Trust and Power*. West Sussex: John Wiley&Sons Ltd, p. 5.

actors; c) the guarantee that the participants in the relationship will meet continuously (at least until the reasons that led them to act are exhausted); d) the ability to blame someone, if trust is misplaced (an assumption of responsibility by those who want to gain trust); e) knowledge of social structures shared with others (actors must be able to obtain information on the morality, culture and norms of the system in which they are trusted).

The social scientists examined so far - between sociologists and psychologists - agree in the construction of the following dialectics: 1. personal trust versus systemic trust; 2. strategic trust versus moralistic-intuitive trust. If we would like to try a further classification of the concept on the basis of logical, instrumental, value or emotional expectations we may have another ranking proposed by the author of this research paper:

- Gnoseological trust, based on previous knowledge of the person to be trusted.
- Value trust, based on our personal way of thinking that guides us in our choice.
- Emotional trust, based on the presumed empathy that the one who gives trust feels towards the one who benefits from it.
- Normative trust, based on the fact that there is a rule (implicit or explicit) that obliges the person who has been invested with trust not to betray the expectations of the person who has granted it, on pain of a sanction (the rule of gift in pre-modern societies, for example).

All the classifications examined are characterised by dichotomous logics that lead to the same conclusions: in everyday social processes a trust granted on moralistic-intuitive-affective categories is more likely.

No theoretical paradigm examined denies the relational evidence of trust. Trust is a reducer of complexity.

Trust is a generator and feeder of bonds and can trigger virtuous circles with the components of the vital worlds: ethical dimension, economic sphere, normative system, cultural beliefs, values, politics.

Trust is ambivalent in nature, because in granting it, it forces the other person not to betray the trust granted. It is an obligation whose strength lies in its weak and tacit way of placing itself and, in this, it possesses characteristics homologous to the gift, as we shall try to show in the following paragraph.

2. Trust, a particular form of gift. Triggering not necessarily virtuous practices

The trust that a community can show in an organization has emerging properties that vary with the subjects and components involved. Moreover, changes in the state of trust are all the more sudden the more the community is subjected to repeated communicative exchanges that jeopardize the overall coherence of the relationship. As the degree of complexity of the interactions increases, it becomes easy to fall into contradiction, even without wanting to.

This is why a society dominated by media exchange increases the phenomenon of oscillation from trust to distrust. The social solidarity that triggers the act of trust can be based on equality as well as difference. Durkheim distinguished between mechanical solidarity (practiced by homogeneous social segments or as a result of the acceptance by individuals of the constraints imposed by the community; this is typical of pre-modern societies) and organic solidarity[17] (this is typical of modern societies based on the division of labour and the differentiation of specialized functions and implies the conscious and free cooperation of social agents), recognizing the latter as a moral character. In postmodern societies, elements are added that Durkheim could not foresee and that modify the classification of the French sociologist (questionable even in the period in which he wrote): communication becomes a dominant and automatic system and relations become weak, highly subject to flexibility and contingency.

The postmodern subject grants trust "without trusting trust", accepting it quickly and forcibly, not being able to do otherwise.

His acts of solidarity can originate from the awareness of interdependence, but also in an anomic or, on the contrary, normalized and ritualized way.

For this reason, according to my thesis, it is not substantially possible to distinguish between forms of mechanical solidarity and forms of organic solidarity.

It is trust that generates acts of solidarity, when a social actor offers his faith to the one who must maintain it. This is a gift. He who has been considered worthy of trust has been made responsible.

If he or she is a person, he or she is aware that he or she can lose the relationship by behaving unreliably; if he or she represents an institution, he or she will keep in mind that he or she can consolidate or break the trust that the person has. This process represents a constraint even if it is weak (as it is neither normalized nor declared punishable).

It follows that trust shares the same logic as gift. Well known and important for the history of anthropology, the theory of gift, as expressed by Marcel

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17 The difference between organic solidarity and mechanical solidarity is analysed in Durkheim, E. (1971). *La divisione del lavoro sociale* Milano: Edizioni di Comunità.

Mauss[18]. The theory of gift is born from the comparison of various ethnographic researches, among which the study of the ritual potlach[19]and the kula[20].

The exchange of the goods of ancient societies was one of the most common and universal ways to create human relations. The gift was, according to Mauss, a total social fact. The expression total social fact is intended to denote that in many facts of associated life the elements belonging to all spheres and at all levels of social reality are involved simultaneously and indissolubly: juridical, economic, political, religious, recreational, artistic, psychological[21].

Godbout defines gift: any provision of goods or services made, without guarantee of return, in order to create, support or recreate the social bond between people[22].

In pre-modernity, the mechanism of gift was articulated in three fundamental moments based on the principle of reciprocity: a) giving; b) receiving (the object must be accepted in order not to offend the donor); c) reciprocating (this too is an obligation linked to prestige, the concept of indebtedness and the shared social practice of gratitude/recognition).

In archaic societies there was a ritualized obligation to return. The value of the gift lay in the absence of guarantees for the donor. An absence that presupposed a great trust in others (this is the link of reciprocity between trust and gift), but the lack of restitution placed the one who had not paid back, in a condition of inferiority: he became 'ungrateful' and could lose credibility, prestige, political weight or the opportunity to be able to count again on other gifts. The pervasiveness of the gift, as an element capable of marking out the relational processes of the ancients, can be understood by examining how densely it was present in linguistic terms: in ancient Greece there were five different words that could be translated with the word gift: *dós, dôron, doreá,*

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18 Mauss, M. (2002). *Saggio sul dono. Forma e motivo dello scambio nelle società arcaiche*. Torino: Einaudi. (*Essai sur le don*, 1ª ed. 1925).

19. The potlatch is a ceremony that takes place between Native American tribes on the Pacific Northwest coast of the United States and Canada. It takes the form of a ritual ceremony that includes a feast of seal meat or salmon, in which destructive practices of goods considered to be of prestige are flaunted. During the ceremony, hierarchical relations between the various groups are established or strengthened through the exchange of gifts. The Potlatch is defined by the anthropologist Franz Boas as an example of gift economy, in which the hosts show their wealth and importance through the distribution of their possessions, encouraging the participants to reciprocate.

20 The kula is a symbolic exchange of gifts made in the Trobriand Islands (in the Pacific Ocean) between the populations of these islands. The kula was first described by anthropologist Bronisław Malinowski in Argonauts of the Western Pacific, a work published in 1922.

21 On the total social fact: Gallino, L. (1993). *Dizionario di sociologia*. Torino: UTET, p. 300.

22 Godbout, J.T. (1993). Lo *spirito del dono*. Torino: Bollati Boringhieri., p. 30.

dósis, dotíne; in the Latin language there were three terms: *donum, munus* e *beneficium*[23].

In the Greco-Roman world, the gift is an act characterized by a very strong collective value, an authentic social glue, a guarantee of community cohesion and, for this reason, connoted by a specific rituality. Trust is the most precious relational gift, so much so that in the Greek world, in this regard, the concept of πίστις was theorized: it includes within it the concepts of trust, belief and fidelity.

I trust in you, I believe in you, I have faith in you: they look like free acts. But in giving to the other person, each of us expects the other to respect a covenant, not to betray the bond that has been triggered.

Trust is a gift that obliges, in a lateral way, reciprocity.

Conversely, the gift is a form of trust, because in the act of offering, the one who offers trusts that the recipient, at the minimum of expectations, will like the gift and, at the maximum of expectations, will reciprocate in similar forms.

What changes in the transition from pre-modernity to modernity? Contrary to the dürkhemian vision, according to the research examined by the author of this essay, the forms of ritualistic gift remain unchanged: in the rules of courtesy, in the codes of affective relations, in economic reciprocity, in political exchanges oriented to the management of consensus, exactly as in the past, with different but still ritualized formulas.

Forms of gift that articulate both correct and deviant behaviour: from philanthropic foundations to clientelary forms; from voluntary organizations to clandestine networks that support fugitives; from charity auctions to the control of essential goods and services by drug traffickers; from social policies to Camorra subsidies to poor families or the families of their armed arms.

In every group, formal or informal, normal or deviant, legal or criminal, there are forms of solidarity that take the form of tangible and intangible gifts.

The act of trust is, in itself, moralistic and corporate, positive for the beneficiary community, but not for the whole community of a social system. What changes with the advent of post-modernity?

If modernity was conditioned by the value of production and an ethical guidance of the intellectual, in post-modernity the value of consumption prevails and the intellectual is replaced by the communicator-influencer.

The gift remains pervasive even in today's complex social systems, but it is not properly mechanical, nor properly organic, only extemporaneously expressed (in particular, in moments of strong systemic crises) and can be more

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23 On the distinction of terms see: Luzzi, R. (2014). *Il dono degli antichi*. In Olivieri, U.M.; Luzzi, R. *Comunità e reciprocità. Il dono nel mondo antico e nelle società tradizionali*. Pomigliano d'Arco: Diogene.

easily violated by single anomic or narcissistic behaviours and more quickly manipulated by forms of communication.

Yet there are very strong similarities between postmodernity and primitive behaviour, as demonstrated by the anthropologist J. McIver Weatherford in his Tribes on the Hill[24].

Through ethnographic analysis and participatory observation of the behaviour of politicians working within the American Capitol Hill, the official seat of the United States Congress, the American anthropologist demonstrates that the practices, ceremonies, gift rituals and forms of consensus management of political groups are virtually identical to the behaviour of ancient tribes.

What changes compared to the past is, perhaps, the reflexivity on gift, because it can be more easily questioned. It follows that the gift takes on a more stringent moral connotation than in the past: gift and trust become riskier to offer, but preserve, as in the past, the silent co-obligation pacts. Philosophers and mathematicians have developed theories and games of cooperation in order to clarify how co-obligatory trust is.

Plato and Aristotle already address this issue, but it is with the correspondence between Blaise Pascal and Pierre de Fermat that a first theory of cooperative and non-cooperative games is sketched. In the 18th century Rousseau proposes an example that will regenerate and recontextualize in the following centuries. This is the dilemma of deer hunting.

With this dilemma it is shown that in many situations to cooperate means to have more, from all points of view[25].

Rousseau on a purely deductive level had understood what mathematicians John Von Neumann, Oskar Morgensten and Nobel Nobel Prize winner John Forbes Nash Jr. formalized mathematically in the 20th century, with game theory and the prisoner's dilemma.

The dilemma of cooperating / not cooperating has represented a problem and an opportunity in all ages. A circuit that generates ambivalence and paradoxes because:

- gift and trust create bonds, capable of determining forms of collaboration, exchange and economic reciprocity;
- they can, however, be instruments of blackmail and moral co-obligation;
- they can represent mere ritualistic expedients aimed at convincing even the most suspicious to behave in solidarity.

24 Weatherford, J. M. (1985). *Tribes on the Hill*. Westport (CT): Bergin & Garvey.

25 The example can be found in: Festa, R. (2007). Teoria dei giochi ed evoluzione delle norme morali. *Ethics & Politics*, IX, pp. 148-181.

The paradox of gift constitutes its strength: if it is true that, on the one hand, giving without demanding a counter-gift represents the very condition of giving; on the other hand, not reciprocating means losing the relationship. Moreover, in the etymology of the word gift there are two opposite meanings. In the Indo-European language ‘to do’ means both 'give' and 'take'.

Similarly, also the word gift, of Germanic origin, in English translates as 'gift', while in German the word gift means 'poison'; and in French the term obligé indicates the condition of debt generated by the gift[26].

Among the semantic folds of the gift are gratuitousness and obligation, spontaneity and constraint, generosity and debt, interest and disinterest, recognition and servitude, exchange and conflict[27].

This versatility allows the gift to serve as a meta-relationship as the foundation of social bond, legal relationship, economic exchange, political pact, moral obligation and religious behaviour.

Trust also presents similar paradoxical elements: granting a strong trust means to load with strong responsibility the one who, if he does not want to lose a bond, must keep the pact.

Gift and trust generate tension, both for those who offer and for those who receive. If gift and trust establish the positive conditions for the continuation of a relationship, they generate a beneficial circuit; but it becomes impossible to establish whether they originate from a selfless impulse towards the other or from individual interests. As the scholar Pavanello wisely states: “We know what a gift is, but we cannot define it”[28]. There are also philosophers who deny the existence of the gift.

According to Derrida, for example, the gift is impossible for thought because it is not intentional. Following the deconstructionist approach - based on questioning every aspect of the term and every theory of the concept - the French thinker states that the giver is not aware of the intrinsic value of what he does. His ability to donate is not sufficient to demonstrate awareness of the importance of the gesture he makes. That is why it is as if he has not done what he has done; in other words, what he does is something, but it is not classifiable as a gift[29].

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26 On the semantic ambiguity of the terms gift and trust see: Iannuzzi, I. (2017). La fiducia e il dono. Due risorse relazionali nel panorama sociale contemporaneo. In *Storiadelmondo* n. 85, p. 4; Satta, G. (2011). *L’ambiguità del dono. Note su dono, violenza e potere nell’Essai di Mauss*. Rasini, V. *Aggressività. Un’indagine polifonica*, Milano: Mimesis, p. 97.

27 On the dialectical oppositions of the gift see: Marci, T. (2012). *Il circolo della gratuità. Il paradosso del dono e la reciprocità sociale.* Trento: Tangram.

28 Pavanello, M. (2008). *Dono e merce: riflessione su due categorie sovradeterminate*. In Aria, M.; Dei F. *Culture del dono*. Roma: Meltemi, pp. 49-50.

29 Derrida, J. (1996). *Donare il tempo. La moneta falsa*. Milano: Raffaello Cortina.

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However, according to my theoretical and empirical research[30], this observation does not confirm the inexistence of the gift, but rather its sui generis and collective foundation: an emerging and generative product of bonds that goes beyond the will and awareness of the individual.

Following a relational perspective (avoiding both the reductionism of methodological individualism that conceives gift as a form of interest and the reductionism of methodological collectivism that classifies gift as an act of solidarity) we can affirm that gift and trust possess logics and values that go beyond the logics and values of each social actor: gift and trust are founding elements of the relationship that, in turn, founds itself thanks to them, in an inextricable circuit that produces relational goods[31], but can also lead to relational ills.

Gift and trust cannot be reduced to free instruments of altruism, nor to mechanisms of mere exchange. They are phenomena that occur when people enter into a relationship and during the course of the relationship evolve, leading to unexpected or predictable behaviour. In both cases:

- They consolidate or weaken a bond.
- They generate expectations that can be met or disregarded.
- They produce obligations of various kinds that can be fulfilled or evaded.

Gift and trust express their strength in 'standing between'. Trust is a gift, but to give is to trust. Gift and trust are not simply concepts, nor tools, nor symbolic rituals: they are relationships that fluidify and mark all other relationships. Therefore, they are second-order relationships or meta-relationships.

The 'trust' meta-relationship is not triggered without the gift meta-relationship and vice versa. Without this epistemological premise, any analysis of trust and gift is reductionism. This chapter shows that trust and gift, from whatever ontological or social perspective they are grasped (even the negationist one), are at the basis of a relationship and can also produce non-cooperative behaviour by triggering unethical attitudes, a theme we will address in the next paragraph.

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30 D'Alessandro, S. (2019). The reflective relationships between society and technology. In *Scienza e Filosofia*, n. 21; D'Alessandro, S. (2019). *La maggioranza silenziosa e la fine del sociale. Riflessioni su Baudrillard.* In *Scienza e Filosofia*, n. 21; D'Alessandro, S. (2014). *L'identità della differenza. Ripensare la relazione nei sistemi sociali*. Milano: Franco Angeli; D'Alessandro, S. (2012). Sociology and the 21st Century: Breaking the Deadlock and Going Beyond the Post-modern Meta-reflection Through the Relational Paradigm. In *World Future: The Journal of Global Education*, 68:4-5, 258-272.

31 According to Pierpaolo Donati's definition (Donati, 1993) a relational good is a good that can only be produced and enjoyed together; by those who are, precisely, the producers and users themselves, through the relationships that connect the subjects involved: the good is, therefore, called relational because it is (lies in) the relationship.

3. Ambiguous and paradoxical relationships between trust, ethics and morals

Since words define the intentions of those who act through the interpreted meanings, it is necessary to start from the etymological origins of the word Ethics, reconstructing meaning and context relationships. Ethics derives from the Greek ethos which means custom, habit.

But it also means home, being inside, belonging. The terms of kinship such as brother-in-law or sister-in-law also derive from the ancient Indo-European root 'své'.

By means of ethics, a solid relationship is semantically built between men, designating a belonging and consolidating bonds and cohesion. It too exists 'among' the members of a group that decides to share a value orientation. Ethics is: a relationship.

This distinguishes it and at the same time brings it closer to the moral term which means costume, from the Latin mos-moris. Ethics concerns the relationship with others, the public and intersubjective dimension, while morality concerns the relationship of the person with himself and with others and his own awareness of good and evil, of right and wrong.

However, there is no personal morality that is not influenced by public ethics.

Before being an institution, a set of regulations[32] or an object of reflection by various humanistic disciplines - philosophy above all - ethics is determined through social practices in which it is negotiated what is right to do together or individually for the common good. From relationships come decisions that become habits and stabilize beliefs that generate different cultures.

Cultures, in turn, are systematized *a posteriori* by social actors (scholars, intellectuals, institutional representatives) in theoretical forms that guide practices. Socrates' ethical theory, for example, held that good is achieved by seeking wisdom.

This is possible through arête - virtue or disposition of mind - which generates solidarity ties. Aristotle will resume the observations of Socrates, to found the first systematic moral theory on virtues. For Aristotle, 'good' is 'what all things tend to'[33].

32 Ethics can be viewed as: institutional, normative and social: a) institutional because it performs a collective function; b) normative because it pushes individuals to act and have positive or negative feelings according to its norms; c) social, because it places limits on the desire of every single individual.

33 Aristotele, *Etica Nicomachea*, Libro I, 1094a; on the historical evolution of ancient morality, see: A. Adkins, *La morale dei greci da Omero ad Aristotele*, Ed. Laterza, Bari 1987.

Any moral theory examines the delicate relationship between trust, law and the calculation of utility. Articulating a speech on what is right or wrong depends on the understanding and inclusion of the aforementioned elements.

We have seen in the previous paragraphs that intuitive trust is also defined as 'moral', because it is guided by value, emotional and experiential references expressed by the person who grants trust.

Therefore, giving trust is a moral and culturally negotiable act. It follows that deciding to share a moral behavior is, in turn, a free act towards a community, because there is a risk that some pretend to accept habits and behaviors that they then do not implement. It follows that ethical / moral behavior is also a fiduciary gift that further consolidates (or breaks down) social bonds.

There are three families of moral theories that have influenced Western cultures - and now also Eastern ones that have accepted the universal declaration of human rights - on the relationship between what is right and what is legal:

a) deontological theories (based on duty); b) consequentialist theories (based on the cost / benefit ratio); c) those based on virtues.

We will focus on the first two theoretical families that still influence the choices of most democratic nations.

Deontological theories emphasize that each of us has certain duties[34].

Christian ethics, for example, is deontological, based on universal defined commandments (or principles) that must be accepted a priori.

The commandments 'not to kill' or 'not to steal' are universal, permanent, indisputable and do not depend on the circumstances. Kantian ethics are also deontological (in fact Kant laicizes Christian morality).

The German philosopher with his moral theory still influences and guides a large part of the constitutional dictates and codes of professional ethics. For Kant an action is moral only if it is performed out of a sense of duty.

Kant called maxims the intentions that determine actions.

A maxim represents the universal principle that inspires the decision that drives action. Kant believed that as human beings, rational beings, we have certain categorical, absolute and unconditional duties.

He thought that there was a fundamental categorical imperative: act according to the maxims you want as universal laws. This principle is known as the maxim of universalization (very similar to the Christian maxim 'do to others what you would like to be done to you', but which we could vary in a secular way with the maxim 'treat other people as ends in themselves and never as means to an end'.

