Emergence In the Loop: Simulating the two way dynamics of norm innovation[1]

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Abstract. In this paper we will present the EMIL project, "EMergence In the Loop: Simulating the two-way dynamics of norm innovation", a three-year project funded by the European Commission (Sixth Framework Programme -Information Society and Technologies) in the framework of the initiative "Simulating Emergent Properties in Complex Systems". The EMIL project intends to contribute to the study of social complex systems by modelling norm innovation as a phenomenon implying interrelationships among multiple levels. It shall endeavour to point out that social dynamics in societies of intelligent agents is necessarily bi-directional, which adds complexity to the emergence processes. The micro-macro link will be modelled and observed in the emergence of properties at the macro-level and their immergence into the micro-level units. The main scientific aim of the EMIL project is to construct a simulator for exploring and experimenting norm-innovation.

Keywords: norm innovation, emergence, immergence, simulation, social complexity.

1. Introduction: an overview of the EMIL project

This paper introduces and illustrates the theoretical underpinning and the research agenda of the EMIL project, "EMergence In the Loop: Simulating the two-way dynamics of norm innovation", a three-year project funded by the European Commission (Sixth Framework Programme -Information Society and Technologies) in the framework of the initiative "Simulating Emergent Properties in Complex Systems", involving six Partners:

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2. University of Bayreuth, Dept. of Philosophy UBT Germany
3. University of Surrey, Centre for Research on Social Simulation UNIS United Kingdom
4. Universität Koblenz-Landau, KL Germany
5. Manchester Metropolitan University, Centre for Policy Modelling MMU United Kingdom
6. AITIA International Informatics Inc. AITIA Hungary

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The current project will greatly benefit from the common activity of this consortium in the Multi Agent Systems (MAS) and Agent-Based Social Simulation (ABSS) fields, which provide a common methodology, vocabulary, way of modelling and observatory for the partners to collaborate towards the achievement of the task objectives.

EMIL is aimed at understanding and developing design strategies able to cope with particular types of complex entities, i.e. social systems. These are characterized by a two-way dynamics, consisting of emergent and immergent processes: emergence from interaction among individual agents, and immergence of entities (norms) at the aggregate level into the agents' minds. A summary of the main theoretical goals is:

- to understand and manage complexity in social systems with autonomous agents;
- to understand how new conventions and norms emerge, innovate, and spread in these systems;
- the study of norm innovation by means of agent-based simulation.

The main technological aim of the project is to construct a simulator for exploring and experimenting norm-innovation. The forecasted impact of the project is to contribute to the regulation of e-communities by handing out a simulator for the emergence of new norms in complex social systems.

EMIL appears as an important scientific opportunity, as it is a simulation project on complex social systems and the object of investigation being both emergence processes and immergence processes, which are peculiar to complex social systems. The process of immergence has not been deeply analyzed yet, and only from a theoretical point of view. EMIL shall provide a more careful, simulation-based investigation of this process. Through the analysis of normative innovation, the EMIL project aims to shed light on the insufficiency of a strictly conventionalist approach to norms and on the resulting need of a theory of (social, legal) norms, where an accurate distinction between norms and conventions is made. As the core of the matter is the way norms not only emerge, but also are innovated, it is clear that norms cannot be considered as conventions, i.e., mere behavioural regularities cannot be innovated.

2. Necessity for a scientific theory of norm innovation

In this section we shall endeavour to clarify some of the fundamental claims and background hypotheses of the project. We will also attempt to provide a wider theoretical perspective, mapping out a state of the art on norm innovation.

In complex social systems, norms and institutions have a short life. Although there are some primordial precepts, like reciprocity and word-keeping, finder-keeper and truth-telling, both legal and social norms often decay rapidly, soon to be replaced by new ones.

This is certainly the case with customary norms and conventions, such as greeting rituals. But it also occurs with legal or institutional norms, which undergo a continuous process of revision and innovation. Norms and institutions often prove inadequate and inconsistent, thereby leading agents to face and try to solve conflicts, assign relative priorities to clashing norms and avoid inconsistencies. This is done either by adjusting to them or elaborating contrary-to-duty obligations – that is how deontic logicians call 'the defective application of norms'. Heavily relying on their social intelligence and competence, individual social agents are expected to harmonise with and restore social order.

We define norm innovation as a particular kind of norm insurgence, i.e., an intended one. This does not necessarily mean that the source of innovation is personal, or that innovation concerns only legal norms. Indeed, we claim that norm innovation implies somebody's will to introduce and spread it. The process of norm innovation poses a number of fundamental scientific questions. These include the mechanisms by which new norms are conceived of; the conditions under which they spread; the extent to which they evolve as they spread through a society; the circumstances under which they become institutionalised and the processes through which they decay and are ultimately lost. There are also questions about the relationship between new norms and the context in which norm innovation takes place, for example, how new norms relate to existing ones.

EMIL is intended to find answers for these issues, obtaining significant advances in the scientific understanding of, and possibly in predicting, a fundamental aspect of social complexity, i.e. norm innovation, by means of computer simulation of complex social systems.

2.1 Background hypothesis: Emergence in the loop

In this section, we will describe at some length a specific dynamic of the micro-macro link, crucial for explaining the process of norm innovation, i.e., emergence and immergence loop.

Complex systems are usually defined as composed of many different interacting elements, with non-linear interactions and network structure [32]. While this definition covers a wide range of systems, the EMIL project will focus on social systems only, composed of many interacting intelligent autonomous agents. Autonomous agents are able to adapt to, and evolve with, a changing environment, taking autonomous decisions. Moreover, autonomous agents with sufficient intelligence, such as humans, form new mental objects and processes consequent to the emergent behaviour of the system they are a part of, and act on the basis of these objects and processes. This is yet another loop that adds to the multiple chains of dependencies typical of complex systems, and is present in social systems uniquely because they result from the interaction of cognitive systems, endowed with intentions and other mental states. In these cases, we talk of social complexity: when change happens at some level, in order for the new pattern to spread over the whole system, some further modification is required in agents' behaviours and beforehand in their minds. This mental change allows agents to modify their behaviour accordingly; we call this phenomenon *immergence* [6]. The macro level and the (possibly many) micro-levels co-evolve while being connected by causal links in both directions, emergent and immergent, thanks to the mediation of the agents' minds. This leads to defining social systems as a special case of complex systems. Social complexity adds to general complexity the specific nature of social intelligent systems, the behaviour of which is regulated by internal, mental states. Hence, innovation in social systems is a bidirectional process:

- bottom-up: emergence of new entity or phenomenon (e.g., a given behavioural regularity, or agent property) at the aggregate level from interaction among agents;
- top-down: immergence of the entity or phenomenon in the minds of the agents, i.e. insurgence in their minds of a new mechanism, representation or process that leads the agents to modify their behaviours in conformity with the emerged effect. This is the key ingredient for the analysis of complex system including autonomous agents.

