Emergent and Immergent Effects in Complex Social Systems

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Abstract

In this paper the notion of emergence in complex social systems is rediscussed as a necessary instrument for a theory of the macro-micro link. Referring to Schelling's model of segregation, *emergent* effects are defined as effects *generated* by (inter)acting micro-social entities, and implemented upon, but not incorporated into, their rules. In the successive section, the *way back* from macro to micro, i.e. downward causation, is examined. Simple and complex loops are distinguished, with reference to concrete examples drawn from the social scientific and the computational literature. Next, how a given macro-effect is implemented on the lower levels is shown, and two specific mechanisms of implementation, 2nd order emergence and immergence, are discussed.

Keywords: emergence, immergence, 2nd order emergence, social complexity.

Introduction

At the beginning of the last century, some social scientists and anthropologists (Alexander, 1920; Broad, 1925) referred to emergent the macro-social as properties that *cannot* be *deduced* from properties at the lower social level. This assertion was heavily criticised (Hempel and Oppenheim, 1948) and argued to build on a logical confusion between propositions and properties. As the epistemologists observed, propositions, and not properties, can be deduced. Consequently, the emergentist assertion must be referred to a given theory at a given stage of its development. While doing so, the assertion is weakened and transformed into a relativistic one, which states that propositions about macro-social properties cannot be deduced from propositions about micro-social ones under *current theoretical boundaries*.

However, such a formulation dispenses away with the notion of emergence at once: in the new relativistic assertion, emergent properties are simply not (yet) deduced. Hence, what emerges is what is (still) unexplained. Once explained (Epstein, 2007), any phenomenon ceases to be emergent. Consequently, the notion of emergence is lacking any scientific value.

In the present paper, we take a different perspective on the subject matter. We start from a crucial aspect of complex social systems, i.e. the difference between implementation and incorporation: a macro-social entity is always implemented on a micro-social one since it may act and take effect only through the actions of micro-social entities, i.e. individuals. Sometimes, a macro-social entity may be incorporated into a lower level one, when it is represented within it, for example within its rules.

On the grounds of such a fundamental distinction, we may define as *emergent* any effect implemented upon (inter)acting micro-social entities but not incorporated into them.

In the next section, we will briefly present a multi-level process, i.e. *generation* from micro to macro, and discuss emergence in social complex systems as a portion in the process of generation. We will do so while shortly illustrating Schelling's model of segregation.

In the successive section, we will discuss the *way back* from macro to micro, i.e. downward causation, a process that is certainly not new to the scientific community (see Campbell, 1974). Indeed, the micro-macro dynamics may be shown to consist of several, simple and complex, feedback loops (see Andersen et al., 2000).

In the third section, we will illustrate how a given macro-effect can be implemented on the lower, intand will introduce the distinction between

- immergence, where macro-social properties cause new micro properties that reproduce or support the effect. As a result, emergent effects may even come to be partially incorporated into micro-social systems, but this is not necessarily so. In any case, it is not the representation of the effect per se that implements the macrosocial effect, but a new property, mechanism or rule, arising from the higher-level properties.
- Incorporation, in which the emergent effect gets represented in the producing system, and this representation contributes to replicate the effect.

In these different types of implementation, one can envisage a quintessential feature of social complexity. A typical example is norm-emergence, and more specifically,

norm-innovation. In our view, norm-innovation is characterized by the occurrence of two complementary processes, emergence and immergence: norms cannot emerge unless they simultaneously immerge into the agents' minds. In another paper (Andrighetto et al., 2007), we present a normative agent architecture and illustrate its functioning.

Final remarks conclude the paper.

Generation and Emergence

For the sake of the present analysis, we will assume that generation is ultimately coincident with deduction (a view that is shared by some computer scientists and simulators, see Epstein, 2007). We will then reformulate the abovementioned notion of emergence in terms of generation, rather than deduction. I think no one, not even the so called old emergentists, would deny that macro-social properties are *generated* by micro-social ones. But what does this really mean?

Consider agent-based social simulation. A number of interesting social phenomena can be generated by this means. Take the example of segregation: in the famous model by Schelling - a variant of which can be accessed on the Internet (see Wilensky's NetLogo Segregation model <http://ccl.northwestern.edu/netlogo/models/Segregation>) - two randomly distributed groups of agents move on a two-dimensional grid according to a simple rule of (un)happiness with one's neighbourhood. When agents are unhappy - e.g., are surrounded by out-groups - they move to a new random location.