34 On the classification of moral theories see: N. Warburton, *Il primo libro di filosofia,* Einaudi, Torino, 2007, pp. 48-49.

Deontological ethical theories that refer to the notion of the universalization of moral judgements have been criticized because they are not useful when it comes to making decisions between two right choices that are mutually exclusive.

There are specific cases where a certain duty such as 'always tell the truth' can conflict with another duty such as 'do no harm to those you love by saying things you might avoid saying'. If we were to stick to Kantian duties, we would often end up deciding not to decide.

Daily human behaviour is subject to emotions, pleasures, threats, economic difficulties, emotional ties, sympathies that obscure the rational ability to choose between categorical and universal duties as philosophers such as Nietzsche, Wittgenstein and Heidegger have shown in the last century, highlighting the link between action, emotional components and knowledge, denouncing the limits of a self-referential rationality[35].

Finally, deontological theories do not take into account the consequences of actions, since "well-intentioned idiots who unintentionally cause a large number of deaths due to their incompetence could be morally acceptable"[36].

To respond to the shortcomings of deontological theories, consequentialist theories intervene. If a deontological moralist judges that an act is always morally wrong, whatever benefits it may bring, a consequentialist, on the contrary, admits the appropriateness of an action based on the results it may produce. Among the consequentialist moral theories, the best known comes from Bentham's utilitarian approach. According to this approach, the action is to be considered right if, applying itself in a specific circumstance, it succeeds in producing more happiness or the best balance between happiness and unhappiness: the cost/benefit analysis is a consequentialist approach.

Obviously, the consequentialist approach has to do with probable, but not certain consequences. Moreover, in such an approach it is not what is right universally and a priori that matters, but what produces the most benefits, reasoning on a case-by-case basis. Obviously, this theory facilitates the operational plan of those who want to decide on specific problems.

However, this path also opens up considerable problems.

First of all, problems are created between individual benefits and collective benefits. When is it appropriate to choose in favour of one or the other?

Secondly, problems arise with the definition of the concept of benefit - not to mention the even more complex and nuanced concept of happiness - whose meaning changes according to the cultural approaches, collective beliefs and values of each individual whose morals do not coincide with collective ethics.

35 F. Crespi, *La sociologia come conoscenza e l'ambivalenza dell'agire sociale* in R. Cipriani (a cura di), *Nuovo Manuale di Sociologia*, Maggioli, Sant'Arcangelo di Romagna, 2018, p. 50.
36 N. Warburton, 2007, p. 57.

Here we will examine some specific examples, dwelling on the different choices in the way to deal with the Corona Virus, in particular on the Swedish model considered, in the collective imagination, the 'divergent' system par excellence.

When the epidemic broke out in the West, European nations took different paths conditioned by their own values and cultural references: countries such as Italy, Spain, Greece, then France, Denmark, Norway and Finland decided to make the so-called lockdown (some of these countries in a very strict way, others in a soft way) - consisting in closing most of the economic activities and isolating the most infected areas by inviting the population to stay at home - opting for a moral deontological universalist approach - evidently influenced by the constitutional dictates, derived from the Christian and Kantian cultural heritage - consisting in the attempt to take care of everyone, regardless of age and previous health conditions, following the universal maxim: every life is unique and deserves to be saved.

At first the United Kingdom, Holland, Switzerland, Portugal and Sweden opted for a cost/benefit analysis, following the utilitarian tradition, looking for the maximum possible happiness for the community. The United Kingdom, through its Prime Minister, spoke explicitly of herd immunity, based on the following logic: in infectious diseases that are transmitted from individual to individual, the chain of infection can be interrupted when a large number of members of the population are immune or not susceptible to the disease.

The higher the percentage of individuals who are resistant, the less likely an individual is to be infected. If the pathogen does not find receptive individuals, it circulates less, thus reducing the overall risk in the group.

Herd immunity is a form of indirect protection from infectious disease that occurs when a sufficient percentage of a population has become immune to an infection[37].

The choice of herd immunity involves a laissez faire to the pervasiveness of the virus and implies a considerable number of deaths and the contamination of at least 60% of the population before the goal of total immunization is achieved: a choice that trades the functioning of the economic system for the health of citizens (Weber would have considered this choice as consistent with the Protestant and Calvinist ethics underlying the capitalist spirit).

This first decision of the British government - a decision that was abruptly abandoned - followed a variant of utilitarianism: negative utilitarianism.

According to this approach, in all circumstances the best action is not the one that produces the best overall balance between happiness and unhappiness for the greatest number of people, but the one that produces the least total amount

37 https://en.wikipedia.org/wiki/Herd_immunity

of unhappiness: it was assumed that stopping all economic activities by keeping people at home would produce more deaths than the epidemic.

Sweden proposed a divergent model and never went back on its choices, trusting in the virtuous behaviour of its citizens, giving indications on how to avoid risky behaviour without stopping social and economic activities, starting from the assumption that we have to live with the virus for a long time.

Here too we have the herd immunity, but the government does not openly declare it. This does not mean that the Swedish government has not taken measures to contain the contagion: it has closed schools and universities (which have continued to operate with e-learning); it has banned the gathering of people; it has recommended social distancing and minimum distances in supermarkets and other indoor places.

Economic and recreational activities remained open; at the same time, citizens were asked to be responsible, in order to avoid any opportunity for contagion.

Sweden has been able to afford to act against the trend compared to most European countries also for a series of social and territorial elements: a) almost 50 percent of the Swedish population is single-family; b) public opinion is more willing to accept a different risk / benefit ratio in strategic choices; c) Swedes have a vision of independence and a relationship with loneliness that facilitates them when social distance becomes the norm; d) Sweden has a low population density; e) the Swedes have been able to build a balanced relationship between city and countryside, between personal spaces and work spaces, between medium-sized cities and villages; f) the Swedish state has built a highly trusting relationship with its citizens which it considers responsible regardless of the requirements imposed; g) the institutional communication strategy has tried to reassure the population in times of crisis to avoid hysteria and psychosis, counteracting media alarmism; h) the scientific decision support pool of the Swedish state assumes that there is no evidence that forcing everyone to stay at home can make a difference; much better to introduce strict measures at specific intervals without blocking the economic system; i) while other nations need to use fear and norms as deterrents, to force the community to behave respectfully, the Swedish government gains confidence even in situations of normality and for this reason it also faces crises in an ordinary way; a strategy that has also worked for other issues such as, for example, vaccination.

In Sweden there is no law requiring parents to vaccinate their children against known epidemic diseases, yet the vaccination coverage rate reaches almost 99% of the overall coverage; l) It is in the Swedish tradition to be a pioneer of divergent choices.

The Swedish cultural approach is based on trust and a sense of individual responsibility. The government adopts a variant of negative utilitarianism, defined as 'utilitarianism of the rule' which attempts to combine the best aspects of utilitarianism with the best aspects of deontological ethics.

General rules are adopted which tend to produce greater benefits for all or for the greatest number of people, leaving them free to choose.

The Swedish government believes that its citizens can respond better to recommendations than obligations. We could define it as a 'nudge' that has already given some fruits, as many companies have independently decided to reorganize themselves with smart working. But there are also historical reasons that led to the evolution of this approach.

The historian Peter Baldwin, in the book Contagion and the State in Europe 1830-1930, reconstructs the impact of the eighteenth-nineteenth-century debate between the "contagionists-quarantine" and their opponents, in the strategies of containment of devastating epidemics-pandemics such as cholera, smallpox and syphilis.

With the cholera epidemic of 1830, Sweden has a radical tendency towards quarantine. With the Spanish fever (1918-1920) Sweden changed strategy. Benefited from war neutrality, it overcomes the pandemic with fewer deaths than other nations: a third of the infected country (for a population of 5.8 million), 34,500 deaths and a lethality of 1.8% with peaks of 3% in the most hit. This past experience has inspired the current government and its consultants in the strategy of combating Covid-19.

South Korea - considered by international public opinion the virtuous model of sweet lockdown par excellence - has also adopted a compromising model between universalistic maxims and cost / benefit analysis, following the path of organized and intelligent remote control: a) on the one hand, it made the execution of a large number of swabs widespread; b) on the other hand, it applied contact tracing, or the possibility of reconstructing the chain of contacts starting from a diagnosed case and then proceeding to isolation and quarantine.

This nation has developed an extremely sophisticated system for intercepting positives and their contacts, based on the activities and movements of people with the infection.

At the beginning of the epidemic, to keep track of cases, those arriving from China had to provide their mobile number and fill out an app daily, reporting their health status.

Finally, China has pursued a form of forced egalitarianism of behavior, imposing a total restriction of the freedoms of the individual components of its population. This was possible, because this nation has an authoritarian system. In this case he opted for Hume's moral theory: when it is difficult to agree on the choices, the Leviathan intervenes and decides for everyone.

The aforementioned specific examples that arise from different ethical approaches show us:

- That it is difficult to determine and enforce universal rights and duties that are not consonant with socially shared values.
- That the outcomes produced by historically inherited cultures and beliefs can produce paradoxes, rejections and perverse effects as in the example of the United Kingdom.
- That the dilemma to cooperate / not to cooperate remains at the foundation of all formal and informal relationships of human sociality; even in the Covid emergency we did not experiment with a globally shared strategy. This did not happen even in other situations (2008 economic crisis, Sars, Earthquake, signing of the Kyoto Protocol, interventions for peace or war in the Middle East, etc.). If we reduce the behavior of each nation to the behavior of an individual, we may come to the conclusion that individual morals have blocked a shared ethical process.

Both the theoretical recognition of ethical approaches and the specific examples show how the moral approach can change according to the historical evolution of countries; many countries have done nothing but comply with current morals, applying what the population would have accepted.

Governments that did not understand their community had to change their strategy. Regardless of the Chinese option, all the decisions adopted by democratic nations were able to be applied not only on the basis of prescriptions and sanctions, but above all thanks to the support of social actors belonging to the community.

In Italy, the government has managed to recall the fundamental values of its culture, together with the deterrent of fear, to convince the population to respect the rules.

In the United Kingdom, through the polls, the government understood that the path of herd immunity - among other things communicated in a cynically explicit way - would not be accepted; the government's ethical approach has clashed with common morality.

The Swedish government, minimizing the problem, did not have the need to use the deterrent of fear, but preferred to follow what has always been more suitable for its community: to face extraordinary phenomena in an ordinary way, relying on the principle of individual and collective responsibility.

These cases show that the behaviors determined by moral choices are not immediately stimulated by the rules of law, but by values, fear, emotions.

The transgression of a moral commandment appears analogous to the betrayal of trust, as well as violating the rule of reciprocation and gratitude for the gift received. Beyond the normative sanctions - which pertain to the prescriptive logic of the law - there is a social foundation linked to our categories of meaning, our emotions and the legitimacy established by the fiduciary agreement[38].

For this reason, before the norm there is an aligned or misaligned relationship between trust, ethics and gift that is established regardless of any possible instrumentalization or measurement of benefits.

Social action has an ambivalent relationship with norms. Its ambivalence is dictated by drives coming from System 1 (intuition-emotion-morality) and System 2 (rationality), as mentioned in the previous paragraphs, but with a clear prevalence of System 1.

There is a social logic that goes beyond the logic of each person and recreates, on a daily basis, the circle between trust, gift and ethics.

It is not possible to articulate an organization without trust. It is not possible to direct it towards plausible categories of meaning if a dialectic between right and wrong is not constructed (even when this dialectic is modified with respect to changing times). It is not possible to articulate such a dialectic if we do not trust the following statement: "doing right things creates more favourable conditions for survival, cohesion and development".

It is not possible to experience social cohesion if we do not start the circle, giving confidence in a choice considered right. But this choice considered right is not necessarily right for everyone or in every circumstance. Following the epistemological and logical thread started in the previous paragraphs and continued with the description of moral theories and specific examples described in this paragraph, we have the following relational links:

- Trust and ethics are particular forms of gift and constitutive foundations of the relationship.
- Trust and ethics are particular forms of gift that imply a co-obligation between those who grant trust (following an ethically shared maxim) and those who benefit from the trust granted (being able to respond equally correctly).
- Trust and ethics are ambivalent - like all forms of gift - because they oscillate between freedom and constraint in a lateral way and because they change their meta-relational forms according to the contexts.
- The violation of trust determines the violation of ethics and vice versa, implying the deactivation of the circle (with relative failure of the

38 This normativity constitutes an indispensable epistemological presupposition for the social sciences.

relationship) or its displacement to other areas of action (regeneration in other smaller communities that replace and contrast ethics through personal morals).

- Trust and ethics are necessary conditions, but not sufficient to generate cooperative behaviour; they can also be used as a justification for incorrect, violent and destructive behaviour, in a logic of moralistic conflict between antagonistic positions.

We can compare the ambivalent nature of ethics with the law. Both ethics and law govern relationships between individuals, but they rely on different means. While the law is based on valid territorial law (the law is promulgated so that we are aware that if it is not respected it will be followed by a penalty), ethics is based on a moral law known to the community and shared informally.

Law establishes the rules of coexistence between individuals, ethics marks the daily practices of human conduct and goes beyond the norm, because it is capable of determining a choice even in the absence of a law.

The ethical choice has a weaker sanction, but a stronger influence than the law, in social practices. Ethics includes what the law excludes.

Ethics accepts the dialectic with what is not ethical, understanding the contradictions arising from those who are marginalized. Ethics does not mean 'order'; it does not mean rejection of the values of others.

Ethics goes beyond the functional concept, negotiating with what is other than itself, triggering an effect of reciprocity that is typical of the relationship.

Following the relational perspective, if we suspend the relationship with the other, we also suspend the relationship with the self[39]: in this sense, ethics provides additional elements for the construction of individual and collective identities. Ethics is value and function, but above all it is relationship.

It arises 'between' people and allows for the negotiation and inclusion (or exclusion) of values and behaviors. This is why ethics does not depend on the strength of law, but on the solidity of trust.

An ethical attitude depends on the degree of openness towards trust in people, institutions, economic forecasts, collective rules.

Eloi Laurent[40], taking up the thesis supported by Keynes in 1936, analytically describes its foundation in institutional and economic relations.

Laurent's studies show that in societies where trust prevails over a sense of mistrust, there is a reduction in the phenomenon of corruption.

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39 On the emerging effects of the relationship, see: P. Donati, *Teoria relazionale della società: i concetti di base,* Franco Angeli, Milano, 2009.

40 E. Laurent, *Economia della fiducia,* Lit Edizioni, Roma, 2013.

But this does not mean that societies where corruption, nepotism or tax fraud reigns have a high rate of distrust. Criminal organizations are communities in which interpersonal trust networks are high and replace trust in institutions.

Distrust in a subject, therefore, does not cause generalized distrust, but builds and regenerates trust elsewhere, with alternative subjects.

As writer Herman Melville wrote: mistrust is a phase of trust.

The circularity between trust, ethics and gift is inevitable. A circle that is not eliminated, but moved or transformed, narrowed or enlarged in its relations.

The fact that there is a circle does not mean that it always produces relational benefits or goods. It follows that the fundamental problem is not: how to restore the circle of trust? But it is: where and how to direct trust?

A clan trust could enter into open conflict with the institution or build a valid alliance with it. Laurent speaks of the 'crisis of trust' that characterizes complex social systems, distinguishing it from the crisis between trusting social actors. However, the author 'trusts' too much in strategic trust, compared to moral trust. For my experience as a researcher in the field - and in coherence also with my epistemological references - it is exactly the opposite.

Trust possesses an intrinsic morality that must be directed towards adequate and sustainable paths, avoiding relational evils that arise from misalignments between the official collective ethics of a nation state and the heterogeneity of moral approaches shared by groups belonging to that same civil society, which is fragmented every time it takes a position on specific issues (think of divorce, euthanasia, the concept of just war, the relationship between merit and social equity).

The misalignment between ethics and group morals causes tensions that can lead to the marginalization of the deviant group or a revision of the official rules (think of the victory of divorce in Italy where discordant opinions have emerged among Catholics on the inseparability of marriage, leading to a revision of behaviour and changing the way of judging those who decide to divorce).

If an inclusive review of marginal groups with dissonant morals is not carried out in the social system, it will increase the contrast between the groups and the tearing of the bond of solidarity. At that point, each group will follow its own path. In Italy, this fragmentation is evident: multiple morals blocking the birth of shared ethics.

If we want to avoid tensions and divisions between groups, producing a shared ethical sustainability, we must build "that cultural humus that generates the perception of legality as a substantial value and a precondition for development and well-being.[41]

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41 On this topic See: C. T. Siciliano, *Come promuovere la cultura dell'etica e della legalità per uno sviluppo sostenibile delle comunità,* Labour&Law Issues, Vol. 1, n. 2, 2015, p. 46.

This is determined by a system's ability to communicate what the positive and negative effects of trust are and what the obvious links between ethics and trust are, by analysing specific examples and valuing good practices. In terms of prevention, the dissuasive effect is the direct consequence of greater transparency and participation that increase the level of awareness and intransigence through the culture of ethics and legality in daily action.

But without the daily and concrete perception of the example, it is difficult to make appropriate behaviour replicable.

Moreover, communicating on a daily basis the ability of law enforcement agencies to suppress negative phenomena does not contribute to the restoration of confidence, but rather fuels a perception of insecurity and a culture of resignation: perverse effects of social action.

As we will see in the next paragraph, in contemporary complex systems, univocal and positively oriented communication affects trust more than in the past, but determines minimal effects of change.

While a communication of the negative is immediately perceived in both attitudes and behaviours.

In complex systems, positive feedback should be greater than negative feedback. It follows that the media should have more responsibility than in the past. This should imply more contrast against those who produce fake news.

But contrast can not only be normative or punitive, but must be accompanied by cultural awareness and nudging.

4. Misalignment between ethics and trust in the perception of reality distorted by the infosphere

Before entering into the critical analysis of the process of perceptual distortion - determined by the interpersonal, mass-media and cross-media systems of communication - we list some paradigmatic examples from which the ambiguities and paradoxes of this phenomenon emerge:

- *First example*. Exaggerated perception of decline and insecurity in general, compared to the statistical data. Robert Duffy, director of the English section of the Ipsos research company, in a multi-year study - launched in 2014 and involving 38 countries - shows that Italy is the nation with the most distorted perception of reality. Italians are the people with the highest level of negative perception of almost all the phenomena that happen in the country: they assume that 49% of their compatriots of working age are unemployed, when in reality it is 12%; they believe that immigrants make up 30% of the population, when the real figure is 5%; they believe that 35% of people in Italy have diabetes, when in reality it is only 5%. In the ranking drawn up by the English researcher, the United States is in second place and France in third place.[42]. An analysis that comprehensively clarifies the era in which we live, where the perception of reality is altered by a communicative system that feeds the rhetoric of decline and alarm[43].

- *Second example*. Exaggerated perception of levels of corruption, compared to reality. In the research carried out by the magistrate Giovanni Tartaglia Polcini, *La corruzione tra realtà e rappresentazione. Ovvero: come si può alterare la reputazione di un paese,* presented in January 2019[44], the author shows that in Italy the perceived levels of corruption are much higher than the real ones. We suffer from 'Botswana syndrome'. We think we are more corrupt and uncivilized than we are. Moreover, we also suffer from the well-known Trocadero Paradox: the more effectively we pursue corruptive phenomena in terms of prevention and crime in terms of repression, the greater the perception of the corruptive phenomenon[45]. Since 2012, the year in which the anti-corruption law (Legge Severino) was passed, Italy has climbed eighteen places in the Global Corruption Perception Index: from 72nd to 54th. This figure is included in Transparency International's ranking which measures the Corruption Perception Index (CPI), the perceived corruption index[46]. The data is known by professionals, in particular the judiciary and law enforcement agencies. However, the media have addressed the issue a few times. Italy is the country with the highest perceived corruption (around 90%), but with more than 30% confidence in the government, which is higher than that of other countries with a lower perception of corruption: Greece, Portugal, Spain and Slovenia (between 80% and 90%). 85% of Italians are convinced that institutions and politicians are corrupt and yet, to the specific question asked to a sample of citizens, if they had experienced, directly or through a member of their family, a case of corruption in the last 12 months, the answer was negative in the majority of cases, in line with other developed nations.