To be able to understand and manage socially complex systems, innovative approaches such as social, and more specifically agent-based, simulation appear to be essential for any serious scientific progress (for a discussion of when and why the agent base is vital for social simulation, see Gilbert, 2004). To avoid the pitfall of oversimplification, simulation approaches must take into account both the emergence of novel properties in the system, and the agents' immergent reaction to this.

2.2 State of the art

On the one hand, normative emergence has been the object of a wide amount of studies in several different academic disciplines. Apart from law sciences, there are also interesting contributions from Philosophy, Game Theory and Economics. On the other hand, norm innovation is a subject still not widely investigated and references are scanty if any.

In the scientific literature, two major views of norms co-exist: the social philosophical tradition [23] that equalises norms to conventions spontaneously emerging in a population, and the complementary notion of legal norms, offered by the deontic tradition and by the philosophy of law. Unfortunately, these two views have never been satisfactorily integrated [11, 12]. To questions like "where do institutional artefacts such as norms come from and how do they evolve?", the two traditions give totally different answers. For philosophers of law, norms are issued by central authorities. Within game theory, social norms are essentially seen as conventions, that is, behavioural conformities that do not presuppose any explicit agreement among agents, and emerge from their individual interests [23; 27; 28]. The function of these norms is essentially one of permitting or improving co-ordination among participants. Therefore, conventionalists identify norms with cooperation and fairness, finding their source in repeated interaction, or in reputation [22], etc. A convention gradually emerges from interactional practices, establishing who should do what. So, the emergence of cooperative (and fair) behaviour as a norm itself is driven by a particular order of preferences (in which strong emphasis is laid on the preferences defined as "social") [5].

Although this approach has significantly improved the possibility for game theory to describe and predict the behaviour of players, some preference changes are still obscure. For instance, the theory that fairness evolves among egoists as a rational solution to the problem of reciprocity [3] certainly accounts for an important function of social norms – namely, that of ensuring reciprocity in exchange – but it does not tell us how those norms evolve and spread, whether each agent separately "discovers" the advantage of fair moves or instead decides to conform to external pressures that converge on fair moves, and if so for what reasons, through which representations, etc.

With regard to the social side of norms, we auspicate a unitary view bridging the gap between conventions and norms. This, among other things, will allow to shed light on the question of norm-innovation. The conventionalist view can easily account for the proliferation of social rules, but it finds harder to explain how these can change, other than by mutation.

Indeed, hitherto, the only bridge between conventions and norms has been found in sanctions. As both conventions and norms are costly behaviours, they provide a rational incentive for violation. To compensate or neutralise this incentive, they are often associated with sanctions for transgressors [4]. However, this solution raises other problems:

- How can we distinguish between norm-based sanctions from mere coercion? How can we model agents that are able to tell (and take into account) the difference?
- While rendering norm-abiding rational, the administering of sanctions increases the global cost of norm-based social order. It is appropriate, then, to explore the issue of cost distribution in norm-based social order. To preserve equity, some mechanisms should apply to ensure a redistribution of the costs of normative compliance. Plausibly, the decision to comply with norms in mixed populations, where norm observers may happen to interact with cheaters, could be strongly disadvantageous for individual norm observers.

The same intuition is at the basis of the economic interest and game theoretical approach to norms. In economics, at a first glance, the idea of complete contract was introduced in order to permit an efficient conclusion of transactions, always challenged by interest conflicts between parties [8]. Making institutions as part of this process has led to improving the efficiency of some interactions and to the completion of economic transactions. Nevertheless, on the one hand, this introduction proved of poor utility in those cases in which complete contracts were not possible [21], and, on the other, it hindered a better interpretation of most kinds of social interactions in real life – in particular, the most problematic ones, such as those needing coordination, or public good provision and, more generally, collective dilemmas. Hence, we need an operational and computational theory of norm-innovation, which gives norms a specific space, between mere conventions and pure coercion.

By importing and reinterpreting contributions, definitions, mechanisms, etc. from the social and legal fields, also computer scientists have (re)discovered the wheels of social order. And, as the problems mentioned above have been haunting social scientists for the last two or three hundred years, they now begin to trouble the minds of computer scientists. The issues related to the regulation of Multi-Agent Systems (MAS) are far more numerous and complex than could have been expected even a few years ago. When norms started to circulate in the field of MAS, they were seen as a concern of people working in the legal domain. But things have rapidly changed. The amount of MAS work on norms and institutions is on the increase. Whereas the conventionalist view of norms has inspired the work of Shoham and Tennenholtz [21], examples of the complementary view are countless [6, 10, 15]. Moreover, the reasons of interest, and the answers and solutions provided, have changed in a qualitative sense. Norms and institutions are now of concern to scientists and designers of multi-agent systems and electronic societies, and more generally to scientists, designers, and managers of information societies.

Agent-based simulation of normative behaviour can be considered as a part of social simulation and, then, as one of the most promising tools in order to address some unsolved issues in the social sciences. Social simulation started to have a significant impact for social sciences in the 1990s [20], even though a few famous attempts can be dated earlier [28], and to our knowledge is the only instrument apt to deal with social complexity.

Finally, norms can be considered as the ideal example of a complex social artefact, because of their role in connecting emergence and immergence. Intelligent agents, which act (at the local level) on the basis of intentions and other mental states, can produce change at the system level. Recognition of system level changes, and reaction to them (immergence), is an option available to intelligent agents only. To make immergence possible, agents must create and utilise specific representations in the form of cognitive artefacts: the main example being norms. Thus, norms can act as a pivot connecting emergence and immergence, located at the intersection between the micro-to -macro and the macro-to-micro processes.

3. EMIL theoretical, technological and application challenges

In this section, we shall endeavour to give an account of the main EMIL theoretical, technological and application challenges.

3.1 Theoretical

As we have illustrated, the EMIL project is aimed at providing a theory of norm innovation (EMIL-T) by means of agent-based simulation, understanding not only how new conventions and norms emerge, but also how they immerge in the minds of autonomous agents.