As one can easily perceive, under such conditions clustering is soon bound to emerge, even with a highly inclusive rule (agents are happy with the majority but not the totality of neighbours). But the effect in question will become more visible for increasing values of the rule: the higher the unhappiness with own neighbours and the consequent propensity to move away from them, the stronger the effect. At the onset of simulation, no segregation is visible on the screen, but after a number of ticks - depending on the rule's value - it inevitably appears. We can say that segregation is generated, *grown* by the model, or more specifically, it is generated by the happiness rule.

To state it otherwise, micro-social entities generate effects at the macro-social level that they do not perceive, nor *a fortiori* aim at. Part of the generative process is external to their minds. Nonetheless, the generative process occurs *de facto*, and takes effect: no agent in Schelling's model aims at the effect brought about and observed on the grid.

Here, it is of some interest to notice that, although the programmer and the scientist did in fact aim at this effect, they did not generate it. They simply brought about the conditions for its generation. This remark leads us to better specify our notion of generation, differentiating it from concurrent types of causation. A conclusive analysis of causation is by far beyond the limits of the present work. However, one can say that causation includes producing effects by creating the conditions for them to arise or be generated. For example, when Nero Wolf constantly and moderately watered his orchids, he created vital conditions for their growth. However, not him, but the fertilized ground generated the beautiful flowers. The difference resides in a special type of causation: a generative cause puts the effect into existence. On the contrary, a producing, non-generative cause creates the conditions for a given effect to be put into existence.

The Way Back: Downward Causation

Can an emergent, macro-social property generate effects at the lower level? Yes, indeed. There are two main ways in which downward causation occurs:

- *Simple loop*: this consists of the closure of the macro-micro circuit. The emergent effect retroacts on the lower level by determining a new property of the generating system.
- *Complex loop or implementation*: the emergent effect determines new properties by means of which the effect is reproduced again. This includes two sub-processes
    - Immergence, i.e. the process by means of which the emergent effect modifies the way of functioning of the generating system, affecting its generating rules or mechanisms in such a way that it is likelier to be reproduced.
    - 2nd order emergence (or incorporation): i.e. the process by means of which an emergent effect is recognised by the producing systems and by this means, the effect is likelier to be reproduced (Dennett 1995, Gilbert, 2001).

Emergent effects may retroact on their generating systems either closing the circuit, or opening up a new loop.

Simple loop

The emergent effect retroacts on the generating systems, determining new properties that might interfere negatively or positively with the micro systems' further activity. This is the case with a number of properties, such as rights, social status and social power, as well as the evaluations that agents form on one another (for example, reputation).

Let us see one example of simple downward causation: the power of negotiation.

Dependence Networks. In a common environment, actions done by one agent take effects on the goals of other agents. These are limitedly self-sufficient in the sense that they not always possess all the resources required to achieve their goals. Under these conditions, social dependence networks (Sichman et al., 1994; Sichman and Conte, 2002) emerge as interconnections among agents endowed with a finite number of goals and resources for achieving them.

Suppose for example that in the set of agents <a, b, c>, a is endowed with goal *p* and action *a(q)*, while b and c are both endowed with goal *q* and action *a(p)*. Their interconnections result in a dependence network, where agents b and c are socially dependent on a, while a OR-depends on either b or c. In turn, this non-uniform distribution of exchange power determines a new effect at the lower level: agents derive an equal power of choice, or, as we called it, negotiation power (cf. also Conte et al. 1998). In particular, a gets a higher negotiation power than either b or c: a will be in the position to make a choice, i.e. to choose its partner of exchange, while b and c have no choice. Presumably, due to this heterogeneous distribution of power, exchange will provide unequal outcomes (payoffs) to the participants, where agent a will be better off than either b or c.

This example clearly shows that an emergent effect (for example, a dependence network) may affect the lower level. This type of downward causation - or, in our terms, *downward generation* - generates new properties (negotiation power) of the lower level systems, interfering positively or negatively with their successive achievements.

A problem about downward causation is to what extent it contributes to further dynamics in the global system. Undoubtedly, properties like social power, including negotiation power, and reputation have a definite but indirect impact on agents' further achievements: agents may suffer from or enjoy their effects in force of the actions that others, who interact with them, undertake based on their representations of such properties.

Sometimes, these new properties not only interfere with the degree of adaptation of the individual agents, but also set off new emergent effect at the higher social level. This is what we call a complex loop.

Complex loop (Implementation)

Sometimes, this retroaction on lower levels may start up a new complex dynamics, by means of which the new properties reinforce or reproduce the emergent effect. The effect at the higher level more or less gradually gets implemented, selects a specific routine by means of which it is (repeatedly) executed by the individual agents.