42 B. Duffy, *I rischi della percezione. Perché ci sbagliamo su quasi tutto,* Einaudi, Torino, 2019.
43 https://perils.ipsos.com/archive/index.html
44 https://www.italiandiplomaticacademy.org/la-corruzione-tra-realta-e-rappresentazione-ovvero-come-si-puo-alterare-la-reputazione-di-un-paese/
45 http://www.dirittopenaleglobalizzazione.it/wp-content/uploads/2017/10/Il-Paradosso-di-Trocadero.pdf
46 www.transparency.org.

- *Third example*. The increase in confidence in institutions during the Crown Virus pandemic due to fear and lack of alternatives. The first study conducted on trust at the time of Covid19 (carried out by the Trust, Theory and Technology group and Evaluation Research group of the National Research Council's Institute of Science and Technology of Cognition, addressed to a significant sample of Italian citizens: 4260 interviewed), confirms the high values of trust expressed in the various responses. The high level of trust, supported by arguments, is due to the strong activity of the authorities and the perception of an imminent danger: a typical dynamic of trust. In particular, in their conclusions the authors of the research state: “As argued by many trust theorists ([Luhmann, 1979], [Batson, 1991], [Hardin, 2002], [Gambetta, 1988]) and also shown in our model ([Falcone&Castelfranchi, 2001]; [Castelfranchi&Falcone, 2010]), a fundamental function (psycho-social, individual and collective) of trust is to face uncertainty: to reduce risk perception; trust gives subjective (before objective) security. Trust makes it possible to face risk and to assume it: trust is accepting to expose oneself to risk ([Mayer et al., 1995]) (...) In fact, trusting Public Authorities (the only ones who in this case are the engine, coordinator and active operator of the response to the threat) becomes (...) a goal of citizens (...) there are no possible alternatives to the interlocutors to whom we can entrust ourselves (who else can we delegate the task of saving ourselves?)”[47].
- *Fourth example*. Meritocracy blocks the social lift and consolidates the power of elite consortia that it should paradoxically fight. In 1958 the American sociologist Michael Young coined the neologism meritocracy, writing a dystopian pamphlet on the negative consequences of the ideology of merit. He argues that stratification, when it develops on the basis of principles of merit, is accepted by each social stratum and paradoxically consolidates social immobility[48]. However, the term meritocracy will be used in the opposite key to Young's thesis[49]. In 1981 Boudon talks about the perverse effects that are produced even when

47 R. Falcone, C. Castelfranchi, E. Colì, *Ricerca esplorativa su Corona Virus e Fiducia*, 2020. www.cnr.it/sites/default/files/public/media/rassegna_stampa/cnr%20istc_nota_coronavirus%20e%20fiducia_una%20ricerca%20esplorativa-2.pdf, pp. 20-21.
48 M. D. Young, *The rise of the Meritocracy*, Taylor and Francis, 1958, p. 99; il tema è ripreso in M. Boarelli, *Contro l’ideologia del merito,* Laterza, Roma-Bari, 2019.
49 This is a magnificent and ironic example of perverse meta-effect: perverse effect in perverse effect.

everything is done to avoid them[50]. In 2006 Marie Duru-Bellat demonstrates that the increasing improvement in general education has not led to a significant increase in social mobility[51]. The French sociologist does not identify a strong direct effect of the opening up of the French education system - enshrined in the reforms undertaken between the 1960s and 1980s - on social fluidity. According to the author, the distribution of school credentials has remained strongly uneven and has allowed the wealthier social strata to maintain their advantage. This has been done through different strategies: a) prolonging the course of study; b) addressing the most prestigious educational chains and the most accredited institutions (and/or sections). What would make the difference would no longer be the mere possession of an educational qualification, but the type and where it was obtained. The hierarchy in access to school credentials is evident in the grandes écoles, the higher education institutions for the training of the ruling class, which are characteristic of the French system. These institutions are accused of promoting the social reproduction of the elite. This process has increased distrust of the educational system in general. In 2019 the historian Mauro Boarelli confirms the same dynamic also in the Italian case: the rigid application of the meritocratic principle has generated even more marked social inequality[52]. The mass media have never brought on the agenda the scientific validity of this debate, favouring the consolidation of the perverse effect and the false belief that merit is linked to the capacity of the subject and not to his caste advantages.

- *Fifth example*. Perverse effects of Whatsapp and Telegram on trust, prophylaxis, sociality and unfair competition with the media. It is clear that the free messaging of smartphones has replaced or amplified - depending on the circumstances - many interpersonal and informal community dynamics that used to be practiced in public places, particularly gossip. At the same time, these universes have become the places where fake news quickly goes viral. Paradoxically, the increase

50 Boudon R., *Gli effetti perversi dell'azione sociale,* Feltrinelli, Milano, 1981. Although I agree with Boudon's basic thesis, I do not share the paradigm of the theory of rational choice supported by the French sociologist. According to my experience as a researcher, perverse effects are produced by unintentional processes, by an individual rational action that is not synchronized with the rationality of others, but also by individual and group irrationality. Therefore, the perverse effect is not an exceptional or infrequent phenomenon, but a daily phenomenon, even if not necessarily catastrophic.

51 M. Duru-Bellat, *L'inflation scolaire. Les désillusions de la méritocratie*, Seuil, Paris, 2006.

52 M. Boarelli, *Contro L'ideologia del merito,* Laterza, Bari-Roma. 2019.

in fake news about the pandemic has played a positive role - albeit unintentionally triggered - in the virtuous behaviour of citizens, keeping the tension high and fuelling fears and alarms even greater than the phenomenon. These instruments have also fuelled the self-referentiality of deniers. At the same time, the same instruments have changed the relationship between gift, trust and ethics with respect to the problem of newspapers sent free in whatsapp and telegram groups: this act, perceived by many as a gift, has completely covered the damage caused to newspapers (over 800,000 readers lost in Italy between 2018 and 2019). The misconduct is officially condemned by the official media (public ethics), but morally accepted by the telegram and whatsapp (group morality) groups. The gift consolidates the strategies of cognitive reinforcement (a posteriori coherence) of justification of the incorrect behaviour: the donor claims to do it for others. The beneficiaries accept it for convenience, but also in order not to hurt the donor's sensitivity. In other cases, misbehaviour is minimized because it is compared to much more serious misbehaviour or is perceived as compensation compared to other damage suffered in times of crisis. This is how the donor circle/ trust/ethics shifts or evolves into donation/ distrust/moral.

The above examples, on the one hand, show how the unpredictable combination of chains of independent actions can generate perverse effects (even opposite to the planned goals) and on the other hand how perverse effects can be the rule (not the exception). The system of communication alters the perception of social facts, building a close relationship between prejudice and stereotype. The media increase the triggering of perverse effects. A society that communicates a lot, increases the phenomenon without having any chance of managing it. In times of crisis this state of affairs is further accentuated.

This is why rational decision-making in complex communication systems in times of crisis produces the same results as a random decision[53].

Both perverse and virtuous effects feed prejudices and stereotypes. From an etymological point of view, the term prejudice indicates a judgment that precedes experience, made in the absence of sufficient data.

The social sciences have taken an interest in prejudice, incorporating the additional meaning of misconception and obstacle to knowledge[54].

There is a maximum level of generalization of the term (prejudice as a judgement preceding experience) which could lead us to conclude that 'everything is prejudice', considering it an unchangeable characteristic of

53 On this topic: S. D'Alessandro, *Creatività: normalissima improbabilità?* Aracne, 2010.

54 M. Mazzara, *Stereotipi e pregiudizi*, Il Mulino, Bologna, 1997; P.L. Berger T. Luckmann, *La realtà come costruzione sociale*, Il Mulino, Bologna, 1997.

mankind. This level does not allow to propose an analysis of prejudices aimed at finding strategies to reduce them and, after all, it also includes prejudices that do not pose any social problem.

But there are prejudices that arise from a deliberately distorted and consciously incomplete use of data and that determine an unjustifiably unfavourable (or favourable) perception of the phenomena examined.

Alongside the concept of prejudice, in a relationship of implication, there is the stereotype[55] which constitutes the “cognitive nucleus of prejudice”[56]: the set of information and beliefs relating to a certain category of objects, reworked into a coherent and rather stable image, capable of directing the evaluation of the data in the direction of prejudice[57].

As Lyotard already pointed out in 1979, in post-modern society culture becomes an object of stereotypical consumption and simplification: intellectuals no longer guide the processes of change, evolving into mere media entertainers who have to build numerous generalizations in a short time.

Tenbruck, again in 1979, states that all societies, except today's, have had to rely on some intellectual authority that could successfully declare a superior knowledge of society[58].

The societies of the past needed an intellectual class to be addressed (whether philosophers, priests, poets, scientists or academics), while in post-modern society, cultured leadership is marginalized.

It is not recognized as the holder of legitimate, credible and indisputable knowledge. Moreover, for the first time, knowledge becomes simply a commodity, consumption and form of entertainment.

The web has simply accentuated a phenomenon that was already present in previous decades. In the last 40 years we have witnessed the progressive construction of a redundant and pervasive system-communication that has overturned the relationship of force with social, cultural and political reality, gradually replacing the aforementioned systems.

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55 Stereotype is a term coming from the typographic environment where it was coined towards the end of the eighteenth century to indicate the reproduction of printed images by means of fixed forms. The first translated use of this term was made in psychiatry, in reference to pathological behaviour characterized by obsessive repetitiveness of gestures and expressions. The introduction into the social sciences is due to the journalist Walter Lippmann who in 1922 published an innovative volume on the processes of public opinion formation, arguing that the cognitive relationship with reality is not direct, but mediated by mental images (stereotypes) that everyone forms because they are conditioned by the press.

56 In Mazzara, M. 1997, p. 16.

57 S. D’Alessandro, *La ricostruzione Post-Sisma della città de L’Aquila come fenomeno mediatico* in «Sociologia e Politiche Sociali Fascicolo» n. 3/2018, pp. 161-162.

58 F. Tenbruck, *Sociologia della cultura*, Bulzoni, Roma, 2002 (1979), p. 50.

Baudrillard in 1980 spoke of 'perfect crime': the disappearance of reality, replaced by a hyper-reality that simulates the intentions of the social. Donolo analyzes the behavior of ruling classes homogenized by the media process, attentive to representation, but unable to change processes. Culture no longer changes the social, it no longer functions as a collective resource capable of regenerating social capital. Intellectuals are unable to align institutional expectations with social ones, because they are silenced by the dictatorship of communication, the container-vector that replaces contents and agents. Observing the historical evolution of the Italian mass media, starting from the second half of the twentieth century to the present day, we can distinguish:

- a first phase in which the mass media accompanied the modernization process of the country, just out of the Second World War, becoming important spreaders and repeaters of the socio-cultural goals that are collectively shared[59], contributing to the construction of a collective ethics based on the re-construction of a world open to better possibilities, orienting a balanced relationship between freedom and social equity, state and market, welfare and self-realization;
- a second phase, starting from the 1970s in which politics - parliamentary and extra-parliamentary - used the ability of the media to change attitudes and behaviors, in order to build or destroy consensus, fueling a strategy of tension and ideological conflict between classes through the recurring practice of counter-information;
- a third phase, inaugurated by the crisis of the first Republic - exacerbated by the decline of parties, the deregulation of the market, the weakening of the welfare state, the betrayal of the generational pact, the crisis of training agencies (schools and universities) and the failure of the world of traditional information - in which socially significant spaces have been progressively eroded, replaced by a communicative system that has built a dissonant and antagonistic narrative with respect to the institutions it claims to replace. This phase breaks the pact of accompaniment and connection between civil society and institutions. Mass media from accompanying tools for democratization and modernization processes, evolve into constructors of conflicts, prejudices and stereotypes aimed at delegitimizing the other social, political and cultural components of the system[60].

59 M. Morcellini, *La società che comunica,* in R. Cipriani (a cura di), *Nuovo Manuale di Sociologia,* Maggioli, Sant'Arcangelo di Romagna, 2018, p. 275.
60 M. Morcellini, 2018, pp. 278-280.

In the current social system, communication is not a collateral element, but it is the system that claims to make up for the shortcomings of the other components.

We are talking about a communication system - and not an information system - because the communicative universe is much more complex: it is that set of mediated and immediate, traditional and digital, interpersonal and cross-media components that cross social networks including, excluding or mingling with information supported by verified sources.

The system is not based on the credibility of the source or on the legitimacy of those who convey it, but on the pervasiveness of its planning, on the needs of its target and on the verisimilitude (non-truthfulness) of a social fact.

Following this logic, we accept what is imposed on us and if the information is denied *a posteriori* it does not weaken, but remains anchored to a system of beliefs and is, generally, indelible and unchangeable, because it is difficult to trace, despite the existence of the ‘oblivion right’.

In the communication system there is not only the communication generated by the human, but also that processed automatically by the algorithms that feed what the human produces or searches. This hypertrophy of the infosphere - conscious or automatic - increases anomic effects, paradoxes and contradictions that contribute to the misalignment between collective trust and intersubjective trust systems, between ethics and personal morality.

If it is true, as noted in the previous paragraphs, that ethics can be fueled by trust, otherwise its practical behavior is demotivated and moved to other places, it is equally true that a communication system unable to synchronize with the values and expectations of civil society, collapses the circle of trust or displaces it. When ethics and trust are not reflected in everyone's community, they recreate themselves in small communities that pursue their own particular interests.

In 1994, before the advent of the web, Karl Popper suggested the idea of finding a limit to communicative hypertrophy.

The Austrian epistemologist argued that whoever manages a medium has a high responsibility towards society and therefore it is necessary that he be evaluated by the Government and that he is granted an authorization to carry out his work only if in possession of the necessary requirements, as for those who drive a car or care for the sick. An authorization that can also be withdrawn if the person to whom it was granted does not adopt ethical principles[61].

The system that selects those who should intervene to sanction those who do not communicate information correctly should be public, not contaminated by market rules or lobbies. It should also be an independent system with respect to

61 K. Popper, *Cattiva maestra televisione*, Feltrinelli, Milano, 1994.

the registers or disciplinary commissions of the category, because each register defends the members of its own category in a self-referential way.

Obviously, this system too could be easily circumvented, but it would be a way to constitute a *super partes* category capable of regulating the positive and negative flows of information. If those who communicate with a large audience repeatedly behave irresponsibly or promote misperception by manipulating data, they should be prosecuted.

This thought by Popper has been endorsed by other studies that have demonstrated the persuasive power of communication tools, their ability to change attitudes and behaviors (desensitization to violence, detachment from politics, increase in narcissism, consumerist indoctrination, etc.)[62].

The persuasive effects of communication have been studied by social psychology: coherence, repetition, auctoritas, scarcity, empathy, sympathy, motivation are the basic principles of persuasion[63].

These principles modify the attitudes of the subject, affecting the automatic behaviors of System 1. Trust means developing a relationship based on the perception we have of a person, an institution or an informal group.

Perception feeds, positively or negatively, the halo effect described in the previous paragraphs. Ethical behavior is altered or blocked by perception.

Acting ethically means trusting in one's own values, but also in the feedback and appreciation of the community of reference. If the social actor develops the perception that his way of behaving is not appreciated, he could change his behavior or address this orientation to a smaller circle of people.

Failure, alteration and displacement of the trust/ ethics/ gift circle depend on perception, the outcomes of which are not predictable a priori, as shown in the examples examined.

5. Conclusion

On the basis of the relational links proposed in the previous paragraphs, we can conclude that giving confidence reduces the complexity of relationships and decision-making processes (decreasing the cognitive load that would be determined if we had to research the credibility of any person or organization with whom we want to establish relations) and belongs structurally to human relations.

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62 G. Bettetini, A. Fumagalli, *Quel che resta dei media*, Franco Angeli, Milano,1998.

63 R. B. Cialdini, *Le armi della persuasione,* Giunti, Firenze, 1995.

The building of trust relies on relationships that are repeated over time and evolve into recurring and reliable relationships: this requires a long time and consistency in the way we behave.

A single element of inconsistency, compared to previous exchanges, could undermine the foundations of Trust, while distrust takes root quickly and expands rapidly. Trust is ambivalent, fragile and generating social actions with unexpected outcomes, even perverse and paradoxical.

This denies any functionalist attempt to engineer and optimize performance.

The ambivalence of trust, in terms of social practices, represents a strength from an evolutionary point of view, because its reversal in distrust creates limits to gambling.

Contemporary society is subject to greater risks linked to trust, because globalization on the one hand has weakened emotional and family ties, and on the other has forced each social actor to make rapid choices with people from worlds and cultures that are not consonant with their own.

Consequently, in our world, relying on trust has become a necessity and a recurring and fast practice. Trust represents a particular form of gift that obliges, in a lateral way, reciprocity. Just as the gift is triggered by trust, in an action of liking or reciprocity on the part of the other.

In the circular relationship between gift and trust - terms that could be defined as co-causative of a relationship - gratuitousness and obligation, spontaneity and constraint, generosity and debt, interest and disinterest, recognition and servitude, exchange and conflict are combined.

This dialectical dynamic allows the gift and trust to found the social bond, the legal relationship, the economic exchange, the political pact, the moral obligation and the religious behaviour.

Reflexivity on gift and trust is typical of contemporary society because the risk has increased.

Therefore, gift and trust take on stronger moral connotations than in the past.

From the sociological point of view, trust can be personal or systemic, strategic or intuitive, but in collective processes the intuitive/ moralistic/ emotional one prevails, because all the processes concerning recurring collective behaviours cannot be taken slowly and on the basis of accurate information searches, otherwise our daily regularity would be missed[64].

The ambivalences of intuitive trust can lead to forms of collaboration, exchange and economic reciprocity; but they can also give rise to forms of blackmail or represent mere expedients of manipulation.

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64 Giddens defines them: ontological securities in A. Giddens, *The consequences of Modernity,* Standford University Press, Stanford (CA), 1990.

What we can say with certainty about these two terms is that they are processes, relationships, meta-relational devices that:

- Consolidate or weaken a bond.
- Generate expectations that can be respected or disregarded.
- They produce obligations of various kinds that can be fulfilled or evaded.
- Can generate good practices or perverse effects.

Trust and gift, from whatever ontological and social perspective they are grasped, are at the basis of the relationship and builders of all cooperative and solidarity-based behaviour, but also behaviour that can generate distrust and refusal of gift (in the double meaning of lack of generosity towards the other and ingratitude when the other gives us something), triggering behaviour that affects the low propensity to respect a shared ethical or personal moral code. Reasoning in systemic terms, there is a structural coupling between trust and ethics, being two particular forms of gift.

Reasoning in relational terms, trust and ethics mark the daily construction or destruction of social bonds, founding the emerging basis of any action or behaviour generated by expectation. Ethics - like trust - is also a particular form of gift that can trigger ambiguous social practices: obligation and concession, interest and disinterest, expectation and desire.

Ethics is intimately linked to intuitive trust (because it is guided by value, emotional and experiential references, expressed by the person who grants trust). Therefore, giving trust is a moral act that negotiates with collective ethics. Ethics, while inspiring law, includes what law excludes, accepting the dialectic with what is unethical.

Ethics is a process that goes beyond the functional concept, negotiating with what is other than itself, triggering an effect of reciprocity typical of the relationship and generating perverse, negative and unforeseen effects further fuelled by the distorting effects of a contemporary system in which communication is no longer a collateral element, but a dominant system that claims to make up for the shortcomings of the other components of society.

The specific examples examined in the previous paragraphs demonstrate the ambiguities and paradoxes generated by the relationship between ethics and trust, altered or distorted by a pervasive, automatic (not guided by an intellectual class) communication system that feeds the construction of stereotypes and prejudices, without supporting cohesive processes and shared goals.