To understand norm-innovation, the project needs to model the 2-way dynamics of sociality (EMIL-M), consisting of emergent processes [14, 17] and immergent effects [6, 12]. In particular, the two-way dynamics of social complexity allows a number of questions to be highlighted, that can be listed as follows:

- What are the factors (both inter and intra agent) that give birth to the emergence and diffusion of new conventions in a complex society (by convention essentially meaning a behavioural regularity observed in a given population at a given time)?

- What are the conditions that favour the stabilization of new conventions?
- What is the difference, if any, between a convention and a norm? Intuitively, a norm is a legitimate *prescription*. What are the objective and immergent correspondents of this notion [10] and how to operationalise it?
- How do new norms relate to existing ones? More generally, what is the relationship between new norms and the context in which norm innovation takes place?
- Finally, when and why does a norm become useless and/or non-prescriptive, when does it come to decay and, in the end, disappear?

Both theoretical and applicative tasks of the EMIL project are directed to provide an answer to these questions.

3.2 Technological

A theory of social order must be bi-directional [9, 33] and show how innovative phenomena (e.g., institutions) affect the social systems they emerge from.

While research on the construction of interacting artificial cognitive agents is not a new area [30], current systems still lack the scalability necessary for large scale modelling. For this reason the main technological aim of EMIL is to construct a system that is capable of performing norm innovation at the appropriate scale (EMIL-S). In order to build this system, we will need to

- develop a platform for simulation of cognitive agents using appropriate Open Source and readily available technologies;
- integrate simulations on different agent levels (e.g. agent, institution, and society), modelling the interplay among different levels in norm innovation;
- integrate data acquisition and modelling, by taking into account data from simulation while modelling and building the simulator.

3.3 Application

The EMIL project is expected to contribute to the regulation of e-communities by handing out a simulator for the emergence and innovation of new norms in complex social systems, whereby situated experiments can be run. While the simulator will be designed as a general-purpose tool, some specific case studies will be selected so as to provide the necessary grounding parameters. The selected field of application will be the rise of collaborative community norms in the Open Source community, where new conventions have been established and new norms are being invoked. The stabilization of both is a major concern in this community, which offers (a) an interesting observatory of the mechanisms and processes of norm innovation, (b) an appropriate environment from which to draw essential data to be fed into the EMIL Model (EMIL-M) and Simulator (EMIL-S), and (c) an application field for testing its utility.

4. Relevance

EMIL is intended to provide both theoretical and implementative advances in those fields of critical information infrastructures that are of crucial interest for economy, as they can improve the competitiveness of businesses and firms, and for society at large, as they can provide a sound and multi-purpose tool for policy making, norm enforcement and trust enhancement.

In particular, it is concerned with norm innovation, an issue of growing concern in natural, electronic and artificial societies. In order to figure out the social impact of the EMIL project, suffice to think of the variety of concrete phenomena and examples to which norm innovation applies. A social, institutional, technological and natural environment in constant and rapid transformation requires an equally assiduous updating of policies and customs, habits and conventions. The necessity for tools and instruments allowing the temporal, structural and behavioural conditions for norm innovation to be detected, tested and predicted, thus becomes transparent.

Furthermore, attention paid to norm innovation is on the increase in several fields of Information and Communications Technology (ICT), and is strictly intertwined with software development and diffusion. This is certainly the case in the field of agent systems - e.g., in teamwork and robotic applications to domestic work and assistance - where the necessity to bring together human and software agents, in hybrid systems of interaction and advanced technology soon became clear. In other ICT settings, norm-innovation is perhaps an even more urgent necessity. In e-markets and businesses, as well as in e-communities like those formed around the Open Source, the problem of trustworthiness is widely perceived as the problem "number one" for a decisive consolidation of the new tools. In turn, trustworthiness requires new conventions and social norms being brought about for governing and at the same time giving impulse to complex agentized environments [13, 24]. To drive innovation and growth in agent applications requires the invigoration of the problem of social order in the context of the new economy and society. On one hand, a scientific, explicit and operational theory about what type of norms will emerge under which conditions and to what extent is much wanted. On the other hand, for the assumption of social complexity as formulated above, this requires a theory about how, when and to what extent any given norm, once emerged, will have impact on the agents' behaviour. For the assumption of autonomous agency, this implies that we develop a theory of how a norm is implemented in the mind.

After centuries, the problem of social order is still waiting for a theory that accounts for similarities and differences among different types of norms (conventions, social and legal norms), as well as for their prescriptive force, and that establishes a clear-cut confine between norms and mere coercion (which is also based on sanctions). Whereas the emergence of conventions has received considerable attention, the way-down in the circuit of emergence has been accounted for, if only, in purely behavioural terms. Hence, the process of immergence has being generally overlooked, and with it, the emergence of norms as something in connection with, but distinct from, mere conventions and coercion.

A two-way theory of norm innovation is a necessity for the technological advance of society and a challenge for science. Moreover, or more generally, no development of the science of complexity in the direction of social matters is possible without accepting and taking into account the assumption of social complexity.

Our objectives, both theoretical and technological, will be pursued throughout the project, by building a solid theoretical framework to be used for modelling norm innovation as a two-way social dynamics, by applying this model to concrete empirical scenarios, and by developing simulations, integrating data and revising the theory and the computational tool on the grounds of the findings obtained.

Our project could not be carried our without developing a model of emergence of aggregate behaviour, considered both at the macro-level (the emergent property) and at the micro-level (mental objects and processes agents develop as a consequence of the emergent property, guiding their actions in a complex environment). This model is aimed at simulating and experimenting upon the conditions favouring the immergence of a given emergent property (a norm), thereby allowing for the process of norm innovation to be checked and possibly predicted.

5. EMIL potential impact

EMIL's expected impact is proportional to the increasing necessity, within the IT field, for regulated e-societies and communities, and consequently for norm-innovation. Hence, the impact of the project is proportional to the achievement of its objectives; in particular, the building of a platform for simulating multi-agent interaction is expected to allow the conditions under which given norms emerge, innovate, and spread to be explored and experimented upon; hence, conditions favouring the insurgence and stability of such norms might be predicted and fostered. Indeed, one of the main problems faced by designers of advanced technologies of interaction in different domains is the need for distributed regulation, i.e. conventions and social norms evolving and spreading with none or reduced need for centralised and deliberate intervention. The strategic impact of EMIL essentially lies in its contribution to predict and promote the regulation of e-communities by means of new norms and conventions. A simulator of norm innovation in a society of artificial agents endowed with variable autonomy and intelligence will be developed.