When does this happen, and how? This is what we turn to in the next two sub-sections.

Immergence. Here, the macro-social property affects the generating systems through the latter's mechanisms, increasing the probability to be reproduced by them.

Let us consider social conformity, i.e. behavioural regularities, as a fundamental factor of social regulation. According to Mary Douglas (1986), agents "squeeze one another" into what result to be common practices, or social institutions. In other words, as the swarming behaviour of lower species shows, collective effects may be implemented on simple rules with no need for a perception or understanding of the resulting effect.

To be noted, immergence is not an exclusive of simple organisms. Even among humans, behavioural regularity may be implemented on a number of different mechanisms, which include but are not reduced to a real majority rule. Indeed, the latter is not always applied, nor is always efficient (see below **Stalemate**). Behavioural regularities obtain from more or less intelligent forms of inter-agent adaptation (for a review, cf. Conte and Paolucci, 2001; Conte, 2002), which include, beside the classic typologies of social learning, (social facilitation, local enhancement, imitation, etc.), less known mechanisms:

- *effect arena*, by means of which others' behaviour b_i in a common environment forces each one to an increasingly reinforced behaviour b_{i+n} in order to maintain efficiency (in a noisy pub, each must raise own voice on others' to be barely audible by one's neighbours). Obviously, no-one wants the noise to grow, nor needs to perceive that it is growing. A special case is the *vulnerable position,* in which agents are urged to behave as others do to avoid a risky position (for example, cars are forced to speed up on the highway).
    - Emergent effect: asymptotic increase of behavioural regularity b_i on one of its dimensions.
    - Immergent rule: "update b_i to b_{i+n} to maintain effect".
- *Garden-party shower*, in which each can tell what is going on from observing others, and conform to it in order to obtain a shared, but not yet common result: people will look for repair when observing others do the same, as they infer that it is raining (cf. also Searle, 1999).
    - Emergent effect: behavioural regularity.
    - Immergent rule: "if others' behaviours is more efficient to own goals, adapt to it".
- *Social monitoring,* in which agents look for conventions and social rules in force in the settings they are involved in, by checking others as sources of information (cf., Conte and Dignum, 2001).
    - Emergent effect: conformity
    - Immergent rule: "behave appropriately,

and check others to know what is appropriate under current circumstances"

Now, the circuit from micro-social properties to macroscopic emergent effects becomes recursive. Societies are characterized by out-of-equilibrium phenomena and processes of this sort. Precisely for this reason they require a generative approach that couples bottom-up and top-down process.

Immergence of Norms. The most striking example of immergence is social norms. Social norms are social prescriptions implicitly transmitted from one agent to another, based upon deontics of the type "one *must* do …", "people are obliged to … ", sometimes conveyed under evaluations in the form "it is good/bad to do …".

Norms emerge as a mechanism of social regulation or to solve problems of coordination. agents do not need to represent the effects of norms in order to comply with them. All they must do is accept the norm. How is this possibile?

In a view of norms as two-sided, external (social) and internal (mental) objects (Conte and Castelfranchi, 1995; Conte, 1998; Conte and Castelfranchi, 1999, etc.), a norm emerges *as a norm* only when it emerges *into the minds* of the involved agents, not only *through* their minds. The mind is an integrated system for storing and manipulating representations to achieve goals (see Miller, Galanter and Pribram, 1960). In other words, it works as a norm only when agents *recognise* it as a norm. Norm emergence implies its *immergence* in the agent's mind. A social norm is a norm only after its immergence. When its normative, i.e. prescriptive, character is recognized by the agent, the norm gives rise to a normative behaviour of that agent. Thus, immergence is a necessary correlate of emergence of at least a subset of macro-social phenomena, such as norms.

One still insufficiently explored aspect of norms is the mechanisms allowing them to affect the behaviours of autonomous intelligent agents, or to state it other wise, that implement them. Norms not only regulate behaviour but also act on different aspects of the mind.

In Andrighetto et al. (2007), an analysis of the *inter agents* and *intra agent* processes needed to deal with norm emergence is presented. On the one hand, inter agents processes contribute to characterize the transmission of the norm; on the other hand, intra agent properties and processes define its immergence. As to the inter-agents processes, in that paper special attention is paid to the mechanisms of emergence and diffusion of entities or properties at the aggregate level, from interaction among agents. As to the intra-agent processes, a normative architecture designed for norm recognition, innovation, compliance and defence, is presented.