In societies where trust prevails over distrust, there is a reduction in the phenomenon of corruption and social conflicts. But this does not mean that societies where corruption, nepotism or tax fraud reign, have a high rate of distrust.

Criminal organizations are communities where interpersonal trust is high and replaces systemic trust. It follows that distrust in a social actor or an institution does not lead to widespread distrust, but builds and regenerates trust with alternative social actors. For this reason, it becomes fundamental to create a pact with the communication system that is able to increase the visibility of good practices.

In conclusion, after following a theoretical logical method[65], unfolded in stages along the paragraphs, we can state, with a certain degree of consistency, that:

- Trust and ethics are particular forms of gift and constitutive foundations of the relationship.
- Trust and ethics imply a co-obligation.
- Trust and ethics are ambivalent in nature - like all forms of gift - because they oscillate between freedom and constraint and because they change their meta-relational forms according to contexts.
- The violation of trust determines the violation of ethics and vice versa, implying the deactivation of the circle (with relative failure of the relationship) or its displacement to other areas of action (regeneration in other communities).
- Trust and ethics are necessary conditions, but not sufficient to generate social cohesion and cooperation; they can also be used as justification for incorrect, violent, destructive behaviour in a logic of moralistic conflict between antagonistic positions.

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Are low testosterone and sex differences in immune responses causing mass hysteria during the coronavirus pandemic?

Roy Barzilai[1]

Abstract

By integrating the entire body of research in human sexual dynamics, immune responses, and sociocultural behavior, we can conclude that the mass hysteria our society is currently experiencing originates in our evolved psychological adaptations to pandemic conditions[1]. A lack of hormonal balance[2], due to a collapse in testosterone levels, may cause a disproportionate immune response that leads to the destruction of our cherished sociopolitical institutions—the very institutions that are design to protect human liberty and prosperity. What is playing out at a societal level is similar to an excessive immune response that causes the body to attack itself: decreased testosterone causing the kind of auto-immune response that is more prevalent in females.
Keywords: sex hormones, cultural evolution, behavioral immune system.[2]

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1. Introduction

In a short period of only six months since the Coronavirus Pandemic, originating in China, hit the Western world, the global hysteria and panic response has reached unprecedented levels: Mass lockdowns have infringed on once sacred individual rights, which are being trampled on by increasingly authoritarian government decrees. A coordinated global economic collapse has pushed unemployment levels to 1930s Great Depression rates of over 20% worldwide.

2. Political Polarization

This has also further stirred up the growing momentous trend toward political polarization between conservatives/libertarians and liberal progressives in their views of the severity of the danger caused by the virus and ideas about adequate responses. Republicans and libertarians view the threat as minor and the response disproportional, causing economic and social devastation. Many conservatives are calling the cure worse than the disease. Democrat liberals, on the other hand, want to take further, severe, nation-wide measures to counter this perceived danger until there is a vaccine developed, which may require years.

A recent article on the Social Science Research Network (SSRN) warns that such partisanship exceeds public health concerns when it comes to choices about social distancing. Reviewing almost half a million responses, the researchers concluded that "rampant partisanship" increased in the March 4–June 6 survey period and created "the largest obstacle to the social distancing most experts see as critical to limiting the spread of the COVID-19 pandemic."[3]

Moreover, these researchers cite the increase in Republican partisanship particularly: "All else equal, the relative importance of partisanship for the increasing (un)willingness of Republicans to engage in social distancing highlights the challenge that politics poses for public health."[4] Hence, liberals view conservatives as reckless and selfish, seeking economic growth at the cost of human life, while conservatives view their counterparts as hysterical to the point of destroying the political and economic basis for Western prosperity, causing a depressive economic environment.

3. Sex hormones and behavioral immune system

As my previous work on political polarization and sex differences suggests, I would like to present how sex hormones cause this effect of cultural divide and political strife. It is been the thesis of my work that low testosterone levels are causing the radical feminization of Western culture and a declining social trend over the last 70 years. Since the growth of liberty and capitalism in the 1950s, this decline has reached an extreme in 2020. Low testosterone is at the root of the anti-masculine bias of liberal-socialist politics, but it has reached a pinnacle with the current hysterical response to this health crises. To understand this phenomenon we need to delve into the evolution of the human immune system and how it is shaped by sex hormones.

Females have a much stronger immune response than males because females carry the burden of reproduction and raising infants, and hence their well-being beginning at the age of fertility (beginning at 12 -14 years old) is more essential for the creation of future generations. Testosterone can actually have the effect of suppressing the male immune system relative to females in general.[5] However, this is a double-edged sword, as the strong female immune response can also cause the body to attack itself, which leads to many catastrophic auto-immune diseases;[6] nevertheless, more men die from the coronavirus pandemic. A study in April 2020 of 5,700 COVID-19 patients showed that 60% were male and that male mortality rates were higher than female.[7] Likewise, a more recent study indicated that with age increases, male deaths increase at a higher rate than female deaths.[8]

Furthermore, a 2018 scientific discovery found a new link between immune cells and the differentiation in utero of sex traits, further supporting the connection between how our immune systems operate in relation to biological sex.[9] The great gender divine in our immune system also manifests itself in human behavior, according to an evolutionary biology theory of a *behavioral immune system*. The critical need for human defense against pathogens, including disease, has led our species to not only develop chemical immune responses but also "proactive behavioural mechanisms that inhibit contact with pathogens in the first place."[10] Marc Schaller writes:

> *This behavioural immune system comprises psychological processes that infer infection risk from perceptual cues, and that respond to these perceptual cues through the activation of aversive emotions, cognitions and behavioural impulses….These processes have important implications for human social cognition and social behaviour—including implications for social gregariousness, person perception, intergroup prejudice, mate preferences, sexual behaviour and conformity.*[11]

4. Conclusion

By integrating this entire body of research in human sexual dynamics, immune responses, and sociocultural behavior, we can conclude that the mass hysteria our society is currently experiencing originates in our evolved psychological adaptations to pandemic conditions. However, a lack of hormonal balance, due to a collapse in testosterone levels, may cause a disproportionate immune response that leads to the destruction of our cherished sociopolitical institutions—the very institutions that are design to protect human liberty and prosperity. What is playing out at a societal level is similar to an excessive immune response that causes the body to attack itself: decreased testosterone causing the kind of auto-immune response that is more prevalent in females.

During the period of the American founders, Benjamin Franklin once said, “Those who would give up essential Liberty, to purchase a little temporary Safety, deserve neither Liberty nor Safety.” In this, Franklin was expressing the masculine, more high-testosterone, risk-taking culture that led to more than two centuries of Western prosperity. The current auto-immune attack on our own society in the form of “rampant partisanship” and division along with the heavy-handed government restrictions will depress liberty and destroy our society from the inside out like the ravages on the body of an MS patient if we do not recognize the disease and work together toward a cure.

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The Covid-19 and the defeat of conspiracy theories. The renewal of public faith in scientific research

Roberto Veraldi♣

Abstract

Conspiracy theories integrate, connect and catalogue together what are clearly independent and unrelated events in order to demonstrate correlation and construct impossible, fabricated tales of causation (Bessi, et al., 2015). In a narrative sense, these extremely sophisticated stories are often very intriguing, and their diffusion comes about due to a legitimate desire to enrich the non-scientific literature available. In other cases, despite the cultural maturity of the Western world, conspiracy theories are promoted as real news, able to upset public opinion and to involve a part of the population in Pindaric flights. Moreover, in many cases the creators of these illogical conspiracies are held as suffragists of so-called 'free thought', departing from mainstream theories and opening up the mind of the population to new and elevated levels of comprehension of reality (Melley, 2000) and at the moment, the spread of Covid-19 produces a greater awareness of the societal role of the individual.

Keywords: Covid-19; conspiracy theories; scientific research.[1]

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1. The topic of fear: Covid-19

From a sociological and philosophical standpoint, one of the most interesting phenomena concerning the realm of public opinion concerns the emergence of international conspiracies theories and their strong relation to fear. In fact, the topic of fear is the thematic thread connecting the issues addressed in this short paper. Both unemployment and the arrival of immigrants from far off lands often increase fear, compromising a sense of identity that would otherwise represent an outlet for individual and collective anxieties. Conspiracy theories integrate, connect and catalogue together what are clearly independent and unrelated events in order to demonstrate correlation and construct impossible, fabricated tales of causation (Bessi, et al., 2015). In a narrative sense, these extremely sophisticated stories are often very intriguing, and their diffusion comes about due to a legitimate desire to enrich the non-scientific literature available. In other cases, despite the cultural maturity of the Western world, conspiracy theories are promoted as real news, able to upset public opinion and to involve a part of the population in Pindaric flights. Moreover, in many cases the creators of these illogical conspiracies are held as suffragists of so-called ‘free thought’, departing from mainstream theories and opening up the mind of the population to new and elevated levels of comprehension of reality (Melley, 2000).

At the beginning of this year, and probably at the end of the past year, a strong flu virus upset public order and healthcare systems throughout the World. Covid-19, otherwise known as 2019-nCoV or simply coronavirus, is the seventh coronavirus to attack the human population, causing one of the most rapid infections in medical history (Zhu, et al., 2020). Excluding the 1918-1919 Spanish flu pandemic, which killed about 50 million people worldwide, of the global infections in recent history, Covid-19 is the most powerful and difficult to eradicate, to date. With nearly 100,000 infections and a death toll surpassing 10,000, the imposed lockdown and forced quarantine have been the only methods able to contain the crisis.

The Covid-19 virus is 79.6% similar to that of SARS (Severe Acute Respiratory Syndrome), which upset China in 2002. It is 96% similar to bat coronavirus, and for this reason, as well as other technical reasons, it is reasonably certain that the origin of Covid-19 is avian. Additionally, there is evidence that other past flu pandemics were also avian in origin (Zhou, et al., 2020).

Above all, this type of flu spreads very rapidly because it does not normally appear in the World population; the antibodies disappear quickly, and since the infection has not been present in the human environment for long, people do not have a strong predisposition for self-protection from it. Furthermore, the diffusion of an avian flu cannot be stopped because, in contrast to other animals, the removal of a large part of the infected population is impossible. The conditions for diffusion and the infectious power are therefore reasonably (if not certainly) ascribable to the genetic mutation of a preexisting avian virus.

Since human imagination is second only to human lunacy, theories of an international conspiracy to voluntarily diffuse Covid-19 by human means have quickly established a foothold. Without going into detail about the authors of these theories (even if they are well known to the public), the following paragraphs will attempt to summarize the main arguments of these hypotheses.

The story begins even before the epidemic, with the United States' economic difficulty in obstructing the expansion of the Chinese economy and its acquisition of power. Being unable to slow down Chinese exportation and progress through import duties or tariffs, they might have a connection with the diffusion of Covid-19 in Wuhan. The United States' labs would have bioengineered the virus and brought it to the Chinese city. The foundation of this suspicion would be a study by the University of Delhi that found evident traces of genetic manipulation within the virus. According to conspiracy theorists, this research was withdrawn for no apparent reason. All of this, of course, would be possible because it is apparently very easy to force a researcher or University to withdraw his own research, even when it could significantly benefit the whole community.

Conspiracy theorists then claim that there were confirmations by important scientists of the artificial origin of this virus. Furthermore, the seventh edition of the International Military World Games, held in Wuhan in October 2019, would have provided the right moment to spread the virus by utilizing the help of the American armed forces. Moreover, the literature promoting this conspiracy idea would even be eliminated from Amazon's price list. To complete this picture of madness, the conspiracy theorists managed to connect the closure of a US laboratory during the summer of 2019 within this framework. In summary, the virus would have been created or designed in the United States and intentionally exported to China.

2. Some final considerations

The publication of such conspiracy theories encourages an intense and profound sociological discussion. It is not possible to debate all of the sociological repercussions of this type of conspiracy outcome. Therefore, in these few paragraphs, only the implications to public perception of scientific research that the diffusion of Covid-19 has caused will be discussed. Despite the fact that conspiracy theories generally have a positive social function, during this pandemic, they have been promoted less with respect to other periods (e.g. chemtrails, 9-11, etc.).

From a societal perspective, many people have the need to attribute meaning to their existence. However, the exact substance of this meaning bears no importance-- any meaning will do. Despite the fact that conspiracy theories are capable of attracting only a specific part of the population, the possibility of acquiring ‘alternative knowledge’ and feeling like “free thinkers” can bring about two important advantages to this group of people.

The first is the aggregation within a community of like-minded people and the opportunity to share an idea, which allows for the emergence of new identities and strong self-awareness. Second, it brings the population back to reading and documentation- despite this being a rather questionable methodological approach. Nevertheless, the problem of widespread conspiracy theories over recent decades cannot be ignored and must be analyzed in the light of the negative effects which it could have for a population on a cultural level.

At the moment, the spread of Covid-19 produces a greater awareness of the societal role of the individual. Despite the fact that support for the health and safety measures put in place is not fully shared by a considerable part of the population, the measures to ensure the respect of the quarantine seems to be rather effective. The campaigns promoted by individuals and the sharing of personal experiences are providing a new level of documentation concerning this disease, as well as proper conduct to ensure its containment. Within this context, greater importance is being given to the competencies of recognized professionals from the international scientific community, taking precedence over other far-fetched hypotheses promoted on the web. The population’s awareness of the need for valid researchers to face this emergency is reawakening a more realistic and accurate vision of the importance of science within the greater society.

In the future, it is now likely that the position of scientists will be elevated and that the diffusion of fake news will cease to have such a strong impact on the validity and reliability of the news produced by the mainstream media. In a society which had lost confidence in scientific professionals and institutions, restoration to the value of science within public opinion appeared to be of extreme necessity. Now this return to a position of greater reverence will likely soon become reality.

Obviously, conspiracy theories are not the only cause of the spread of skepticism surrounding science. Competition within scientific research - which promotes careers on the basis of the number of internationally published articles produced, rather than on the capacity of research to reveal and disseminate information regarding truly important discoveries or knowledge - has played its role in the creation of the currently complex relationship between the general population and science. A new definition of the population-science paradigm is, therefore, anticipated, along with a redefinition of the epistemological value of truth seeking. In the current state of opinion crisis, which could be defined as the 'society of worldwide risk' (Beck, 2008), this potentially destructive situation can and must be transformed into a constructive challenge.

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Helix hyperoperation in teaching research

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Abstract

Interaction between sciences has always been an optimum. Within this frame of interdisciplinary approach, an attempt is made to apply a method, a *mathematical model*, used in the *Hyperstructure Theory*, in teaching and research procedure. More specifically, when dealing with a great amount of data arranged in a 'linear' disposal, it is quite difficult to teach. This is the case when the Helix Model is suggested to be used. With the Helix Model, every single piece of data is present and every element maintains its independence.

Keywords: Helix hyperoperation; hyperoperation; teaching.[2]

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1 Introduction on hyperstructures

Interaction between sciences has always been an optimal goal among scientists all over the world. We can see that in every specific science there are methods and applications that can be used both within different branches of the same discipline and in other sciences as well. In this paper we present a method, a Mathematical Model, used in the *hyperstructure theory*, for possible application in teaching and research procedure. Interestingly, the method is likely to be subconsciously used in teaching and research procedure.

The largest class of hyperstructures are called *H_v-structures* and were introduced in 1990 by T. Vougiouklis. They satisfy the *weak axioms* where the non-empty intersection replaces the equality.

Basic definitions, see [1], [3], [8], [9], [10], [11], [14]:

In a set H equipped with a hyperoperation (abbreviation *hyperoperation=hope*)

$$\cdot : H\times H \to P(H)-\{\varnothing\} : (x,y) \to x\cdot y \subset H$$

we call ($\cdot$) *weak associative* if $(xy)z\cap x(yz)\neq\varnothing,\ \forall x,y,z\in H$, and we call it *weak commutative* if $xy\cap yx\neq\varnothing,\ \forall x,y\in H$.

The hyperstructure (H,·) is called *H_v-semigroup* if it is weak associative, it is called *H_v-group* if it is reproductive H_v-semigroup, i.e. $xH=Hx=H,\ \forall x\in H$. The hyperstructure (R,+,·) is called *H_v-ring* if both (+) and (·) are weak associative, the reproduction axiom is valid for (+) and (·) is *weak distributive* with respect to

$$(+):\ x(y+z)\cap(xy+xz)\neq\varnothing,\ (x+y)z\cap(xz+yz)\neq\varnothing,\ \forall x,y,z\in R.$$

Let (R,+,·) be H_v-ring, (M,+) be weak commutative H_v-group and there exists an external hope

$$\cdot :\ R\times M \to P(M):\ (a,x) \to ax$$

such that, $\forall a,b\in R$ and $\forall x,y\in M$, we have

$$a(x+y)\cap(ax+ay)\neq\varnothing,\ (a+b)x\cap(ax+bx)\neq\varnothing,\ (ab)x\cap a(bx)\neq\varnothing,$$

then M is called an *H_v-module* over F. In the case of an H_v-field F, which is defined later, instead of an H_v-ring R, then the *H_v-vector space* is defined.

Let (H,·), (H,*) be H_v-semigroups. (·) is *smaller* than (*) iff there exists

$$f\in Aut(H,*):\ xy\subset f(x*y),\ \forall x,y\in H.$$

Theorem 1.1 *(The Little Theorem)* [3], [9], [10]. Greater hopes than the ones which are weak associative or weak commutative, are also weak associative or weak commutative, respectively.

The main tool to study hyperstructures is the *fundamental relations* β^*, γ^* and ε^*, which are defined, in H_v-groups, H_v-rings and H_v-vector spaces, respectively, as the smallest equivalences so that the quotient to be group, ring and vector space, respectively.

Theorem 1.2 Let $(H,\cdot)$ be an H_v-group and denote by U the set of all finite products of elements of H. Define β in H by setting $x\beta y$ iff $\{x,y\}\subset u$ where $u\in U$. Then β^* is the transitive closure of β.

An element is called *single* if its fundamental class is singleton.

More general structures can be defined by using the fundamental structures.

Definition 1.3 An H_v-ring $(R,+,\cdot)$ is called *H_v-field* if R/γ^* is a field.

Definition 1.4 The H_v-semigroup $(H,\cdot)$ is called *h/v-group* if the H/β^* is a group.

Similarly, the *h/v-rings*, h/v-fields, *h/v-vector spaces* etc, are defined.

2 Helix-hopes

Definition 2.1 [2], [4], [5], [6], [7], [12], [13], [14]. Let $A=(a_{ij})\in M_{m\times n}$ be an $m\times n$ matrix and $s,t\in N$, such that $1\le s\le m$, $1\le t\le n$. Define a mod-like map $\underline{st}$ from $M_{m\times n}$ to $M_{s\times t}$ by corresponding to A the matrix $A\underline{st}=(\underline{a}_{ij})$ which has entries the sets

$$\underline{a}_{ij}=\{a_{i+\kappa s,j+\lambda t} \mid 1\le i\le s,\ 1\le j\le t, \text{ and } \kappa,\lambda\in N,\ i+\kappa s\le m,\ j+\lambda t\le n\}.$$

Thus, we have the map

$$\underline{st}: M_{m\times n}\to M_{s\times t}: A\to A\underline{st}=(\underline{a}_{ij}).$$

We call this multivalued map *helix-projection* of type $\underline{st}$. Thus $A\underline{st}$ is a set of $s\times t$-matrices $X=(x_{ij})$ such that $x_{ij}\in\underline{a}_{ij}$, $\forall i,j$. Obviously $A\underline{mn}=A$.