The setting to which the proposed project is inspired is the Open Source, as a scenario in which innovation is demanded and appears to depend on both theoretical and technological advances. Although the Open Source community has made substantive advances in the last few years, it is now about to cope with a major challenge, i.e. reduce proliferation of licenses on the one hand and tackle the issue of deployment. While technical problems are surmountable, the emergence and acceptance of regulation, conventions and standards seem more questionable and are strongly dependent on a scientific understanding of how the emergence, innovation, and spreading of norms and standards are conceived of. To be noted, the competitiveness of the Open Source is highly related to its community coping with this challenge. To quote Michael Tiemann (in his speech at the O'Reilly Open Source Convention, 2001), "this issue is important because it is about the future of software (the increasing substance of technology), it is about the increasingly important aspect of technology as it relates to our economy, and it is also about the code-as-law that will ultimately govern us".

Indeed, Open Source not only means access to un-obfuscate source code, but also conformity with a number of criteria, such as free redistribution (license shall not require a royalty or other fee for sale); integrity; no discrimination against persons or groups, nor against fields of endeavour (be it a business, or genetic research); distribution of license (to forbid closing up software by indirect means such as requiring a non-disclosure agreement). Furthermore, license must not be specific to a product, nor should it restrict other software. Finally, licenses must be technology-neutral. The future of advanced technology and, for that matter, the future of scientific discovery is somehow conditioned to the destiny of Open Source. Writing good software with sensible licensing terms encourages a better, more transparent, more trustworthy architecture for computing, it empowers individuals, promotes free and equal competition, and enables freedom at higher levels so that others can build applications with confidence. Indeed, the Open Source community has learned that rapid evolutionary process produces better software than the traditional closed model, in which only a very few programmers can see the source and everybody else must blindly use an opaque block of bits: "…when programmers can read, redistribute, and modify the source code for a piece of software, the software evolves. People improve it, people adapt it, people fix bugs. And this can happen at a speed that, if one is used to the slow pace of conventional software development, seems astonishing." (Official site of the Open Source Initiative, http://opensource.org/index.php)

On the other hand, the Open Source development has led to a proliferation of new licenses, which in turn represents a significant barrier to open-source deployment. Let us see why. Open-source software has developed to a degree that would have been unimaginable a decade ago. Governments around the world have responded to the open-source message with initiatives and funding. Our entire economy and the society around it has benefited as the new and larger open-source community gave software consumers and technology users everywhere a whole new range of choices.

However, there are three problems around software, i.e. development of high-quality, innovative and reliable products; its distribution; its deployment, i.e. the management of the technical and legal complexity of software in use.

The first problem is no more a serious concern. That open-source developers out-compete proprietary software in innovation is no more news, although the interesting question is why, to what extent and under which conditions this is the case.

As to the second problem, it must be said that open-source licensing and the explosive growth of the Internet has combined into a mutually-reinforcing attack on software distribution costs. Hence, even distribution is no more an issue.

However, solutions to the development and distribution dilemma create a problem of deployment. Why? Because the central activity of the open-source community is to create, re-use, and re-combine source code. Combination can leave software developers, users, and distributors uncertain as to their rights and responsibilities. Uncertainty makes people afraid and prevents them from making any move; thus raising the costs of using Open Source; and injures everyone. The problems can indeed be solved, as technical difficulties are surmountable. As usual, the real problems stem from social cognitive aspects. A change is needed in the criteria used to approve licenses. The license should be original, solving a problem not sufficiently addressed before, and must be clear and reusable. In particular, as to reusability, licenses that tend to create ghetto-ed communities attached to a single firm or vendor are discouraged. Corporate players ought to be let to observe the benefits of giving up proprietary control gradually, rather than asking them to give up all control immediately thereby pushing them into a defensive position. Since licenses reduce the growth of development communities, corporate players that originally promoted them now complain about the proliferation of licenses and the legal complexity created by license collisions.

Therefore, the best way to serve corporations and the entire open-source community is to insist on reusability without qualification and a general removal of legal barriers. The new criteria might annoy and even anger some people, and this is a necessary evil, if one wants the proliferation problem to be addressed seriously. But how to encourage search for approval and acceptance of new criteria?

To develop an anti-proliferation policy means to develop a scientific understanding of the standards and of the criteria there under, as well as of the processes and conditions leading to people's acceptance of standards and their decision to meet new criteria.

6. EMIL Workplan

EMIL is articulated in three main building tasks, EMIL M, EMIL S, EMIL T, and in two testing tasks aimed at collecting real data and simulation findings: one task dealing with the Open Sources scenarios, the other with the simulation executions. In this section we summarise the EMIL workplan, pointing out the main scientific and technological challenges, the focal articulations and the links between the tasks.

6.1 EMIL-M: Theoretical background on norm innovation

EMIL-M works out a general *model* of norm-innovation a complex social dynamics among intelligent social agents, to be tested by means of agent-based simulation in a specified context.

The case of the emergence of norms in Open Source will be analyzed in another task of the project (one of the two testing tasks) in order to provide empirical examples of the emergence of such norms contributing to the construction of a grounded EMIL-M. Open Source here refers not just to Open Source software, but also to other domains where participants freely provide intellectual goods to others, outside a market relationship. EMIL-M will raise questions that will be answered in the EMIL-S and EMIL-T: what is the difference between a norm and a convention? How is it possible to pass from a norm to a convention, or the other way round? When and why will new norms arise? Can we envisage and hypothesize on the conditions under which norm innovation is likely to stabilise and spread? Is it possible to derive a typology of norm innovation, so as to understand the cognitive structures involved?

In order to develop EMIL-M, both conceptual clarification (working out vague concepts, imprecise definitions, unsolved problems) and model development are needed, with the main goal of building formal theories that can be used for simulation. Since norm innovation results from a complex collection of nested theoretical definitions, it will be useful to provide a shared ontology, or in other words, to forge a common vocabulary of interrelated notions with which to work. By ontology we mean a conventional and operational tool, a set of theoretical notions that are defined one in relation to the other. Its goal is to make conceptual links explicit. It is the starting point of the project and provides shared conceptual and theoretical instruments (ontology about norms as well as emergence and immergence theory) for executing the project workplan.

In the picture below, you can see a provisional schema of the shared ontology that we intend to model.

