Abstract
Emergence has a long and controversial history. In this paper we briefly review the primary strands of the debate, paying attention to its use in the fields of philosophy of science and mind, social science and systems theory including the theory of complex systems. We argue that it is important to recognize why emergence in social systems is fundamentally different from other natural systems. The key characteristics of reflexivity are discussed and a distinction between two classes of emergence proposed. Non-reflexive emergence: where the agents in the system under study are not self-aware, and Reflexive emergence: where the agents in the system under study are self-aware and linguistically capable. We specify the generative processes we believe are associated with each of these categories and argue for the adoption of this distinction in both theoretical and practical modeling of human social systems.

Introduction
The concept of emergence has become widely used within the social simulation community. The concept continues to be vaguely defined and to stand in for different propositions about social generative mechanisms. Within the social simulation community, the concept has focused primarily on upward causation (consistent with its usage within complex systems theory and associated research programs such as those into artificial life) (Sawyer, 2003). Few attempts have been made to reconcile this use of the concept with its wider philosophical use and with the parallel debates about the micro-macro link and the relationship between structure and agency within the social sciences. Relatively little attempt has been made to identify the defining characteristics of human social systems and to critically re-examine the concept within this context. Similarly derivative concepts such as downward causation and ‘immergence’ (Castelfranchi, 1998b) have only recently begun to be explored in the simulation of human social systems. One current attempt to advance our understanding of upward and downward causation in social systems is the EU funded project Emergence in the Loop (EMIL). EMIL is concerned to explicate the mechanisms of emergence and immergence within the context of human social systems by focusing on processes of ‘normative’ self-organization. The aim is to contribute both to the conceptualization of emergence as well as to how social emergence may be meaningfully modeled.

We argue that the ambiguity, opaqueness and lack of specification of the concept of emergence currently present a significant barrier to its application to the study of social systems. Furthermore we argue that social systems represent a specific class of system, distinct from other natural systems where emergence may be studied. This is due to the capability of human agents to distinguish ‘self’ from ‘other’ and in doing so reflexively distinguish and interact with their environment, greatly increasing the scope and complexity of the emergent structures which are possible. As a consequence we argue that both the form and mechanisms through which emergence occurs are not entirely analogous between natural and social systems.

In this paper we review the historical and contemporary definitions of emergence, paying particular attention to its use in the fields of philosophy of science and mind, social science, general systems theory and complexity theory. This is followed by a discussion of the distinct characteristics of social systems and the implications of this difference for social simulation. The key characteristics of reflexivity will then be discussed and a tentative framework will be proposed for two classes of emergence, specifically:

- Non-reflexive emergence: where the agents in the system under study are not self-aware, and
- Reflexive emergence: where the agents in the system under study are self-aware and linguistically capable.

We then specify the generative processes associated with each of these classes.

In proposing these two classes we do not preclude the distinction of other specific forms of emergence, but seek to highlight the need for differing approaches to the study of different system types, with a view to enhancing the explanatory power and applicability of the emergence concept to various system classes.
A Brief History of the Concept of Emergence

The notion of emergence has a long history, having been invoked in a number of disciplines with varying degrees of centrality to the theoretical and methodological development of associated fields. The concept remains ambiguous and contentious, covering:

...a wide spectrum of ontological commitments.
According to some the emergents are no more than patterns, with no causal powers of their own; for others they are substances in their own right... (Clayton, 2006: 14).

The first explicit use of the concept has been attributed to George Henry Lewes, in 1875 (Ablowitz, 1939). Following Lewes the concept rose to prominence primarily within the philosophy of science but more recently can be seen to have been advanced within three distinct streams: philosophy, particularly philosophy of mind; systems theory, in particular complex systems; and social science where it has largely been referred to under the heading of the micro-macro link and/or the problem of structure and agency. Interestingly there has been relatively little cross influence between these streams. While it is beyond the scope of this paper to present a full comparison or to attempt a synthesis of the different streams, some brief comments are offered on the alternative perspectives and contribution of each to the wider debate.

The Contribution from Philosophy of science

The philosophy of science and philosophy of mind stream remains focused on explaining differences between organic and inorganic elements in order to explain the qualitative difference between known forces, but rather to the system harnessing existing forces for its own ends. The problem is to understand how this harnessing happens, not at the level of individual intermolecular interactions, but overall – as a coherent project. It appears that once a system is sufficiently complex, then new top down rules of causation emerge (Davies 2006: 48).