Let $A=(a_{ij})\in M_{m\times n}$ be matrix and $s,t\in N$ with $1\le s\le m$, $1\le t\le n$. Then we can apply helix-projection on columns and then on rows, the result is the same if we apply the helix-projection on both. Thus,

$$(A\underline{sn})\underline{st}=(A\underline{mt})\underline{st}=A\underline{st}.$$

Definitions 2.2 (a) Let $A=(a_{ij})\in M_{m\times n}$ and $B=(b_{ij})\in M_{u\times v}$ be matrices and $s=\min(m,u)$, $t=\min(n,u)$. We define a hope, called *helix-addition* or *helix-sum*, as follows:

$$\oplus: M_{m\times n}\times M_{u\times v}\to P(M_{s\times t}): (A,B)\to A\oplus B=A\underline{st}+B\underline{st}=(\underline{a}_{ij})+(\underline{b}_{ij})\subset M_{s\times t},$$

where

$$(\underline{a}_{ij})+(\underline{b}_{ij})=\{(c_{ij})=(a_{ij}+b_{ij}) \mid a_{ij}\in\underline{a}_{ij} \text{ and } b_{ij}\in\underline{b}_{ij}\}.$$

(b) Let $A=(a_{ij})\in M_{m\times n}$ and $B=(b_{ij})\in M_{u\times v}$ be matrices and $s=\min(n,u)$. We define a hope, called *helix-multiplication* or *helix-product*, as follows:

$$\otimes: M_{m\times n}\times M_{u\times v}\to P(M_{m\times v}): (A,B)\to A\otimes B=A\underline{ms}\cdot B\underline{sv}=(\underline{a}_{ij})\cdot(\underline{b}_{ij})\subset M_{m\times v},$$

where

$$(\underline{a}_{ij})\cdot(\underline{b}_{ij})=\{(c_{ij})=(\sum a_{it}b_{tj}) \mid a_{ij}\in\underline{a}_{ij} \text{ and } b_{ij}\in\underline{b}_{ij}\}.$$

The helix-addition is an external hope since it is defined on different sets and the result is also in different set. The commutativity is valid in the helix-addition. For the helix-multiplication we remark that we have $A\otimes B=A\underline{ms}\cdot B\underline{sv}$ so we have either $A\underline{ms}=A$ or $B\underline{sv}=B$, that means that the helix-projection was applied only in one matrix and only in the rows or in the columns.

Remark that the helix multiplication is weak associative.

Let us restrict ourselves on the matrices $M_{m\times n}$ where $m<n$. Obviously, we have analogous cases where $m>n$ and for $m=n$ we have the classical theory.

Notation: For given $\kappa\in\mathbb{N}$-{0}, we denote by $\underline{\kappa}$ the remainder resulting from its division by m if the remainder is non zero, and $\underline{\kappa}$=m if the remainder is zero.

A matrix $A=(a_{\kappa\lambda})\in M_{m\times n}$, m<n is called a *cut-helix matrix* if we have $a_{\kappa\lambda}=a_{\underline{\kappa}\underline{\lambda}}$, $\forall\kappa,\lambda\in\mathbb{N}$-{0}.

Moreover, denote by $I_c=(c_{\kappa\lambda})$ the *cut-helix unit matrix* which the cut matrix is the unit matrix I_m. Therefore, since $I_m=(\delta_{\kappa\lambda})$, where $\delta_{\kappa\lambda}$ is the Kronecker's delta, we obtain that, $\forall\kappa,\lambda$, we have $c_{\kappa\lambda}=\delta_{\underline{\kappa}\underline{\lambda}}$.

3 Examples on helix-hopes

Example 3.1 Consider the matrices

$$\boldsymbol{A} = \begin{pmatrix} 1 & 2 & 0 & 0 \\ 0 & 1 & 1 & 0 \end{pmatrix} \quad \text{and} \quad \boldsymbol{B} = \begin{pmatrix} 0 & 1 & 2 & 1 \\ 3 & 2 & 1 & 3 \\ 1 & 1 & 2 & 1 \end{pmatrix}$$

then:

$$\boldsymbol{A}\otimes\boldsymbol{B} = \begin{pmatrix} \{0,1\} & 2 & 0 \\ 0 & 1 & 1 \end{pmatrix} \begin{pmatrix} 0 & 1 & 2 & 1 \\ 3 & 2 & 1 & 2 \\ 1 & 1 & 2 & 1 \end{pmatrix} = \begin{pmatrix} 6 & \{4,5\} & \{2,4\} & \{6,7\} \\ 4 & 3 & 3 & 4 \end{pmatrix} =$$

$$= \left\{ \begin{pmatrix} 6 & 4 & 2 & 6 \\ 4 & 3 & 3 & 4 \end{pmatrix}, \begin{pmatrix} 6 & 4 & 2 & 7 \\ 4 & 3 & 3 & 4 \end{pmatrix}, \begin{pmatrix} 6 & 4 & 4 & 6 \\ 4 & 3 & 3 & 4 \end{pmatrix}, \begin{pmatrix} 6 & 4 & 4 & 7 \\ 4 & 3 & 3 & 4 \end{pmatrix}, \begin{pmatrix} 6 & 5 & 2 & 6 \\ 4 & 3 & 3 & 4 \end{pmatrix}, \begin{pmatrix} 6 & 5 & 2 & 7 \\ 4 & 3 & 3 & 4 \end{pmatrix}, \begin{pmatrix} 6 & 5 & 4 & 6 \\ 4 & 3 & 3 & 4 \end{pmatrix}, \begin{pmatrix} 6 & 5 & 4 & 7 \\ 4 & 3 & 3 & 4 \end{pmatrix} \right\}$$

Example 3.2 Consider the matrices

$$\boldsymbol{A} = \begin{pmatrix} -1 & 2 \\ 2 & 0 \\ 3 & 2 \end{pmatrix} \quad \text{and} \quad \boldsymbol{B} = \begin{pmatrix} 1 & 1 \\ -1 & 2 \\ -2 & 1 \\ 0 & 3 \end{pmatrix}$$

then:

$$\boldsymbol{A}\otimes\boldsymbol{B} = \begin{pmatrix} -1 & 2 \\ 2 & 0 \\ 3 & 2 \end{pmatrix} \begin{pmatrix} \{1,-2\} & 1 \\ \{-1,0\} & \{2,3\} \end{pmatrix} = \begin{pmatrix} \{-3,-1,0,2\} & \{3,5\} \\ \{2,-4\} & 2 \\ \{1,3,-8,-6\} & \{7,9\} \end{pmatrix}.$$

There are 128 matrices of type 3×2 in the set!

Example 3.3 A hyper-matrix representation of 4-dimensional non-degenerate case with helix-hope: On the field of real or complex numbers we consider all 3×5 matrices of the type

$$\boldsymbol{A} = \begin{pmatrix} 1 & a & b & 1 & d \\ 0 & 1 & c & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

This set is closed under the helix hope. That means that the helix-hope, (hyper-product) of two such matrices is a 3×5 matrix, of the same type. In fact, we have

$$\boldsymbol{A \otimes A'} = \begin{pmatrix} 1 & a & b & 1 & d \\ 0 & 1 & c & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix} \otimes \begin{pmatrix} 1 & a' & b' & 1 & d' \\ 0 & 1 & c' & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix} =$$

$$= \begin{pmatrix} 1 & \{a,d\} & b \\ 0 & 1 & c \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & a' & b' & 1 & d' \\ 0 & 1 & c' & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix} =$$

$$= \begin{pmatrix} 1 & \{a+a', d+a'\} & \{b+b'+ac', b+b'+dc'\} & 1 & \{a+d', d+d'\} \\ 0 & 1 & c+c' & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

Therefore, the result is asset with 8 matrices.

Example 3.4 The 3×7 matrix

$$\boldsymbol{A} = \begin{pmatrix} -1 & 2 & -3 & -1 & 2 & -3 & -1 \\ 5 & -2 & 3 & 5 & -2 & 3 & 5 \\ -6 & 0 & -1 & -6 & 0 & -1 & -6 \end{pmatrix}$$

is a cut-helix matrix because the 4th and 7th columns are equal to the 1st, the 5th column is equal to the 2nd, and the 6th column is equal to the 3rd. Notice that if we use cut-helix matrices in helix-hopes then the results are simplified because they are singletons.

4 The meaning of the helix-hope

Now let us try to explain the way that helix-hope acts in order to find out whether we could use it in other sciences in similar circumstances.

Let us take a matrix, with entries positive integers, of type 3×5, as the following

$$\boldsymbol{A} = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 \\ 0 & 1 & 6 & 7 & 8 \\ 1 & 0 & 9 & 1 & 0 \end{pmatrix}$$

The usual product of this matrix from the left, with a matrix of the same type, is not defined. The reason is that our matrix must have 3 columns. If we delete the 4th and 5th columns, then we will lose the information contained in the entries of those two columns. Therefore, we can use the helix-hope in order to define the product using all the entries and at the same time we move from operations to hyperoperations, from single valued to multivalued cases. In order to apply the helix-hope we take the entries from the 4th column and shift them to the row corresponding elements of the 1st column.

We do not add those two elements, but we consider them as elements of the same set. Then we take the next column 5 and shift its entries to the corresponding entries of the 2nd column. In the case that we have more columns, we follow the same procedure. Thus, in our example, we take the following matrix where instead of numbers as entries, we have the elements:

$$\boldsymbol{A'} = \begin{pmatrix} \{1,4\} & \{2,5\} & 3 \\ \{0,7\} & \{1,8\} & 6 \\ 1 & 0 & 9 \end{pmatrix}$$

With this form of the matrix the product is defined. The only change is that now we have sets as entries. In this way we have a hyperproduct.

Here we should remark that if the transferred element is the same with the corresponding entry, we do not have a set, but we have an element. In our example, this can be noticed in positions (3,1) and (3,2).

To recap, we claim that the helix-hope replaces some elements and shift them together along with the corresponding elements, treating them in the same way, as elements of a set. This replacement in mathematics is called modulo-like procedure. One can say that this modulo-like procedure reminds us of the 'repetition' in teaching or the 'motivos' in music compositions.

5 Conclusion

When dealing with a great amount of data, any type of information, arranged either in a 'linear' disposal or without any arrangement, grouping or systematization of any kind, we encounter the serious problem of managing all this data so as that once embedded in our minds, then to be accessible, easy to teach or transfer to another person-receiver. The Mathematical Model Helix might give an easily applicable method- solution in cases like that. This difficult to manage amount of data, information or elements to be taught can be placed in a 'helix' way instead of being placed linearly. In this way, every element is present and, most important, every element maintains its independence, appears self-contained and is always easily available. Moreover, especially in the teaching process, the overlapping nature of the Helix-hyperoperation, describes and promotes one of the most important principles of teaching, that of repetition as repeating the encounter fuses it into one's awareness.

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Data of covid-19 infection in Italy and mathematical models (Dati dell'infezione da Covid-19 in Italia e modelli matematici)♣

Luigi Togliani♦

Abstract

In this paper I consider some data of Covid-19 infection in Italy from the 20th of February to the 29th of June 2020. Data are analyzed using some fits based on mathematical models. This analysis may be proposed to students of the last class of the Liceo Scientifico in order to debate a real problem with mathematical tools.
Keywords: Logistic Function, Sigmoid Function, Verhulst, Gompertz, 4PL, Covid-19.

Sunto

In questa nota prendo in esame i dati dei contagiati da Covid-19 in Italia dal 20 febbraio al 29 giugno 2020. I dati vengono analizzati con l'uso di alcuni fit basati su modelli matematici. Questa analisi può essere proposta in un'ultima classe di Liceo Scientifico come esempio di problema reale trattato con strumenti matematici.
Parole chiave: Funzione Logistica, Sigmoide, Verhulst, Gompertz, 4PL, Covid-19.

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1 Premessa

L'emergenza sanitaria da Covid-19 ha portato molti ricercatori ad approfondire lo studio dell'epidemia anche dal punto di vista della Matematica, con lo scopo di aiutare medici, infettivologi e virologi a conoscere meglio la portata di questa calamità e a presentarne possibili scenari futuri. In questa breve nota cerco di presentare alcuni opportuni modelli matematici e un loro possibile utilizzo per trattare il caso in esame in Italia, uno dei paesi maggiormente colpiti dalla pandemia. La modalità di presentazione può fornire spunti didattici per studenti alla conclusione del ciclo di studi di scuola secondaria.

2 Il modello di Verhulst

Pierre François Verhulst (1804-1849), matematico belga docente all'Università di Gand, elaborò nel 1838 un modello demografico statistico per spiegare la dinamica delle popolazioni. Nel suo saggio *Notice sur la loi que la population suit dans son accroissement* egli mette in evidenza la criticità del modello esponenziale di Malthus che prevede una crescita illimitata della popolazione e che non tiene conto della limitatezza delle risorse necessarie per la vita.[1] Più precisamente Verhulst sostituisce l'equazione differenziale di Malthus

$$\frac{dy}{dt} = my$$

che porta ad un modello esponenziale di crescita, con la seguente

$$\frac{dy}{dt} = my - \varphi(y)$$

dove y rappresenta la numerosità della popolazione all'istante t , m una costante positiva (tasso di crescita) e $\varphi(y)$ una funzione di y (Verhulst la chiama *force retardatrice*) che ha il ruolo di mitigare la crescita di y. Tra le infinite possibilità, viene ipotizzato che $\varphi(y)=ny^2$, con n costante positiva. Risolvendo l'equazione differenziale

$$\frac{dy}{dt} = my - ny^2$$

si giunge alla soluzione

[1] Verhulst P. (1838). *Notice sur la loi que la population suit dans son accroissement*, p. 113. Ho lievemente cambiato la simbologia usata da Verhulst: uso y anzichè p per indicare la numerosità della popolazione e y_0 anziché p' per indicare la popolazione iniziale.

$$y = \frac{m y_0 e^{mt}}{m - n y_0 + n y_0 e^{mt}}$$

ove $y_0 = y(0)$ è la popolazione iniziale; ovviamente è necessario che $0 < ny < m$ affinchè la popolazione sia in crescita. Il rapporto *m/n* fornisce il limite superiore della popolazione, cui *y* tende al tendere di *t* all'infinito.

Posto: $k = m/n$, $b = m - n y_0$, $r = m$, con $k,r,b>0$, possiamo riscrivere la precedente equazione nella seguente forma maggiormente conosciuta

$$y = \frac{k e^{rt}}{b + e^{rt}} = \frac{k}{1 + b e^{-rt}} .$$

La funzione è crescente, tra due asintoti orizzontali di equazioni $y=0$ e $y=k$; *k* rappresenta il limite superiore della funzione. Il grafico di *y(t)* è quello di una sigmoide o logistica, che ha senso per $t>0$; la curva presenta un unico flesso nel punto di ascissa $t_1 = \frac{\ln b}{r}$, con $b>1$. Il coefficiente angolare della tangente inflessionale è $y'\left(\frac{\ln b}{r}\right) = \frac{kr}{4}$ e rappresenta la massima rapidità di crescita della popolazione *y*. La funzione raggiunge il suo valore di mezzo *k*/2 per $t_2 = \frac{\ln b}{r}$ (*halfway point*), che coincide col punto di flesso t_1.

Volendo evidenziare t_1, si può riscrivere l'equazione di Verhulst in questa forma:

$$y = \frac{k}{1 + e^{-r(t - t_1)}} \tag{1}$$

Il grafico della funzione di Verhulst è simmetrico rispetto al suo flesso.

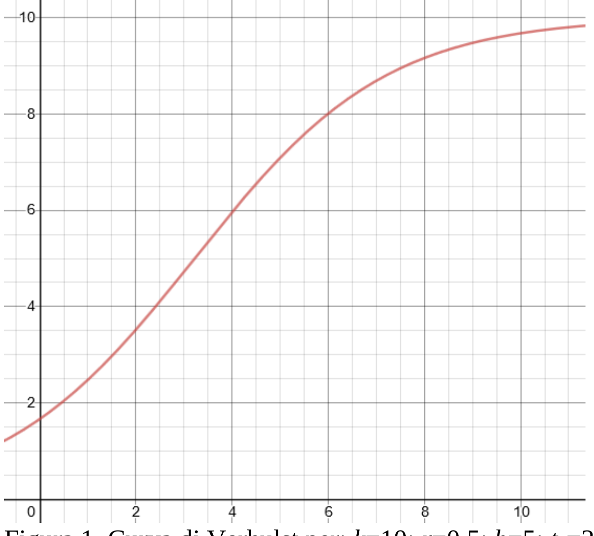

Figura 1. Curva di Verhulst per: $k=10$; $r=0,5$; $b=5$; $t_1=2\ln 5$.

Verhulst applicò la sua teoria alla crescita della popolazione francese dal 1817 al 1831 e delle popolazioni di Belgio, Inghilterra (Contea dell'Essex) e Russia (comunità greca) in periodi analoghi: le tabelle demografiche riportate mostrano la corrispondenza tra i dati statistici e le previsioni del modello adottato.[2] Approfondite osservazioni sullo studio di Verhulst relativamente al Belgio sono state fatte da Nicolas Bacaër.[3]

3 Il modello di Gompertz

Benjamin Gompertz (1779-1865), matematico inglese, si interessò particolarmente di matematica delle assicurazioni. In un suo saggio del 1825 studiò in particolare la mortalità e l'esistenza in vita della popolazione di Northampton dell'epoca.[4]

Dagli studi di Gompertz e da quelli del matematico inglese William Makeham (1826-1891) del 1860[5] si ricava una legge sulla mortalità di una popolazione di numerosità *y* in funzione del tempo *t* (e quindi dell'età) partendo dalla seguente equazione differenziale

$$\frac{dy}{dt} = ry \ln\left(\frac{k}{y}\right)$$

la cui soluzione è data da

$$y = ke^{-be^{-rt}} \tag{2}$$

ove *k* rappresenta il limite superiore (o capacità di carico) della popolazione, *r* il tasso di crescita; inoltre $k,r > 0$ e $b > 1$.[6] Anche la funzione di Gompertz è crescente tra i due asintoti di equazioni $y=0$ e $y=k$ e presenta un unico punto di flesso di ascissa $t_1 = \frac{\ln b}{r}$. Invece, il coefficiente angolare della tangente

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[2] Verhulst P. (1838). *Notice sur la loi que la population suit dans son accroissement*, p. 111-121.
[3] Bacaër N. (2008). *Verhulst et l'équation logistique en dynamique des populations*, p. 1-6.
[4] Gompertz B. (1825*). On the nature of the function expressive of the law of human mortality, and a new mode of determining the value of Life Contingencies*, p. 513-585.
[5] Makeham W. M. (1860). *On the law of mortality and the construction of annuity tables*, p. 301-310.
[6] Ausloos M. (2011). *Gompertz and Verhulst frameworks for growth and decay description*, p. 1-24.

inflessionale è $y'\left(\frac{\ln b}{r}\right)=\frac{kr}{e}$, mentre $y=k/2$ per $t_2=-\frac{\ln(\ln 2/b)}{r}$; risulta $t_2>t_1$, quindi il grafico della funzione di Gompertz si inflette prima di aver raggiunto il suo valore di mezzo $k/2$.

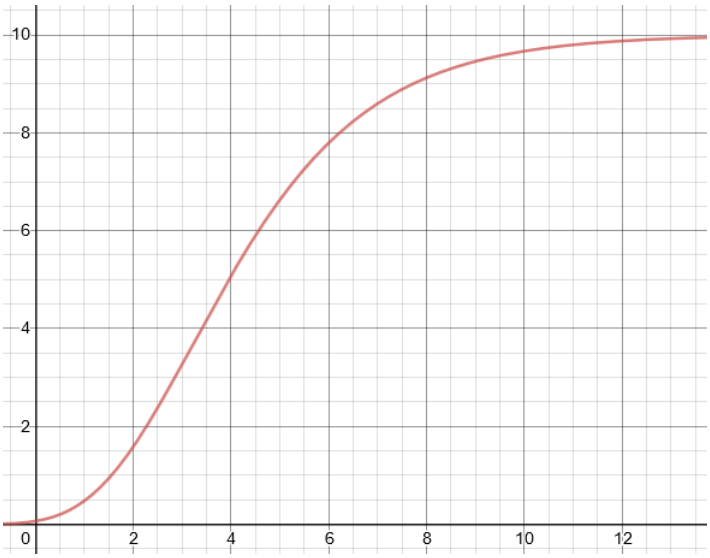


Figura 2. Curva di Gompertz per: k=10; r=0,5; b=5; t_1=2ln5<-2ln(ln2/5)=t_2.