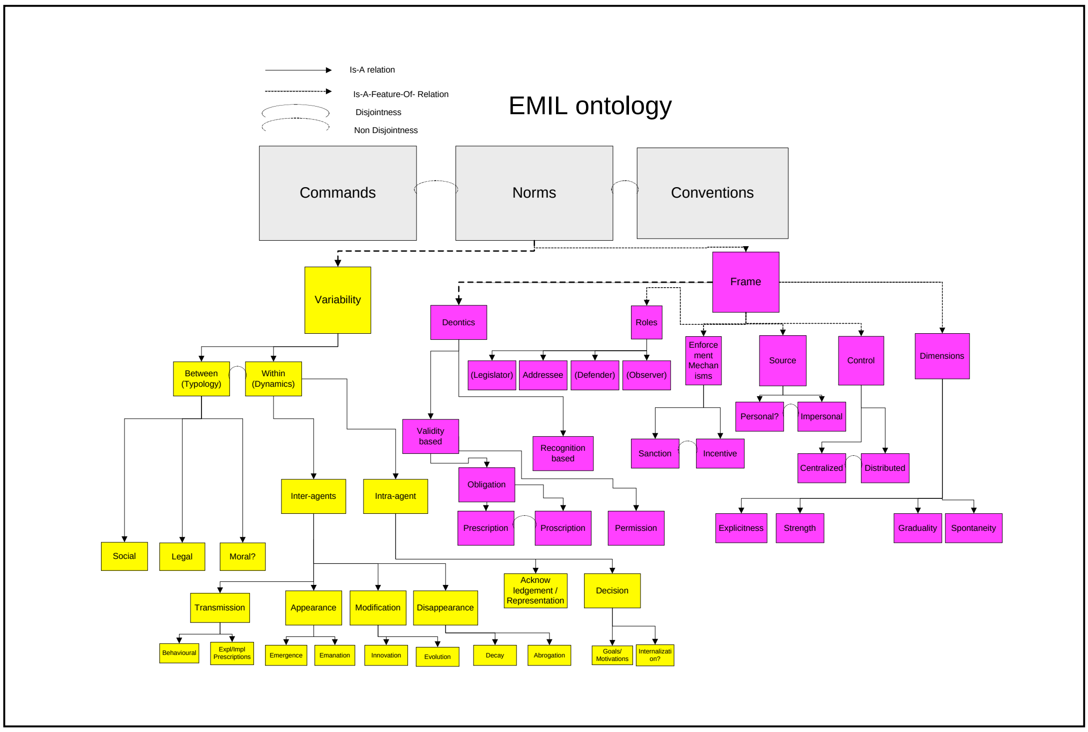

Fig.1: A provisional schema of the EMIL's ontology

As you can see in Figure 1, the first three entries in EMIL's ontology are commands, norms and conventions, notions that constitute the theoretical kernel of the EMIL project. As these concepts can have different definitions in different theoretical fields, we will try at first to find a shared meaning for them, endeavouring to shed light on their similarities and differences. We will then focus attention on the notion of norm, decomposing it in its most important features (that are themselves decomposable), in such a way that it becomes more clear and useful for the aim of the project.

Apart from the shared ontology, EMIL-M will consist of an analysis of the so called inter agents processes and intra agent properties. On the one hand, inter agents processes contribute to characterize the social side of the norm, on the other hand, intra agent properties define the internal side. For the inter-agents processes, special attention will be given to the mechanisms of emergence and diffusion of entities or properties at the aggregate level, from interaction among agents. For the intra-agent ones, the attention will be focused on the mechanism of immergence.

Autonomous agents living in a complex environment are endowed with skills allowing them to modify their world. Their actions not only affect particular states of the world, but also other agents' mental states and actions. Emergent properties are those properties that (a) emerge from interaction among agents and between the agents and the external world; (b) have particular and unpredictable characteristics not deducible from properties of entities at the original level, and (c) produce a change in the overall system.

Emergence is quintessential for the definition of complex systems. However, as we deal with autonomous social agents, emergence is in the loop between bottom-up and top-down processes: emergence of properties at aggregate level cannot be accomplished effectively unless properties feedback on the lower level through a complementary process of immergence into behaviours of units (agents) at the lower level, and beforehand into their minds.

Speaking now of the diffusion of these entities and properties at the aggregate level, we must observe that sociality is not independent of cognition. Norms drive behaviour once they have accomplished the immergent process. Therefore, with cognitive agents, behavioural diffusion of norms can only be predicted on the grounds of the effect of norms on agents' mental processes. Diffusion has to be studied to understand what are the conditions according to which both norms and convention spread and stabilize, and what are the differences between these two categories.

As noted before, there are two main processes adding to the complexity of social systems. On the one hand, entities (like norms) emerge from interaction. On the other hand, agents are affected by these entities (immergence: the effect of emergent properties on the agents' minds) in two consecutive steps: at the mental level and at the behavioural level.

Consider, however, that although the former step is necessary for the latter to be executed, it is not sufficient, since mental immergence can result in norm violation. Immergence makes interaction much more complex and unpredictable, and gives rise to new emergent properties at different ontological levels. Norms emerge from social interaction but agents reason on them and act according to their beliefs; thus, norm diffusion and stabilizing are strongly affected by cognitive processes. For this reason, it is an urgent task to clarify some components of the mental processing of norms.

First of all, a norm becomes a belief in the mind of its subjects, namely the belief that a given behaviour, in a given context, for a given set of agents, is forbidden, obligatory, permitted, etc. More precisely, the belief should be that “there is a norm prohibiting, prescribing, permitting...”. Indeed, norms are aimed at and issued for becoming such beliefs. In other words, norms must be acknowledged as such in order to properly work; this is their function [10, 12]. In order to realize the existence of a norm and its impinging on somebody, the belief that to do something is prescribed or forbidden is not enough. The norm is something more than a mere will, an order of a private agent that obliges us to do or not to do something. The binding force is insufficient, since it characterizes also non-normative commands. The point is the source of the norm, the issuer of commands. For a prescription to be perceived as a norm, who should the source be, how should it be characterized? EMIL-M shall attempt to give an answer to this crucial question, endeavouring to characterize the normative source, i.e., the nature of normative authority.

Believing that a norm exists and concerns us requires at least a second group of beliefs: the beliefs of concern. The norm says what ought to be done by whom: (i) the obligation/permission/prohibition and (ii) the set of agents on which the imperative is impinging. For example, if I am addressed by a given norm (say, "be member of a professional order"), and the norm has to take effect on me, I must recognize this. The prescription is about a set or class of agents, and since I am an instance of that class, the norm applies to me.