Incorporation (2nd Order Emergence). Sometimes, agents gradually become aware of the effects that they contribute to generate. In this case, they develop a specific type of property, the mental representation of the emerged effect. This is what some authors call 2nd order emergence.

Sometimes, agents' representations of emergent effects modify their actions, thereby taking further effect on the higher level. The social dynamics becomes recursive. How can it happen? As described in Dennett (1995), the process called 2nd order emergence is insufficient to account for this complex dynamics since beliefs do not automatically trigger action.

Indeed, sometimes becoming aware of a given emergent effect may interfere and even counteract it.

Segregation. In his replication of the Schelling's model, Gilbert (2001) provides an example of 2nd order emergence that reinforces the emergent effect (in this case, the clustering). This happens because the new belief provides a guideline for action, for example "move only if there are spots where you will be happier". The new belief reinforces the macro-social effect (a stronger effect of clustering) to the extent that it allows a more efficient satisfaction of the local rule (the rule of happiness). The link between the new belief and the consequent adjustment of the rule affects the dynamics of the whole system. The macro-social effect is reinforced by the mental pattern that includes the new belief and the rule execution.

With this type of 2nd order emergence, clustering is implemented on the generating rule. By this means, Gilbert showed how and why 2nd order emergence may in turn affect the dynamics of the global system, and turn it into a complex bidirectional micro-macro loop.

Stalemate. Consider the famous *witness effect* found out by Latané and Darley (1970) in social emergencies. A great deal of experimental and observational evidence shows that the probability of intervention in these situations drops dramatically when bystanders exceed number *three*. Why? The authors put forward a rather elegant explanation, according to which a majority rule (i.e., check what the majority is doing under uncertain conditions) leads to a stalemate when a majority exists, i.e. when bystanders are at least three. Under such conditions, since each one checks what the majority is doing, nobody moves. Participants are frozen in the role of *witnesses*.

The witness effect provides a clear example of emergence: although no one intends to bring it about, the effect is generated by the majority rule, precisely as much as segregation was generated by the rule of happiness. A fragment of the generative process is emergent. To see this, consider that agents may be trained to avoid the witness effect, which is a highly socially undesirable one, simply becoming aware of it.

Moreover, this example illustrates that an emergent effect may modify the mechanism that produced it at the lower level, without being recognised by the generating system. In our example, the stalemate reinforces the local rule: the more likely the stalemate (macro-effect), the stronger the local rule (majority rule): agents are lesser and

lesser likely to break it. The witness effect retroacted on the producing systems temporarily reinforcing the rule. In this process of *implementation*, agents have no idea what is going on. All we may say is that the witness effect is implemented on a rule at the agent level, i.e. the majority rule, which gets reinforced by the effect in question while at the same time reproducing it. There is a temporary modification, namely a reinforcement of the local rule, produced by the macro-social emergent effect.

Advantages of the Present Approach

The present model attempts to contributing to the study of the micro-macro link, and more specifically to a generative view of this process. The generative paradigm will play a decisive role in future developments of the social science, as indicated by some evidence:

- recent official formulation of the generative paradigm for the social science (cf. Epstein 2007)
- fast development of generative methodologies for the study of social phenomena (agent based social simulation)
- continuous growth of simulation toolkits and platforms (from swarm libraries to the *logo languages)
- accessibility of such languages and toolkits to non-expert programmers, etc.

However, generative social science is still formulated in a somewhat unsatisfactory way, namely as a bottom-up process (again see Epstein, 2007, but more generally see the vast majority of simulation and computational models of social and economic processes). With the exception of Axelrod's tribute model (1995), the "bottom" is usually *given* in the rest of the models.

Hence, the notion of emergence itself is usually intended as a one-way process. Indeed, this notion is being substituted by that of generation.

The present analysis can contribute to

- a theory of emergence as distinct from generation
- a view of the micro-macro link as a recursive loop, in which emergent effects at the macro-level retroact on the lower levels, modifying them, thereby

providing a more dynamic, generative view of the micro-level entities.

Concluding Remarks

Society is generated by its members, and is implemented on them: it works thanks to and through their actions and their minds. But this does not implies that society's members aim at, nor are aware of, the way society works.

Moreover, they may be aware of emergent effects, but still this representation is not what makes society works. Sometimes awareness is a requirement for the implementation for society on its members sometimes, this is not the case. An interesting empirical question is when it is, and when instead new properties do not imply a representation of the effects they contribute to produce. How it may happen is a question that we reserve for future work.

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