Anche nell'equazione della sigmoide di Gompertz possiamo evidenziare il punto di flesso t_1, ottenendo:

$$y=ke^{-e^{-r(t-t_1)}}$$

4 Il modello 4PL

Il modello 4PL (*four parameters logistic*) è utilizzato per spiegare la diffusione di epidemie, per la crescita di sistemi biologici, per il dosaggio ottimali di farmaci, per applicazioni in agricoltura e veterinaria… Spesso si trova citato e utilizzato anche il più complesso modello 5PL (*five parameters logistic*), sul quale non mi soffermerò per brevità.[7]

Anche il modello 4PL usa una funzione logistica con grafico sigmoidale; in questo caso l'equazione della curva, definita per $t \geq 0$ è data da

[7] Choi, Bong-Jin (2014). *Statistical Analysis, Modeling, and Algorithms for Pharmaceutical and Cancer Systems*. Graduate Theses and Dissertations.

$$y = k + \frac{a-k}{1+\left(\frac{t}{c}\right)^b} \qquad (3)$$

ove *a*, *b*, *c*, *k* sono i 4 parametri della funzione, con *k*,*c*>0 e *b*>1; *k* è il limite superiore e *a* il limite inferiore della funzione, con *k*>*a*. Si tratta di una funzione crescente, con valori compresi tra *a* e *k* e con asintoto orizzontale di equazione *y*=*k* ; presenta un solo punto di flesso $t_1 = c \cdot \left(\frac{b-1}{b+1}\right)^{1/b}$.

La tangente inflessionale ha per coefficiente angolare $y'(t_1) = \frac{b(k-a)\cdot\left(\frac{b-1}{b+1}\right)^{\frac{b-1}{b}}}{\left(\frac{2b}{b+1}\right)^2}$.

La funzione assume il suo valore di mezzo tra *a* e *k* quando $y = \frac{k+a}{2}$, cioè quando $t = t_2 = c$. Anche in questo caso, come per la sigmoide di Gompertz, si dimostra che la curva si inflette prima di aver raggiunto il suo valore di mezzo.

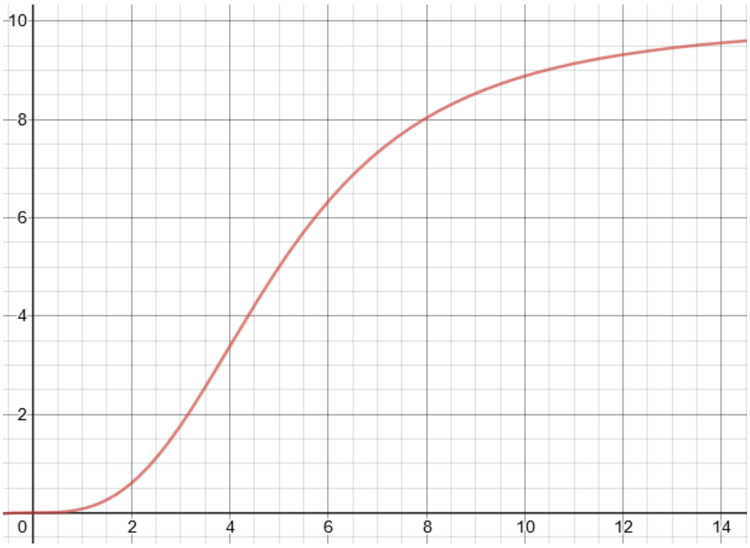


Figura 3. Sigmoide 4PL con: *k*=10; *a*=0; *c*=5; *b*=3.

5 Dati sull'epidemia da Covid-19 in Italia

La terribile pandemia da Covid-19 (SARS-CoV-2) che ha colpito il mondo nel 2020 ha avuto in Italia uno dei teatri più drammatici. A partire dal 20 febbraio 2020 la Protezione Civile ha informato la popolazione sull'andamento epidemico; in particolare vengono forniti quotidianamente i dati di: contagiati (casi totali), morti, guariti (dimessi), attualmente positivi. [8] Sussiste la seguente relazione:

$$\text{contagiati} = \text{morti} + \text{guariti} + \text{positivi} \tag{4}$$

Non entro nel dibattito sulle cause o sulle conseguenze di questa pandemia, né sui provvedimenti presi dalle autorità competenti, né sul comportamento delle popolazioni umane coinvolte, né sugli aspetti di carattere medico, psicologico, economico o sociale. Mi limito a considerare i dati ufficiali italiani nel periodo che va dal 20 febbraio al 29 giugno 2020 e a trattarli con l'uso dei tre modelli matematici presi in considerazione nei paragrafi precedenti.

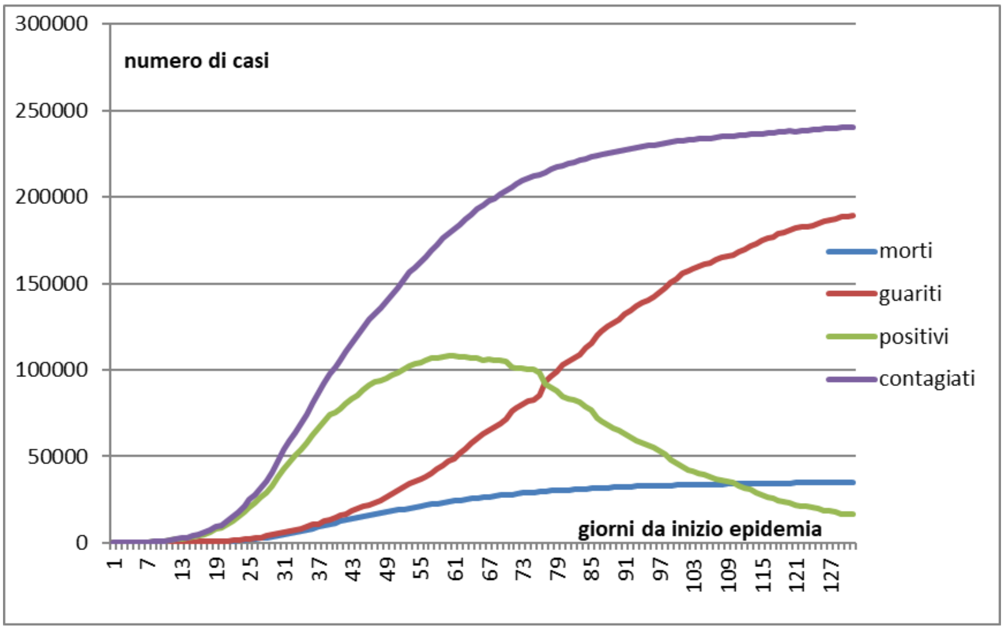


Figura 4. Contagiati, morti, guariti e positivi nell'epidemia Covid-19 in Italia dal 20/02/2020 al 29/06/2020.

[8] Questi e molti altri dati su Covid-19 in Italia e nel mondo sono rintracciabili sul sito ufficiale del Sole 24 Ore in https://lab24.ilsole24ore.com/coronavirus/

Come appare dalla figura 4, la curva dei contagiati ha l'andamento di una sigmoide; lo stesso si può pensare per la curva dei morti e per quella dei guariti. Completamente diverso l'andamento dei positivi, che presenta il suo massimo assoluto di 108˙257 casi al 60-esimo giorno (19 aprile) da inizio epidemia, per poi ridursi gradualmente nel tempo in modo non simmetrico: la crescita del numero dei casi è stata più rapida della decrescita. Tutti i grafici hanno iniziato con crescita di tipo esponenziale, per poi smorzarsi raggiungendo un punto di flesso. Se l'andamento dell'epidemia non subirà involuzioni, la curva dei positivi tenderà a 0 e le altre tre tenderanno a valori asintotici che comunque rispetteranno l'equazione (4).

È di interesse lo studio dei dati ufficiali giornalieri: essi ci dicono che il massimo dei contagiati (casi totali) in un giorno è avvenuto il 21 marzo (31-esimo giorno da inizio epidemia), con 6557 casi. Nella stessa data si è avuto il massimo dei positivi registrati in un giorno, con 4821 casi. Il 27 marzo è stato il giorno col maggior numero di morti, con 969 casi. Per i guariti o dimessi il picco giornaliero è stato registrato molto più tardi, il 6 maggio, con 8014 casi.

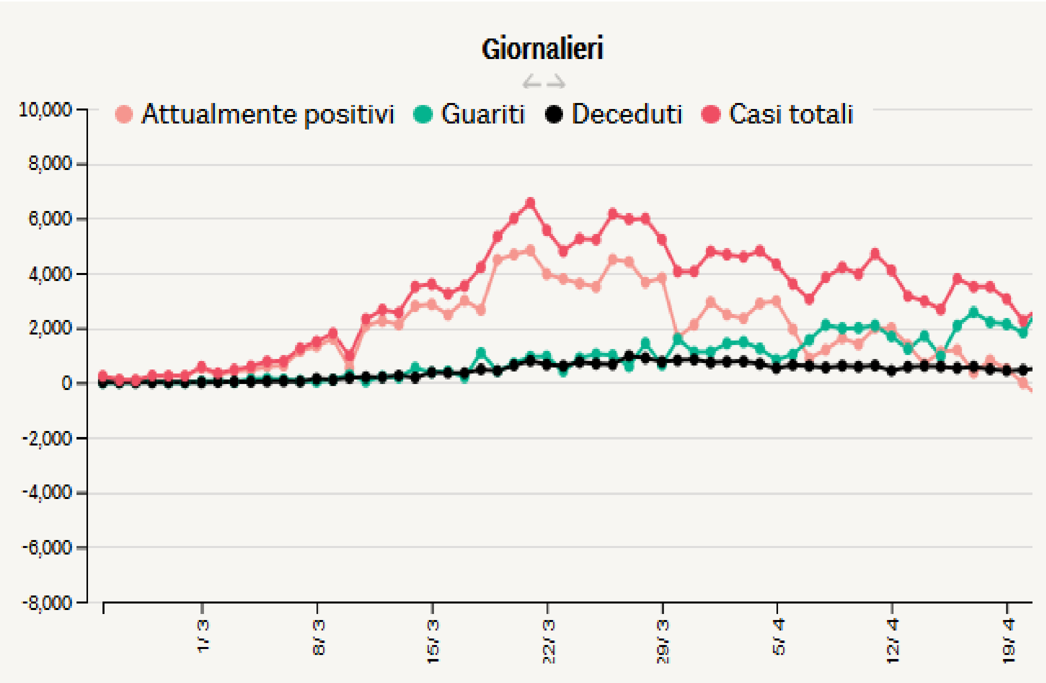


Figura 5a. Dati giornalieri Covid-19 in Italia da inizio epidemia al 20/6/2020 (Lab Sole 24 Ore).

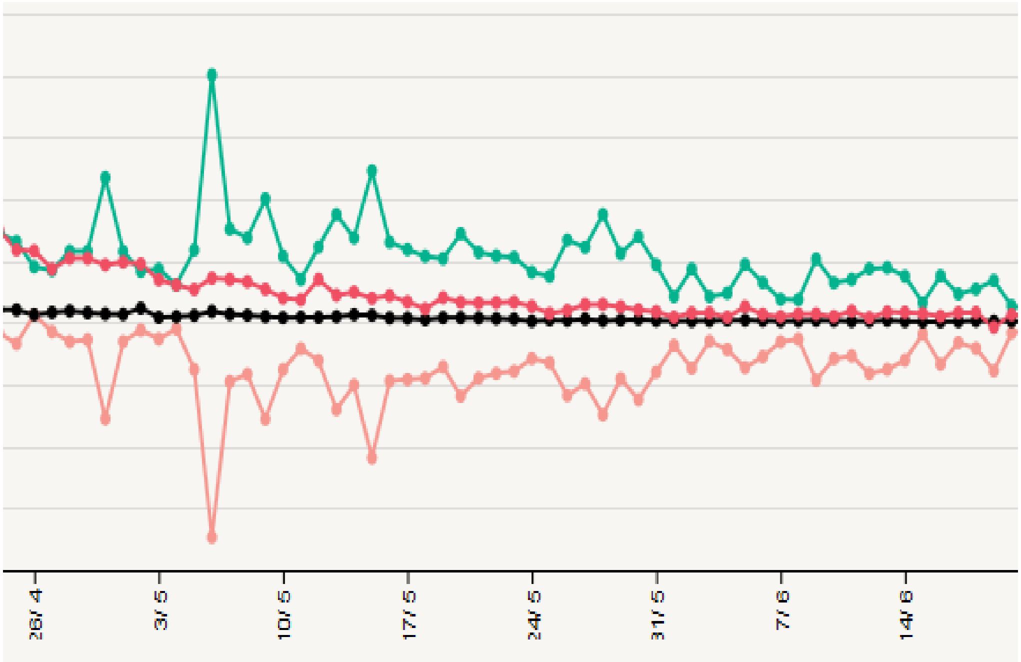


Figura 5b. Dati giornalieri Covid-19 in Italia da inizio epidemia al 20/6/2020 (Lab Sole 24 Ore).

6 Modelli matematici per dati relativi a Covid-19

Considero i dati dei contagiati, rappresentati in figura 4. Utilizzando la app MyCurveFit ho ottenuto per interpolazione il grafico dei dati forniti dalla Protezione Civile usando il modello 4PL, unico disponibile tra i tre sopra trattati. Per fare questo occorre inserire nella tabella della *home page* di MyCurveFit i dati dei giorni (asse x) e del corrispondente numero di contagiati (asse y); poi in Fit Method si seleziona Nonlinear e 4PL (vedi figura 6).[9]

[9] https://mycurvefit.com/ Nella versione *free* è consentito l'impiego di non più di 20 dati.

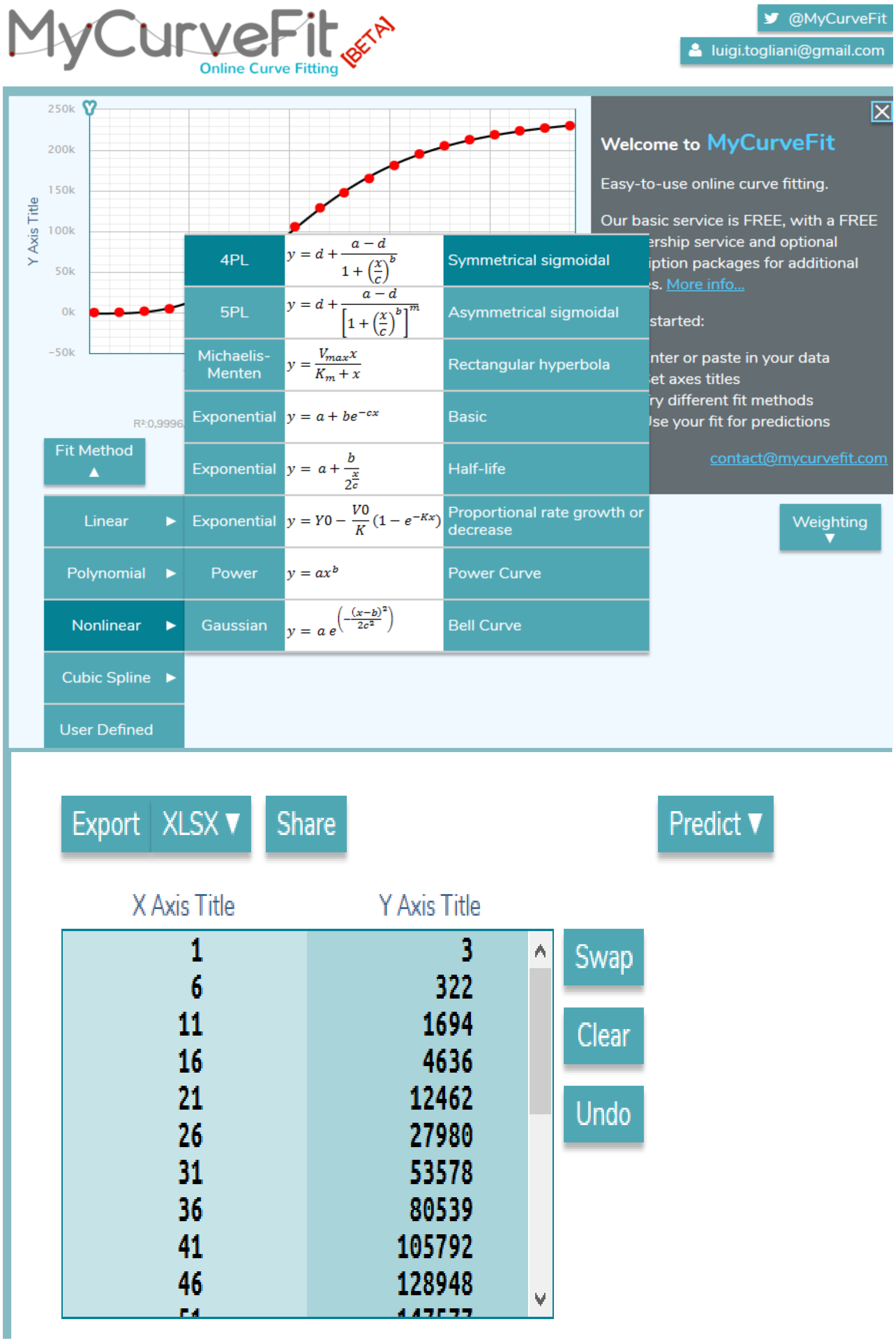


Figura 6. Uso di MyCurveFit per i dati dei contagiati da Covid-19 dal 20/02 al 25/05 (https://mycurvefit.com/).

Il programma fornisce anche i valori dei parametri che figurano nel modello matematico utilizzato. Nel caso in esame, prendendo solo un dato ogni 5 giorni e limitandosi ai primi 20 dati (cioè al periodo che va dal 20 febbraio al 25 maggio 2020, per un totale di 96 giorni), si ottengono i valori statistici e quelli dei parametri *a*, *b*, *c*, *d*=*k* riportati in figura 7.

Goodness Measures What's this?		
R^2		0,9996
aR^2		0,9995
P		0
SE		1926
F		10420
AIC		8
BIC		11,98
DoF		16
AICc		10,67
Coefficients		
a	−1298,299	± 1033
b	3,446156	± 0,08154
c	44,98021	± 0,3398
d	247420,1	± 2270
Equation		
$y = 247420{,}1 + (-1298{,}299 - 247420{,}1)/(1 + (x/44{,}98021)^{3{,}446156})$		

Figura 7. Analisi statistica e parametri del modello 4PL per i contagi da Covid-19 (https://mycurvefit.com/).