However, a normative belief is not yet sufficient to yield a norm-governed behaviour. A complex mental representation is needed, which includes several types of beliefs (normative belief, normative belief of concern), goals (normative goals), meta-goals, and rules of normative reasoning (norm adoption) [10, 12]. In this sense, cognitive ingredients have to be carefully taken into account, properly analyzed and modelled, especially concerning the properties at an aggregate level that come into effect in the agents' minds, this is the main focus of the analysis of the intra agent dynamics. Along with emergence, immergence is the fundamental mechanism of the micro-macro link, whose complex dynamic allows for phenomena like norm-innovation, typical of those societies of agents that are endowed with cognitive ingredients. In order to be understood, norm innovation requires a theory of bidirectional process of both emergence and immergence.

One aspect of the theory of norm immergence still unexplored is the mental object or mechanism that is regulated and affected by the norms, i.e., the mental scope of norms. In other words, norms not only regulate behaviour, as supposed by a BDI architecture, but also act on different aspects of the mind depending upon the agent architecture, namely its beliefs, emotions and decision making.

For what concerns the norms’ impact on beliefs, let us consider common obligations, as in “you OUGHT to believe what your mother says”, or the more extreme obligation “You MUST believe in

God". Notice that although there is a behavioural side of belief acceptance, consisting in agents behaving as if they believed in God or another authority (such as parents), the norm expects not only to regulate the external behaviour but also the underlying mental states. Why should we adopt an obligation to believe something? Part of the prescription recommends that agents do trust certain figures, acknowledging their authority as an emanation of the authority of the norm itself, which expects to be honoured by the subjects. But it is unclear whether this is all we can say about this phenomenon, or there are also other ways in which one can be prescribed to believe.

With regard to the obligation to feel something, it may be interesting to investigate under what circumstances, you MUST feel ashamed, or guilty. The locution: "BE ashamed" appears as an impossible command, of the type "BE spontaneous". In real matters, it is much more efficient. Rarely, people that are told to be or even feel ashamed remain untouched, unmoved by it. Why is it the case, and how is it possible? Again, one might say that what is in the scope of the norm is not the feeling, but its behavioural expression, its open display. But this is not the case: agents cannot help experience a feeling of shame when ordered to do so. Another example is "You OUGHT to do your work out of vocation".

Finally, norms act also on decision-making, and any of these mental objects is decided upon to some extent, included emotions. Let us consider goals. An agent decides to comply with a norm that has been integrated in the agent's knowledge base, giving rise to some sort of normative goal. An agent endowed with this particular kind of goal is allowed to confront it with any other goals of his and, to some extent, to choose which one will be executed. The normative goal can eventually be abandoned, otherwise it becomes an external motivation that drives the agent to act. Sometimes, the decision to comply with norms can have an endogenous drive. In such cases, the norm is followed according to an internal reason, often associated to given emotions, such as shame, remorse, or feeling of guilt. In these circumstances, we say that the norm has been internalized.

To sum up, obligations are represented as specific reasons to believe, feel, want, act, etc. This is important for an integrated theory of the mind. What is not clear yet is whether agents in fact modify their mental states as a consequence, or simply know they ought to. In the latter case, what changes is the goal and the consequent action, with the norm acting as any other incentive. In the former case, the prescribed mental states do in fact get formed or modified as an effect of the normative belief. But how this can happen is still unclear and a more accurate model of immergence is one of the main theoretical challenges of the EMIL project. Together with a theory of norm emergence, it will represent the kernel of EMIL-M.

6.2 Open Source scenarios

A great deal has already been written about the Open Source software (OSS) movement, and there are several projects devoted to various aspects of OSS within the Framework Programme.

This task will not duplicate this work; rather, it will draw on the data and results generated by these projects to develop a history of OSS that focuses especially on the emergence and innovation of norms within the OSS community. Ours is a perspective on OSS that has only been touched on by the existing projects and so, while they have created much data of great use to this task, there may also be a need to go beyond this secondary data to collect some primary data directly. For example, it may be desirable to interview some participants (probably using online interviewing by email or instant messaging, rather than face-to-face) or to re-analyse some of the records that are left for researchers to study by the operation of OSS (e.g. online forums, bug trackers etc.). What really matters by means of taking a new analytical perspective, in accordance with the theoretical model developed in EMIL-M on OSS movement, is to understand which fundamental factors have given birth to the emergence, innovation, and the diffusion of conventions and norms in our complex society. On the grounds of this, EMIL-M will also be translated into a more specific simulation model anchored to the data provided by the above scenario.

Although OSS is the most famous and the most studied example of Open Source, there exist many others and the number is growing. Academic science, although having some distinct characteristics, can be regarded as the 'father' of Open Source and it will be interesting to compare the development of OSS norms with the history of the emergence of the 'norms of science' which have also been studied in depth by historians, philosophers and sociologists of science. This points to the understanding of the emergence of new norms among existing ones. Therefore, it will allow for the analysis of the causes that have brought about the decay of such norms. There are also examples such as Wikipedia which have appeared only within the last couple of years - which should make tracking the history somewhat easier, since the investigation will be almost contemporaneous to the emergence of norms.

We will first collect potential candidates for study, specify the scope of the candidates and their answering the crucial question about norms dynamics, locate sources of existing data about each of them, make contact with prior or current projects that are studying these or similar examples, and end up with the choice of two (or three, depending on the richness of the data) of the examples for further investigation.

For each of the examples selected, a historical survey will be written, focussing on the emergence of norms. The approach adopted in these histories will be strongly influenced by the theoretical approach adopted in EMIL M and will consider not only the ways in which norms (for example, of how one claims authorship of intellectual property) emerge from interactions between participants, but also the ways in which these norms are stabilised, diffused, innovated, and used by the participants to understand the complex domain and act on it. The histories created will be conventional prose accounts. They will be later transformed into a more computational form, so that they can be used to contribute to the modelling of EMIL-S phase as empirical test data for the simulation models.

6.3 EMIL-S: Simulator Building

A simulation platform for experiments, EMIL-S, will be built up with the purpose of testing EMIL-M. EMIL-S will be applied to execute simulations and compare results with available data, especially in the field of Open Source. The simulation platform will be a software architecture, written in an object-oriented language, consisting of ready-made and extensible simulation programs, including software agents that can interact with each other, aimed at giving an account of a precise range of phenomena.

The simulator will provide templates for different kinds of agents (representing both individuals and aggregates) as well as different kinds of environments within which the agents will have to interact.

Agents will be able to keep memories of encounters with other agents and will also generate (incomplete) models of other agents and of their environments. The simulator will provide these technical characteristics of agents and their relations, as well as a protocol for the communication among agents; details about attributes of agents and relations and communication will be worked out in collaboration with the task in which the simulation execution will take place.