Il valore che maggiormente interessa è quello del parametro *d*=*k*=247˙420 che rappresenterebbe il limite superiore (o asintotico) cui tende il numero *y* dei contagiati quando il numero *t* dei giorni è molto elevato. Ho utilizzato questo valore di *k* anche nei modelli di Verhulst e di Gompertz; ho poi cercato di adattare al meglio i valori degli altri due parametri di ciascuno di questi due modelli. Il risultato è riportato nella tabella e nel grafico Excel di figura 8, da me ottenuti per il periodo che va dal 20 febbraio al 29 giugno 2020.

data	*giorni*	*contagiati*	*sigmoide 4PL*	*sigmoide Verhulst*	*sigmoide Gompertz*
20-feb	**1**	**3**	**-1298**	**15581**	**345**
25-feb	**6**	**322**	**-1058**	**20579**	**1402**
01-mar	**11**	**1694**	**627**	**26993**	**4227**
06-mar	**16**	**4636**	**5566**	**35097**	**10073**
11-mar	**21**	**12462**	**15503**	**45136**	**19944**
16-mar	**26**	**27980**	**31375**	**57272**	**34132**
21-mar	**31**	**53578**	**52693**	**71517**	**52086**
26-mar	**36**	**80539**	**77552**	**87672**	**72630**
31-mar	**41**	**105792**	**103375**	**105291**	**94340**
05-apr	**46**	**128948**	**127862**	**123710**	**115890**
10-apr	**51**	**147577**	**149563**	**142129**	**136247**
15-apr	**56**	**165155**	**167905**	**159748**	**154744**
20-apr	**61**	**181228**	**182940**	**175903**	**171042**
25-apr	**66**	**195351**	**195042**	**190148**	**185060**
30-apr	**71**	**205463**	**204694**	**202284**	**196890**
05-mag	**76**	**213013**	**212367**	**212323**	**206725**
10-mag	**81**	**219070**	**218473**	**220427**	**214805**
15-mag	**86**	**223885**	**223349**	**226841**	**221383**
20-mag	**91**	**227364**	**227264**	**231839**	**226698**
25-mag	**96**	**230158**	**230425**	**235686**	**230969**
30-mag	**101**	**232664**	**232995**	**238619**	**234385**
04-giu	**106**	**234013**	**235098**	**240839**	**237107**
09-giu	**111**	**235561**	**236830**	**242511**	**239271**
14-giu	**116**	**236989**	**238267**	**243765**	**240987**
19-giu	**121**	**238011**	**239466**	**244702**	**242345**
24-giu	**126**	**239410**	**240473**	**245400**	**243419**
29-giu	**131**	**240436**	**241324**	**245921**	**244267**

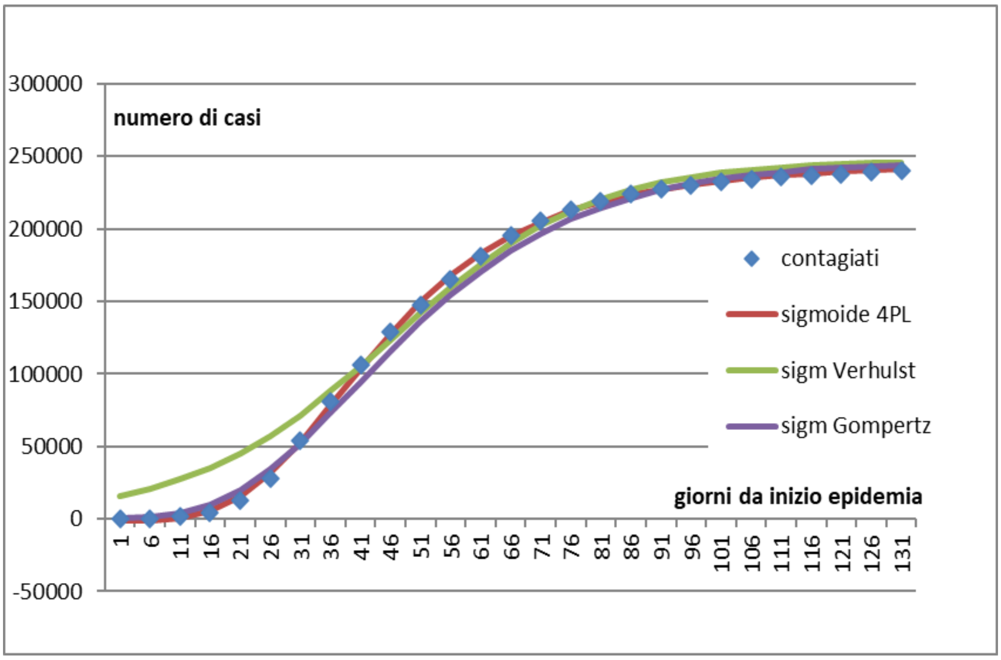


Figura 8. Numero di contagiati e sigmoidi per Covid-19 dal 20/02 a 29/06/2020.

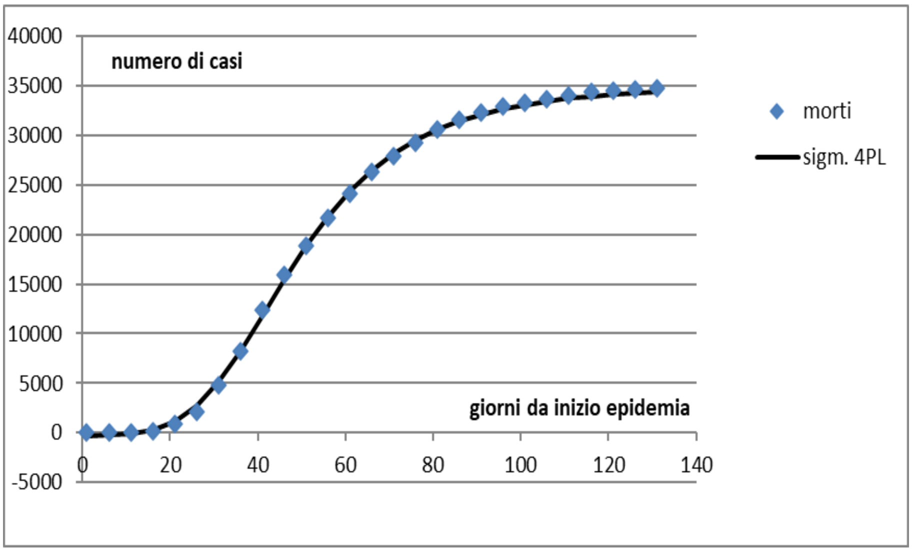
Dalle elaborazioni fatte risulta che la sigmoide 4PL rappresenta bene un po' tutti i dati sperimentali. La curva di Gompertz sembra andare meglio nella parte iniziale e in quella terminale del periodo considerato, mentre quella di Verhulst funziona bene nelle parti centrale e finale dello stesso periodo, ma si scosta molto dai dati registrati dall'inizio dell'epidemia fino a circa il 21 marzo.

Per quanto riguarda il punto di flesso t_1 si può dire che, utilizzando il modello di Verhulst con equazione (1), risulta $t_1 \approx 46$ giorni; mentre il modello di Gompertz con equazione (2) porta a $t_1 = \ln b / r \approx \ln 6{,}9/0{,}048 \approx 40$ giorni. Infine il modello 4PL di equazione (3) fornisce

$$t_1 = c \cdot \left(\frac{b-1}{b+1}\right)^{1/b} \approx 44{,}98 \cdot \left(\frac{3{,}446-1}{3{,}446+1}\right)^{1/3{,}446} \approx 38\,\text{giorni.}$$

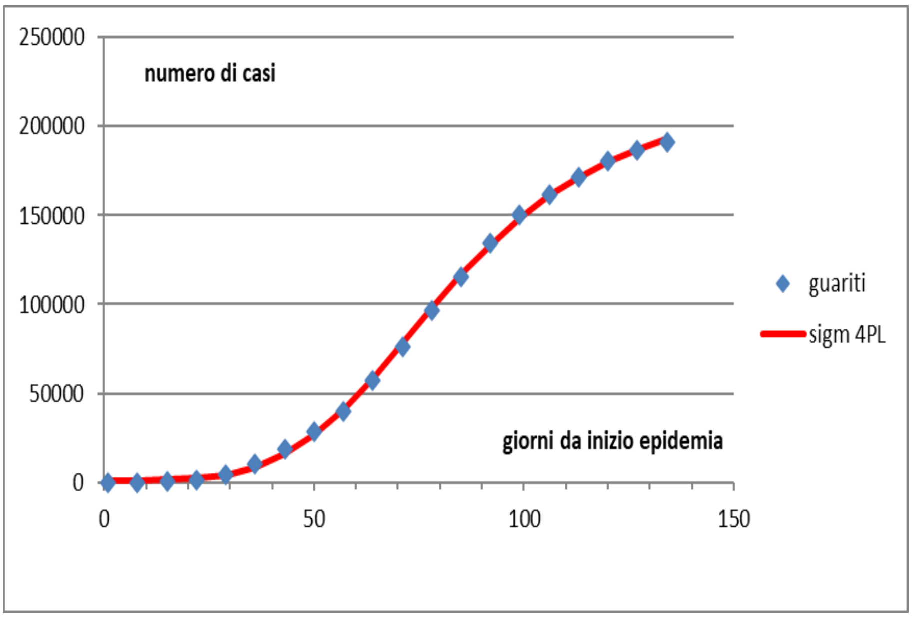
Quindi il punto di flesso dell'epidemia dovrebbe collocarsi tra il 28 marzo e il 5 aprile. Dopo questo intervallo, la crescita dei contagiati avrebbe dovuto rallentare, come confermano i dati giornalieri di figura 5.

È possibile ripetere l'analisi dei dati fatta per i contagiati anche con i dati dei morti e dei guariti di fig. 4. Per brevità mi limito a fornire i grafici relativi a questi due casi, utilizzando per ciascuno solo il modello di sigmoide 4PL, con i calcoli e con l'equazione forniti da MyCurveFit.



y = 35338,43 + (-281,8952 - 35338,43)/(1 + (x/49,0531)^3,74079)

Figura 9. Numero di morti e sigmoide 4PL per Covid-19 dal 20/02 a 29/06/2020.



y = 220837,7 + (1022,859 – 220837,7)/(1 + (x/82,96015)^4,005968)

Figura 10. Numero di guariti e sigmoide 4PL per Covid-19 dal 20/02 a 29/06/2020.

Dal confronto dei dati presenti nelle equazioni delle figure 7, 9 e 10 si evince che, secondo le stime del modello 4PL ottenute con MyCurveFit, il limite superiore (valore asintotico) dei contagiati è 247˙420, quello dei morti è 35˙338 e quello dei guariti è 220˙838. Anche se ammettiamo che al limite il numero dei positivi sia nullo, non viene rispettata l'equazione (4), ma non di molto: 35˙338+220˙838=256˙176 differisce da 247˙420 per meno di 9˙000 casi; ossia lo scostamento percentuale tra il numero atteso dei contagiati e il valore ottenuto sommando i numeri attesi dei morti e dei guariti è del 3,5%.

7 Conclusioni

Il lavoro proposto mostra come, con l'ausilio di semplici strumenti informatici gratuiti, sia possibile analizzare alcuni dati di una situazione reale come quella del Covid-19 e ottenere anche qualche proiezione per il prossimo futuro. L'analisi teorica dei modelli qui considerati, fatta con le competenze di Analisi matematica possedute da studenti dell'ultimo anno di Liceo Scientifico, si armonizza con i dati sperimentali e con l'uso di semplici elementi di Statistica. Ovviamente si potrebbe estendere l'analisi ad altri dati della pandemia, come quello dei ricoverati in ospedale, oppure a considerazioni su altri stati europei o extraeuropei. In ogni caso i modelli matematici possono agevolare la nostra comprensione del fenomeno che stiamo vivendo e possono anche aiutarci ad affrontarlo nel migliore dei modi.[10]

[10] Si vedano, a questo proposito, gli articoli disponibili in rete dei ricercatori Fiorentini, Malato, De Maria, Scarpa e Tonelli citati ai numeri [8], [9] , [10], [11] in Bibliografia.

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A logical framework for democratic decision-making: epistemic logic and liquid democracy

Simone Cuconato[♦]

Abstract
Since Hintikka's epistemic logic, the logic of knowledge, has been a subject of research in philosophy, computer science, artificial intelligence and game theory. This paper presents a framework of dynamic epistemic logic capable of investigating interactive voting decisions in liquid democracy.
Keywords: epistemic logic, applied logic to social and economic sciences, liquid democracy, multiagent systems, game theory.

Sunto
Dalla logica epistemica di Hintikka, la logica della conoscenza, è stata oggetto di ricerca in filosofia, informatica, intelligenza artificiale e teoria dei giochi. Questo articolo presenta un *framework* di logica epistemica dinamica in grado di indagare le decisioni interattive di voto in democrazia liquida.
Parole chiave: logica epistemica, logica applicata alle scienze economiche e sociali, democrazia liquida, sistemi multi-agente, teoria dei giochi.

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1. Introduzione

La creazione di modelli logico-matematici delle capacità deduttive degli agenti razionali è da alcuni decenni percepita come un problema urgente nell'ambito della teoria della decisione. La teoria della decisione si occupa del ragionamento alla base delle scelte di un agente, sia che si tratti di una scelta banale tra l'ordinare una pizza o un hamburger per cena, sia che si tratti di una scelta più delicata sull'opportunità di intraprendere una carriera lavorativa particolarmente impegnativa. Secondo una visione standard, la teoria della decisione si divide in tre rami principali [6]: la teoria delle decisioni individuali (o semplicemente teoria delle decisioni), la teoria delle decisioni interattive (nota anche come teoria dei giochi) e la teoria della scelta sociale. Nonostante siano presenti delle significative sovrapposizioni, la tripartizione è fondata su una *condizione di razionalità* (*cr*) ed è radicata in tre domande distinte, rispettivamente:

> (*cr*): ciò che un agente sceglie di fare in una data occasione è completamente determinato dalle sue convinzioni, desideri o valori e le linee d'azione alternative a sua disposizione hanno una conseguenzialità incerta.
> (1) quali sono i vincoli di "razionalità" da imporre a un individuo?
> (2) qual è una soluzione "razionale" a un'interazione tra agenti?
> (3) come aggregare le preferenze "razionali" individuali in una collettività che esprime la preferenza della società nel suo insieme?

I criteri che definiscono la razionalità di una decisione sono fortemente radicati nel paradigma della razionalità come coerenza che unisce i fondamenti della teoria della decisione e della teoria della probabilità a quelli della logica. Il rapporta fra la logica e la teoria della razionalità economica e sociale ha prodotto, a partire dallo scorso secolo, una notevole mole di ricerca interdisciplinare su almeno cinque problemi fondamentali [3]: il *paradosso di Condorcet*; il *problema del dilemma discorsivo*; il *problema dell'onniscienza logica*; l'applicazione della logica alla teoria dei giochi e la formalizzazione del concetto di "conoscenza condivisa".

Il seguente articolo elabora un *framework* logico in grado di analizzare il metodo di voto noto come *liquid democracy.* La democrazia liquida [1] è una forma di processo decisionale di gruppo in cui gli elettori possono votare direttamente o delegare il proprio voto ad altri elettori. Una delle ragioni del successo della democrazia liquida è il fatto di essere vista come un compromesso pratico tra democrazia diretta e democrazia rappresentativa. È stata utilizzata e resa popolare da campagne per le riforme democratiche (ad esempio *Make Your Laws* negli Stati Uniti) e da partiti politici (come *Demoex* in Svezia e *Piratenpartei* in Germania) per coordinare il comportamento dei rappresentanti del partito nelle assemblee locali e nazionali. In *liquid democracy*, per ogni *evento* presentato da votare, ogni agente può esprimere il proprio voto oppure può delegare il proprio voto a un altro agente, un delegato, e quell'agente, a sua volta, può delegare a un altro agente e così via. Questo differenzia la democrazia liquida dal voto per *delega standard* [9], in cui i delegati non possono delegare ulteriormente il proprio voto (figura 1).

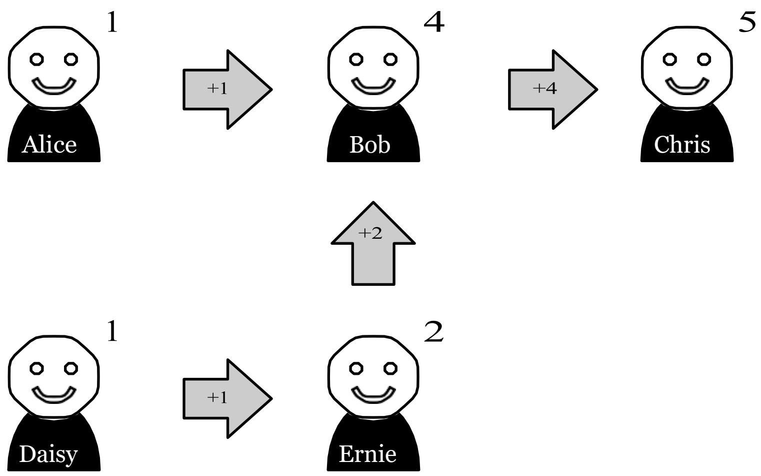

Figura 1: Esempio di delega transitiva: Alice delega a Bob, Daisy delega a Ernie, Ernie delega il suo voto a Bob, che delega tutti i voti di Alice, Daisy e Ernie insieme al suo voto a Chris, che ottiene un potenziale peso di 5 voti[1].

Grazie all'introduzione di due nuovi predicati "vota" e "delega" e alle nozioni di "struttura dinamica", "scenario epistemico", "condizione epistemica", "rete sociale" e "propagazione di opinione", sarà presentato un *framework* logico innovativo in grado di indagare le decisioni interattive di voto nei sistemi multi-agente in democrazia liquida [2].

2. Logica epistemica: sintassi e semantica

Sintassi. La logica epistemica [4, 5, 7, 10, 11, 12] è una estensione della logica classica che ha come oggetto di studio gli enunciati di credenza e di sapere. Esaminiamo il linguaggio logico del primo ordine $\mathcal{L}$. L'*alfabeto* di $\mathcal{L}$ è composto dai seguenti insiemi di simboli:

[1] Immagine tratta da [1].

- lettere proposizionali: $p_1, p_2, p_3, \ldots$
- variabili individuali: $x, y, z, \ldots$
- costanti individuali: 1,2,3, ...
- costanti predicative: P_k^n
- connettivi vero-funzionali: $\neg,\ \wedge,\ \vee,\ \rightarrow, \leftrightarrow$
- operatori modali: $\square$, $\Diamond$
- operatori epistemici: B, K
- quantificatori esistenziali: $\forall, \exists$
- parentesi: (,)

L'*insieme delle formule* φ di $\mathcal{L}$ è definito come segue:

$$\varphi ::= p|\neg p|(\varphi \wedge \varphi)|(\varphi \vee \varphi)|\square\varphi|K_i\varphi|B_i\varphi$$ [1]

Semantica. Le formule associate agli operatori modali ed epistemici verranno valutate vere o false in relazione ad un particolare modello epistemico $\mathcal{M}$. Nello specifico il modello sarà $\mathcal{M} = \langle$W,$\mathrm{R}_{K_{1-n}}$, $\mathrm{R}_{B_{1-n}}$,I$\rangle$[2], dove W sta per un insieme non vuoto di *mondi possibili*, R_K e R_B[3] per una relazione binaria in W e I per la funzione che, dato un mondo $w \in$ W, associa uno e un solo valore di verità (T o F) ad ogni formula atomica di $\mathcal{L}$. Chiameremo la tripla ordinata $\langle$W, $\mathrm{R}_K, \mathrm{R}_B\rangle$ *frame epistemico*.

Definiamo la *verità di una formula nel mondo w del modello $\mathcal{M}$* attraverso le seguenti clausole:

- $\mathcal{M}, w \vDash p$ iff $w \in \mathrm{I}(p)$
- $\mathcal{M}, w \vDash \neg p$ iff $w \notin \mathrm{I}(p)$
- $\mathcal{M}, w \vDash (\varphi_1 \wedge \varphi_2)$ iff $\mathcal{M}, w \vDash \varphi_1$and $\mathcal{M}, w \vDash \varphi_2$
- $\mathcal{M}, w \vDash (\varphi_1 \vee \varphi_2)$ iff $\mathcal{M}, w \vDash \varphi_1$or $\mathcal{M}, w \vDash \varphi_2$
- $\mathcal{M}, w \vDash \square\varphi$ iff $(om\ w')(w\mathrm{R}w'$then $\mathcal{M}, w' \vDash \varphi)$[4]
- $\mathcal{M}, w \vDash K_i\varphi$ iff $(om\ w')(w\mathrm{R}_K w'$then $\mathcal{M}, w' \vDash \varphi)$
- $\mathcal{M}, w \vDash B_i\varphi$ iff $(om\ w')(w\mathrm{R}_B w'$then $\mathcal{M}, w' \vDash \varphi)$

[1] In dettaglio, data una formula φ, $K_i\varphi$ sta per «L'agente cognitivo i sa che φ», mentre $B_i\varphi$ sta per «L'agente cognitivo i crede che φ».
[2] Poiché la credenza è una condizione necessaria perché si abbia conoscenza, assumeremo che R_K sia un sottoinsieme di R_B:$\mathrm{R}_K \subseteq \mathrm{R}_B$.
[3] In generale, la relazione di accessibilità R nei calcoli modali è così definita: R è $seriale$ iff $(om\ w)(ex\ w')(wRw')$; R è $riflessiva$ iff $(om\ w)(wRw)$; R è $simmetrica$ iff $(om\ w)(om\ w')(wRw'$ iff $wRw')$;
R è $transitiva$ iff $(om\ w)(om\ w')(om\ w'')(wRw'$ and $w'Rw''$then $wRw'')$.
[4] $\mathcal{M}, w \vDash\Diamond\ \varphi$ iff $(ex\ w')(w\mathrm{R}w'$and $\mathcal{M}, w' \vDash \varphi)$.

3. Costruzione del *framework*

Sintassi. Per trattare in modo adeguato il concetto di democrazia liquida estendiamo il linguaggio $\mathcal{L}$ per ottenere un linguaggio $\mathcal{L}^+$. L'*alfabeto* di $\mathcal{L}^+$ contiene due nuovi predicati a due posti:

- $\mathcal{V}$, da leggersi "vota"
- $\mathcal{D}$, da leggersi "delega"

L'*insieme delle formule* ψ di $\mathcal{L}^+$ è definito come segue:

$$\psi ::= \Gamma_i^{K \oplus B} p_{w_i} \big| \neg\psi | (\psi \wedge \psi) | \psi \vee \psi$$

Dove $\Gamma_i^{K \oplus B} p_{w_i}$ indica che «L'agente cognitivo i sa (K) o crede (B) p_{w_i}», con p_{w_i} avente la seguente forma:

$$p_{w_i} =_{df} \mathcal{V}_{i \oplus j}^{yes \oplus no} \text{ oppure } \mathcal{D}_{i \oplus j}^{l}$$

Con $\mathcal{V}_{i \oplus j}^{yes \oplus no}$ intendiamo che i o j $vota\ yes$ o no, mentre con $\mathcal{D}_{i \oplus j}^{l}$ intendiamo che i o j $delega$ il voto a l. Di conseguenza, in $\mathcal{L}^+$ l'insieme delle formule ψ è sempre costituito da *formule epistemiche*.
Specifichiamo inoltre l'irriflessività di $\mathcal{D}$:

- $\mathcal{D}$ è irriflessiva iff not $\mathcal{D}_i^i$.

Semantica. Il modello per $\mathcal{L}^+$ è sempre $\mathcal{M} = \langle$W,R$_{K_{1-n}}$, R$_{B_{1-n}}$,I$\rangle$. Naturalmente, in questo caso l'interpretazione I associa uno dei due valori di verità (T/F) come segue:

- $K_i(\mathcal{V}_{i \oplus j}^{yes \oplus no}) = \text{T/F}$
- $B_i(\mathcal{V}_{i \oplus j}^{yes \oplus no}) = \text{T/F}$
- $K_i(\mathcal{D}_{i \oplus j}^{l}) = \text{T/F}$
- $B_i(\mathcal{D}_{i \oplus j}^{l}) = \text{T/F}$

Definiamo la *verità di una formula nel mondo w del modello* $\mathcal{M}$ attraverso le seguenti clausole:

- $\mathcal{M}, w \vDash \Gamma_i^{K \oplus B} P_{w_i}$ iff $K_i(\mathcal{V}_{i \oplus j}^{yes \oplus no})$ or $B_i(\mathcal{V}_{i \oplus j}^{yes \oplus no})$ or $K_i(\mathcal{D}_{i \oplus j}^{l})$ or $B_i(\mathcal{D}_{i \oplus j}^{l})$
- $\mathcal{M}, w \vDash \neg\psi$ iff $\mathcal{M}, w \nvDash \psi$
- $\mathcal{M}, w \vDash (\psi_1 \wedge \psi_2)$ iff $\mathcal{M}, w \vDash \psi_1$and $\mathcal{M}, w \vDash \psi_2$
- $\mathcal{M}, w \vDash (\psi_1 \vee \psi_2)$ iff $\mathcal{M}, w \vDash \psi_1$or $\mathcal{M}, w \vDash \psi_2$

Struttura. Consideriamo la seguente struttura $\mathcal{S} = \langle A, W, P_{w_i}, S, R \rangle$, dove:

- $A = \{1,2,3, \dots\}$ è un insieme non vuoto di agenti;
- $W = \{w_1, \dots, w_m\}$ è un insieme non vuoto di mondi epistemici ($|W| = m \in \mathbb{N}$);
- $P_{w_i} = \left\{p!, p_{1_{w_i}}, \dots, p_{m_{w_i}}\right\}$ è un insieme non vuoto di proposizioni $\left(\left|P_{w_i}\right| = i \in \mathbb{N}\right)$;
- $S_{w_i} = \left\{s_{1_{w_i}}, \dots, s_{m_{w_i}}\right\}$ è un insieme di scenari epistemici $\left(S_{w_i} \in P_{w_1} \text{ and } \left|S_{w_i}\right| = |A|\right)$;
- $R_{w_i} = \left\{r^1_{1_{w_i}}, \dots, r^n_{m_{w_i}}\right\}$ è un insieme di reti sociali $\left(\left|R_{w_i}\right| = \left|S_{w_i}\right|\right)$

$\mathcal{S}$ è una struttura dinamica, una struttura nella quale si verificano *mondi possibili epistemici* W. In ciascun mondo epistemico ogni agente: *i*) possiede uno *scenario epistemico* S, ossia una serie di *credenze dinamiche* su sé stesso e sugli altri agenti; *ii*) non eredita le credenze errate nel primo mondo, tuttavia, ciò non vuol dire che gli agenti non possano avere nuove credenze; e *iii*) appartiene ad una *rete sociale*, un gruppo di agenti connessi tra loro da legami conoscitivi, e la rete non è ereditaria di mondo in mondo. Naturalmente, l'operatori epistemico *dinamico* è B, mentre l'operatore del sapere K è un operatore *statico*. A è l'insieme degli agenti della struttura, mentre P_{w_1} è l'insieme delle proposizioni epistemiche *iniziali* possedute da ciascun individuo appartenente ad A. Nello specifico, ogni agente ha delle *conoscenze di base* $p!$ e delle credenze o conoscenze precise su sé stesso e gli altri agenti $p_{i_{w_i}}$. Mentre $p_{i_{w_i}}$ sappiamo già essere uguale per definizione a $\mathcal{V}^{yes \oplus no}_{i \oplus j}$ oppure $\mathcal{D}^{l}_{i \oplus j}$, al contrario per $p!$ intendiamo:

$$p! =_{df} \bigwedge\nolimits_{i \in A} K_i(\Sigma)$$

Ogni individuo i che appartiene ad A conosce la *condizione epistemica* Σ. Dove a sua volta per Σ intendiamo quattro *sottocondizioni* $\alpha, \beta, \gamma, \delta$:

- α: in $\mathcal{S}$ si ha una *maggioranza assoluta* quando il voto *yes* o il voto *no* prende il $50\% + 1$ di voti;
- β: se non si verifica in w_1 una maggioranza assoluta si passerà ad un mondo epistemico successivo w_2 ed eventualmente a w_3, w_4, ecc.;
- γ: ogni qual volta si effettua il passaggio ad un mondo epistemico successivo si verifica una situazione che chiameremo "*propagazione di opinione*". Per propagazione di opinione intendiamo il fatto che ogni agente all'interno della struttura può modificare il proprio voto *iff* la credenza relativa al voto appena dato è diversa da quella della

maggioranza relativa degli agenti appartenenti alla propria rete sociale. Formalmente:

- $B_i(\mathcal{V}_i^{yes})_{yes}^{no}$;
- $B_i(\mathcal{V}_i^{no})_{no}^{yes}$;
- $B_i(\mathcal{D}_i^{j})_{j}^{l}$

- δ: indicheremo il passaggio da credenza a conoscenza come segue:

$$[\uparrow_B]K_i(\mathcal{V}_{i\oplus j}^{yes\oplus no}) =_{df} \text{da } B_i(\mathcal{V}_{i\oplus j}^{yes\oplus no}) \text{ a } K_i(\mathcal{V}_{i\oplus j}^{yes\oplus no})$$

dove il cambiamento da credenza a conoscenza $[\uparrow_B]K_i$ può verificarsi *iff* almeno il 75% degli agenti appartenenti alla stessa rete sociale sa di votare *yes* o *no*. Formalmente la $verit$à di $[\uparrow_B]K_i(\mathcal{V}_{i\oplus j}^{yes\oplus no})$ $nel\ mondo\ w\ del\ modello\ \mathcal{M}$ sarà:

$\mathcal{M}, w \vDash [\uparrow_B]K_i(\mathcal{V}_{i\oplus j}^{yes\oplus no})$ iff $\forall i$
$\wedge\ (om\ w^*)\left(i \in A \text{ and } w\mathrm{R}_K w^* \text{then } \mathcal{M}, w^* \vDash (\mathcal{V}_{i\oplus j}^{yes\oplus no})\right)$

Inoltre, indicheremo con:

- $[\uparrow_B]K_i(\mathcal{V}_{i\oplus j}^{yes})_{yes}^{no}$;
- $[\uparrow_B]K_i(\mathcal{V}_{i\oplus j}^{no})_{no}^{yes}$

il passaggio da credenza a conoscenza e il relativo cambiamento di opinione da parte di un agente di A.

Posta la condizione epistemica Σ possiamo ora definire l'*operatore di transizione di opinione* μ:

Definizione 1 (operatore di transizione di opinione) Data una struttura $\mathcal{S}$ e una proposizione $p_{i_{w_i}} \in P_{w_i}$, l'operatore di transizione di opinione μ definirà la transizione di opinione come segue:

$$\mu p'_{1_{w_i}}, p'_{2_{w_i}}, \dots, p'_{m_{w_i}} \longleftarrow p_{1_{w_i}}, p_{2_{w_i}}, \dots, p_{m_{w_i}}$$

Nello specifico, μ definirà il passaggio secondo le sottocondizioni γ e δ:

1. $\gamma.\ p'_{i_{w_i}} = [\gamma]p_{i_{w_i}}$
2. $\delta.\ p'_{i_{w_i}} = [\delta]p_{i_{w_i}}$
3. $\gamma + \delta.\ p'_{i_{w_i}} = [\gamma + \delta]p_{i_{w_i}}$
4. not γ and not δ. $p'_{i_{w_i}} = p_{i_{w_i}}$

Algebricamente:

$$\mu p'_{i_{w_i}} \leftarrow p_{i_{w_i}} \equiv \begin{Bmatrix} p'_{i_{w_i}} = [\gamma]p_{i_{w_i}} \text{ se vale } \gamma \\ p'_{i_{w_i}} = [\delta]p_{i_{w_i}} \text{ se vale } \delta \\ p'_{i_{w_i}} = [\gamma+\delta]p_{i_{w_i}} \text{ se vale } \gamma+\delta \\ p'_{i_{w_i}} = p_{i_{w_i}} \text{ se vale not } \gamma \text{ and not } \delta \end{Bmatrix}$$

Ad esempio, data la proposizione epistemica $p_{1_{w_i}} = B_i(\mathcal{V}_i^{yes})$ l'operatore di transizione di opinione μ trasformerà la proposizione nel seguente modo:

$$\mu p'_{1_{w_i}} \leftarrow B_i(\mathcal{V}_i^{yes}) \equiv \begin{Bmatrix} p'_{1_{w_i}} = B_i(\mathcal{V}_i^{yes})_{yes}^{no} \text{ se vale } \gamma \\ p'_{1_{w_i}} = [\uparrow_B]K_i(\mathcal{V}_i^{yes}) \text{ se vale } \delta \\ p'_{1_{w_i}} = [\uparrow_B]K_i(\mathcal{V}_i^{yes})_{yes}^{no} \text{ se vale } \gamma+\delta \\ p'_{1_{w_i}} = B_i(\mathcal{V}_i^{yes}) \text{ se vale not } \gamma \text{ and not } \delta \end{Bmatrix}$$

4. Esempio di $\mathcal{S}$

Consideriamo la seguente struttura $\mathcal{S} = \langle A, W, P_{w_{1,2}}, S_{w_{1,2}}, R_{w_{1,2}} \rangle$:

- $A = \{1, \dots, 8\}$
- $W = \{w_1, w_2\}$
- $P_{w_1} = \left\{p!, p_{1_{w_1}}, \dots, p_{17_{w_1}}\right\}$
- $S_{w_1} = \left\{s_{1_{w_1}}, \dots, s_{8_{w_1}}\right\}$
- $R_{w_1} = \left\{r_{1_{w_1}}, \dots, r_{8_{w_1}}\right\}$

$\boldsymbol{w_1}$:

P_{w_1}:

$$\forall_i \in A, \psi_i: \begin{Bmatrix} \bigwedge_{i\in A} K_i(\Sigma), K_1(\mathcal{V}_1^{yes}), B_1(\mathcal{V}_2^{yes}), B_1(D_5^2), \\ K_2(D_2^7), B_2(D_5^2), K_3(\mathcal{V}_3^{no}), B_3(\mathcal{V}_4^{no}), \\ B_4(\mathcal{D}_4^3), B_4(\mathcal{V}_3^{no}), B_5(D_5^2), B_5(\mathcal{V}_4^{no}), B_6(V_6^{no}), \\ B_6(D_5^1), K_7(\mathcal{V}_7^{yes}), B_8(V_8^{no}), B_8(\mathcal{V}_7^{no}), B_8(\mathcal{V}_1^{yes}) \end{Bmatrix}$$

$\boldsymbol{S_{w_1}}$:
$s_{1_{w_1}}: K_1(\mathcal{V}_1^{yes}), B_1(\mathcal{V}_2^{yes}), B_1(D_5^2);$
$s_{2_{w_1}}: K_2(D_2^7), B_2(D_5^2);$
$s_{3_{w_1}}: K_3(\mathcal{V}_3^{no}), B_3(\mathcal{V}_4^{no});$
$s_{4_{w_1}}: B_4(\mathcal{D}_4^3), B_4(\mathcal{V}_3^{no});$
$s_{5_{w_1}}: B_5(D_5^2), B_5(\mathcal{V}_4^{no});$
$s_{6_{w_1}}: B_6(V_6^{no}), B_6(D_5^1);$
$s_{7_{w_1}}: K_7(\mathcal{V}_7^{yes});$
$s_{8_{w_1}}: B_8(V_8^{no}), B_8(\mathcal{V}_7^{no}), B_8(\mathcal{V}_1^{yes})$

$\boldsymbol{R_{w_1}}$:
$R_{1_{w_1}}: r_1^{1,2,5}$
$R_{2_{w_1}}: r_2^{2,5}$
$R_{3_{w_1}}: r_3^{3,4}$
$R_{4_{w_1}}: r_4^{4,3}$
$R_{5_{w_1}}: r_5^{5,2,4}$
$R_{6_{w_1}}: r_6^{6,5}$
$R_{7_{w_1}}: r_7^{7}$
$R_{8_{w_1}}: r_8^{8,1,7}$

In W_1, dopo la prima votazione sia il *sì* – grazie a i voti di 1,2,5,7 – che il *no* – grazie a i voti di 3,4,6,8 – hanno preso quattro voti. Tuttavia, in R_8 esistono le condizioni affinché si possa verificare una *propagazione di opinione* e il *passaggio da credenza a conoscenza*. Infatti, poiché l'agente 7 e l'agente 1 sanno di votare *yes*, è possibile applicare le sottocondizioni γ e δ alla proposizione dell'agente 8:

$$\mu p'_{i_{w_2}} \longleftarrow B_8(V_8^{no}) \equiv \left\{ p'_{i_{w_2}} = [\uparrow_B] K_8(\mathcal{V}_8^{yes})_{yes}^{no} \text{ se vale } \gamma + \delta \right\}$$

In questo modo, il passaggio al mondo epistemico successivo W_2 segna anche un equilibrio diverso tra i voti a favore del *sì* e del *no*:

- $A = \{1, \dots, 8\}$

- $W = \{w_1, w_2\}$
- $P_{w_2} = \left\{p!, p_{1_{w_2}}, \dots, p_{11_{w_2}}\right\}$
- $S_{w_2} = \left\{s_{1_{w_2}}, \dots, s_{8_{w_2}}\right\}$
- $R_{w_2} = \left\{r_{1_{w_2}}, \dots, r_{8_{w_2}}\right\}$

$\boldsymbol{w_2}$:

$\boldsymbol{P_{w_2}}$:

$$\forall_i \in A, \psi_i: \left\{ \begin{matrix} \bigwedge_{i \in A} K_i(\Sigma), K_1\left(\mathcal{V}_1^{yes}\right), B_1(D_5^2), \\ K_2(D_2^7), B_2(D_5^2), K_3(\mathcal{V}_3^{no}), \\ B_4(\mathcal{D}_4^3), B_4(\mathcal{V}_3^{no}), B_5(D_5^2), B_6(V_6^{no}), \\ K_7\left(\mathcal{V}_7^{yes}\right), K_8\left(V_8^{yes}\right) \end{matrix} \right\}$$

$\boldsymbol{S_{w_2}}$:
$s_{1_{w_2}}: K_1\left(\mathcal{V}_1^{yes}\right), B_1\left(\mathcal{V}_2^{yes}\right)$;
$s_{2_{w_2}}: K_2(D_2^7), B_2(D_5^2)$;
$s_{3_{w_2}}: K_3(\mathcal{V}_3^{no})$;
$s_{4_{w_2}}: B_4(\mathcal{D}_4^3), B_4(\mathcal{V}_3^{no})$;
$s_{5_{w_2}}: B_5(D_5^2)$;
$s_{6_{w_2}}: B_6(V_6^{no})$;
$s_{7_{w_2}}: K_7\left(\mathcal{V}_7^{yes}\right)$;
$s_{8_{w_2}}: K_8\left(V_8^{yes}\right)$

$\boldsymbol{R_{w_2}}$:
$R_{1_{w_2}}: r_1^{1,2}$
$R_{2_{w_2}}: r_2^7$
$R_{3_{w_2}}: r_3^3$
$R_{4_{w_2}}: r_4^{4,3}$
$R_{5_{w_2}}: r_5^5$
$R_{6_{w_2}}: r_6^6$
$R_{7_{w_2}}: r_7^7$
$R_{8_{w_2}}: r_8^8$

Dopo la seconda votazione, si verifica in $\mathcal{S}$ la sottocondizione α grazie al *sì* degli agenti 1,2,5,7,8.

5. Osservazioni conclusive

In questo articolo ho presentato un *framework* logico innovativo in grado di indagare le decisioni interattive di voto nei sistemi multi-agente in democrazia liquida. In particolare, sono stati sintatticamente e semanticamente definiti due nuovi predicati a due posti "vota" e "delega", le nozioni di "struttura dinamica", "scenario epistemico", "condizione epistemica" e "rete sociale" e, infine, la situazione di "propagazione di opinione" con la definizione di uno specifico "operatore di transizione di opinione". Fornire un modello espresso in un linguaggio logico governato da precise regole formali garantisce uno strumento indispensabile alla creazione di una rigorosa teoria della scelta razionale. L'idea che la logica possa svolgere, nell'analisi del comportamento razionale, un ruolo propulsivo analogo a quello che ha svolto, a partire dalla seconda metà del ventesimo secolo, nello sviluppo dell'informatica, è alla base del programma delineato da Rohit Parihk e suggestivamente chiamato *Social Software*[8].

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