EMIL-S is one of the main scientific/technical challenges of the EMIL project. It will provide a research instrument for norm innovation, and will be released in the public domain for customisation and for application to additional experiments and domains; non-research users will be reached by the dissemination assists, and will range from policy makers to international organizations. While aiming to simulate the Open Source scenario, the simulator will be designed as a general-purpose instrument for the analysis of norm innovation. The design and realisation of EMIL-S will be characterized by the following four stages.

At a first step, it will be necessary to enact a thorough analysis of the requirements of the simulator needed for the purposes defined in EMIL-M and in the task concerning the Open Source scenarios. These purposes have to be explicitly linked to answering the questions subtending the whole project (in short, what are the mechanisms by which new norms are conceived; the conditions of their spreading; the circumstances under which they become institutionalised; and the processes through which they decay?). An evaluation of available simulators (REPAST, MASON, Swarm) and agent models (BDI and similar, i.e., JADEX) will open this phase. In any case, we will need a customised user interface and several improvements over the current state of the art, especially for that which regards a) multi-level: agent that can be composed of other agents, and b) internal norm representation and reasoning.

The second step is the design of the simulator. It will consist of

- a formal description of the relation and environment classes as these will form the three main classes to be provided by the simulator, and of
- a graphical user interface which would allow the simulator to output simulation results in textual and graphical ways, the former to allow for further analysis with standard analysis tools (statistical analysis systems etc.), the latter to allow for graphical output of topographies, networks and time-series during the simulation run.

Moreover, we will design an agent architecture specialised in norm manipulation. Agents will be built in increasing levels of elaboration, starting from cellular automata to BDI agents with explicit beliefs and goals. In particular, the more elaborated agents will be able to:

- recognize the onset of conventions, and possibly norms;
- manipulate the factors that give birth and stabilize new conventions and/or norms;
- recognize institutions and interact with them;
- reason upon the interaction between different, possibly contradictory, norms;
- reason upon the possible decay and disappearance of norms.

The result of this part will be a formal description of the agents, in increasing levels of elaboration. Moreover, in order to make the simulation platform usable by the largest possible audience, a graphical user interface will be designed in order to allow users to derive their own agent classes from the templates pre-defined by the simulator.

In the third step, we will implement the design in a more or less platform-independent way and document the implementation in a way that allows users the extension of the simulator and its use as a platform from which user-defined agents, relation and environments can be thus derived from the mentioned built-in templates. It will be necessary to have the simulator run in a distributed way, i.e. on any number of networked machines.

As of today, user-defined agent, relation, and environment classes will be defined in JAVA code (in earlier times it might have been necessary to design textual simulation description languages, but most modern development kits nowadays combine the graphical manipulation of symbols on the user interface with a description of details in one of the ordinary general-purpose languages such as JAVA, and this will also be the policy of the new simulator).

The fourth, and last step, will overview the development process in order to ensure the necessary quality level. In particular, the necessary testing protocols will be issued and tests will be performed. Procedures for software maintenance (bug report and reaction protocol, reaction to software component upgrades, inclusion of third-party future extensions) will be developed.

6.4 Simulations executions

In this task a concrete implementation of an abstract model of norm-innovation in the Open-Source scenario will have been created.

The current task is responsible for creating and executing carefully designed computational experiments in levels of growing complexity. Simulation execution will be carried out with focus on parameter space exploration, efficient execution and accurate result analysis, setting the stage for the final theoretical advances (EMIL-T) and contributing to the refining of the simulation platform (EMIL-S).

Models of complex social systems typically depend on a number of assumptions, quantified in the form of specific values to certain model parameters. Ideally, any such model should be tested with any meaningful combination of these parameters, in order to determine the validity of the model.

In addition to the dimensionality and the size of the parameter space, the *sensitivity analysis* of complex system models has to face the additional challenge of establishing the results' statistical validity, independent of the probabilistic model elements. Because computer programs, and thus computational models, are inherently deterministic, random factors are modelled by using so-called pseudo random number generators (RNGs). RNGs generate a deterministic sequence of numbers, with the desired statistical properties, depending on an initial value termed *seed*. Different seeds result in different random number sequences. Thus, the task of establishing the results' statistical validity involves running the simulation with various RNG seeds and analysing the collected results.

This task will be intended to underline the most relevant quantitative findings on norm innovation, pointing to potential breakthroughs in this field. Data to be collected need to comprise different levels of hierarchical structures (agents, institutions, societies) to point out interdependences and micro-macro dynamics of norm innovation.

It has to be said that running simulations at this scale and complexity is from a computational point of view a particularly intensive task. This creates a special emphasis on the design and sequencing of the experiments, so that they allow for branching depending on earlier results and also for revisiting previously explored areas of the parameter space with greater 'resolution'. Even in case of carefully designed experiment plans, the task may easily exceed the abilities of today's PCs or workstations. Therefore, the execution must be distributed among several computers on the network.

There are two basic approaches to do this. In the first, each simulation instance is run on a single computer, but the many instances required for parameter space exploration are distributed over the network. In the second, even components of the same simulation run (e.g., the agents) may be divided up among the participating computers.

In the former case, neither the size nor the computational requirements of any of the simulation runs to be executed can exceed the capabilities of the participating (single) computers. However, this approach is relatively easy to implement, and can speed-up the execution of the set of experiments (typically involving thousands or tens of thousands of single simulation runs). On the other hand, the latter case allows for the execution of simulation runs that exceed the capacity of any participating computer. However, this comes at a price of considerable implementation efforts on the side of the engineers of the execution platform, and typically also on the side of simulation developers. It also raises the issue of close synchronization among the participating computers, since discrete time models typically assume a single 'central clock', which is often inconvenient in a networked environment with computers with varying computational abilities, it can often be the case that the entire 'computational pool' operates at the rate of the weakest participating unit. Moreover, in case of models with strong interaction/communication among the agents, the second type of distribution is highly impractical due to the increased communications costs. On the other hand, in principle, the open-source scenario deals with agents in a highly distributed physical setting, with particular ways of typically asynchronous communications. Therefore, despite the general wisdom that ABM's typically benefit from the 'first type' of distribution only, as a first step of this task, knowing the exact model developed in EMIL-S, we will consider the option of utilizing the 'second type' of distribution, too.

The first step of this task will consist in assembling a pool of computers for simulation execution and to the automation of the execution of simulations on it. The automation part also includes collecting the generated results from the various computers, and assembling them into a single, coherent database.

Since the anticipated application will be likely to generate large quantities of data, a special consideration to data formats is required in order to ensure the efficient analysis of the results. The simulation execution system will be created using available technology and open-source software. These technologies include functions provided by *grid systems* [16], where a pool of networked computers, whose availability varies in time, is assembled, providing a single access point with a common, unified 'operating system shell' for users. While our execution system will definitely use a pool of networked computers, and while from the point of view of the simulation application, these computers will be accessed via a single access point, we will not need the whole functionality of a grid. This is mainly due to the closed nature of our system: we will not have many individual users.

Our system will be dedicated to the execution of a series of runs of the same simulation (at any given time) with different parameter combinations and to the distribution of these runs across the pool of available computers.

The second step is concerned with the design of the set of computational experiment, focusing on the search of a representative but manageable parameter space. Models of complex social phenomena should be tested with any meaningful combination of parameters, in order to determine the validity of the model. In cases where the model's output depends linearly on the initial parameter values, this task is easy to accomplish. However, this is typically not the case with complex social phenomena.

Experiments will extensively explore the parameter space of the model, concerning both the scale of the system and the internal complexity of the model components (i.e., the agents, institutions, and society). This will involve: (a) establishing the values of parameters and initial conditions (b) defining appropriate output indicators (c) running the simulation and comparing the output with data obtained from the Open Source scenarios task. The dependence of the outputs on the specific values of the parameters will be examined, by using an automated 'sweep' of the parameter space (either by exhaustive iterations - for a few parameters - or by random sampling, or both).

In this phase, the actual execution of EMIL-S based simulations will be carried out. This involves looping through this task and the next one:

- Execution of the simulations.

- (Statistical) Analysis of the results.

These steps will be iterated, incrementally collecting knowledge about the model's behaviour, gradually refining the exploration area based on earlier results. This kind of iterative approach is particularly important due to the expected non-linear nature of the behaviour. For example, the first set of runs might point out important disturbances at a certain range of parameters, which will be further explored in finer details in the subsequent simulations.

Finally**,** we will collect and analyse simulation results. This task will give feed back to the previous one, requesting for more simulation where answers will be statistically uncertain or accelerating parameter sweep where results appear to stabilise.

We will compile a report on the collected findings and provide practical and theoretical interpretations. This also involves evaluating the findings of the computer experiments, among others, by fitting the generated simulation results to the data collected in the Open Sources task.
In the case of any model, especially in the case of computer simulations, a question of paramount importance is the validity of computational investigation. Validity is always assessed in the context of a comparison. The output of the model may be contrasted to the present or future state of the modelled system, but also, to the output of another, pre-existing model, or to theoretical conclusions developed by other scientific means.

This means that validity can only be properly assessed after fixing the purpose of the computational model, which can be of several general types. Often, the model's future is compared to the future state of the target system. We call this *prediction*. In other cases, only similarity of the two systems' behaviour is required. We call this *simulation* (which term here, despite the same word, does not simply denote the execution of the computational model). A well-known example of this approach is Craig Reynolds' popular BOIDS (or flocking) model [26]. Finally, we talk about *thought experiments* when the model's conclusions are not directly compared to the real system, but rather to a set of accepted theories and their conclusions. For example, in its evolution of the cooperation model, Robert Axelrod generates an existence proof by agent-based modelling, showing that spontaneous cooperation can emerge given the generally accepted assumptions about rational, selfish behaviour [1]. In the case of the latter kind of models, scientific work is the collection of a set of sufficient conditions that lead to the emergence of the studied phenomenon.

In the case of the EMIL the goal of model development is two-fold. First, we aim at explaining the emergence and innovation of norms in complex social systems. Therefore, our simulation results must be compared to pre-existing theories and assumptions that will have been collected in the Open Sources task. The second aim is qualitative prediction of the emergence and innovation of norms in the particular domain of our simulation, in the Open Source software development community [31].

6.5 EMIL-T: Integration and theoretical update

After having constructed a model of norm innovation at the social and cognitive levels, described an empirical example of norm innovation (the development of norms in the open-source movement), and applied a computational version of the model to the empirical example by building and executing simulation experiments, EMIL-T shall evaluate the success of the model by comparing the results of the simulations with the empirical data documented in the open-source scenario. The revision and improvement of the theory of norm innovation (EMIL-T) represents one of the scientific challenges of the EMIL project. This task is organized as follows:

Firstly, we shall evaluate the success of the theory in understanding the development of norm innovation in the Open Source movement by comparing the results of the simulation with the empirical data documented in the Open Source scenarios task. The comparison will lead to a revision and improvement of the theory.

Secondly, the experience obtained from previous tasks will be used to reformulate the theory of norm innovation and to consider its applicability to social phenomena other than those used in its construction and validation. The result from this sub-task will constitute the new model, EMIL-T, as well as a set of further applications demonstrating the generality and the limitations of the theory and models.

Finally, the reformulated theory will be used to re-implement and perhaps modify the models produced in EMIL-S in order to test these models in similar but different cases. We consider this replication and extension to be essential to the demonstration of the validity of our results.

On the methodological side, the practice of evaluating social simulations builds on the long tradition of both computer simulation and experimental research. The methodologies proposed for computational models of complex social phenomena usually require three levels of testing [19, 20, 25]. The first one will have been performed by the simulations execution task (see 7.4)

The second test is for external validity, when the insights and conjectures gained from the model are applied to the real system in laboratory experiments, or in natural conditions [25]. This will be done by the aforementioned comparison between empirical data resulting from Open Sources task (see 7.2).

Finally, the third test is for domain validity. This process involves aligning or docking two (or more) models that incorporate different mechanisms so as to explain the same phenomena, in order to determine under which conditions they can produce equivalent results [2]. In this project, we will perform an internal test of domain validity, in order to ascertain the minimum agent complexity and the minimum number of agent levels (i.e., individual agents vs. groups, institutions, society) needed to explain the phenomena in object.

7. Conclusions

In this paper we have presented the EMIL project, a simulation project on complex social systems, whose objects of investigation are both emergence processes and immergence processes, which are peculiar to complex social systems. As mentioned, the scientific aim of the EMIL project is the analysis of norm innovation by means of a simulation-based investigation.

We have specified a number of crucial questions subtending the whole project (in short, what is the difference, if any, between a convention and a norm? What are the mechanisms by which new norms are conceived; the conditions of their spreading; the circumstances under which they become institutionalised; and the processes through which they decay?), and we have pointed out how the EMIL project shall endeavour to provide an answer to them.

Finally, we have sketched out the EMIL workplan, showing the main scientific and technological challenges, the focal articulations and the links between the tasks.

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