For Davies then, top-down causation is associated with self-organization. For Davies it is the ‘openness’ of some systems that ‘provides room’ for self-organizing process to arise, but he concludes, ‘openness to the environment merely explains why there may be room for top-down causation; it tells us nothing about how that causation works.’ The devil then, is in the detail of the mechanisms specific to particular processes in particular contexts and particular phenomenal domains.

The contribution from Social Science

The micro-macro problem – the relationship between the actions of individuals and resulting social structures and the reciprocal constraint those structures place on individual agency – has long standing in social science. The problem is central to many social theories developed throughout the 19th and 20th century. Examples include:

4. Are composed of lower level entities, but lower level entities are insufficient to fully account for emergent entities (irreducibility).
5. May be capable of top-down causation.
6. Are characterized by multiple realization or wild disjunction (Fodor, 1974) (alternative micro-states may generate the same macro states).

A key concept is supervenience: a specification of the ‘loose’ determinisms held to apply between levels such that ‘...an entity cannot change at a higher level without also changing at a lower level’ (Sawyer, 2001: 556). Within this stream prominence of place is given to both downward and upward causation. Clayton and Davies (2006) specify downward causation as involving macro structures placing constraint on lower level processes hence 'Emergent entities provide the context in which local, bottom up causation takes place and is made possible’ (Peterson, 2006: 697). This concept appears similar to that of ‘immersion’ within the social simulation literature and is worth exploring a little more fully as it is otherwise absent within the approach to emergence typical of complex systems inspired approaches (Sawyer, 2003, 2005).

Davies (2006) argues that the mechanism of downward causation can usefully be considered in terms of boundaries. Novelty, he argues, may have its origin in a system being ‘open’. If novel order emerges it must do so within the constraints of physics. He concludes:

... top-down talk refers not to vitalistic augmentation of known forces, but rather to the system harnessing existing forces for its own ends. The problem is to understand how this harnessing happens, not at the level of individual intermolecular interactions, but overall – as a coherent project. It appears that once a system is sufficiently complex, then new top down rules of causation emerge (Davies 2006: 48).

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Marxian dialectical materialism (Engels, 1934) built upon by, among others, Vygotsky (1962) and Lyont’ev (1978); the social constructionism of Berger and Luckmann (1972); Giddens’s structuration theory (1984); and the recent work of critical realists (Archer, 1998; Archer, Bhaskar, Ciollier, Lawson, & Norrie, 1998; Bhaskar, 1997, 1998). These alternative theories are frequently founded on differing assumptions, extending from the essentially objectivist/rationalist theory of Coleman (1994), through the critical theories of Habermas and then to the radical constructivism of Luhmann (1990; 1995).

Fuchs & Hofkirchner (2005: 33) classify into four categories the ontological position of alternative approaches to the micro-macro relationship. The majority of existing social theory, they argue, fall into one or other of the first two categories: individualism and sociologism. Neither of these ‘paradigms’ provides a theoretical foundation which supports exploration, let alone advance understanding, of the interplay between agency and structure. The third category, dualism, was the target of the original emergentists. Only those theories categorized as dialectical therefore have relevance. Even here, it is reasonable to conclude that little practical advance has been achieved, as most positions result in a straddling of bottom up and top-down arguments and/or suffer from excessively vague conceptualisation. What has been largely agreed, despite the very different theoretical and often inadequate handling of this problem, is that structure and agency come together in activity or in bodyhood – the specific psycho-motor state at the instant of enaction. Both Vygotsky and Giddens, for example, focus on action as the point of intersection between human agency and social structures.

The contribution from Systems Theory

Systems language was clearly evident in the work of the early emergentists and in a great deal of sociology and anthropology – notably that of Margaret Mead and Gregory Bateson. However, ‘systems’ as a focus of systematic research arguably took form with Bertalanffy’s attempt to establish a General Systems Theory in 1950 (Bertalanffy, 1950). As the science of ‘wholes’ systems theory stands in contrast to reductionisms concern with parts. In many respects systems theory was put forward as a counter to what was perceived as excessive reductionism dominating scientific discourse during much of the 20th century.

While in the early stages of development of the theory, systems tended to be modeled as ‘black boxes’ (effectively masking the relationship between micro and macro elements), the application of the concept to social science, in particular through the development of social cybernetics (Keeney, 1987) and soft systems approaches (Checkland, 1988) provided a theoretical lense as well as methods useful for describing the systemic behavior of social systems. While the aspiration of GSM to establish a general science of systems is generally regarded to have failed (Jackson, 2000), systems approaches have contributed valuable methods for the study of the interplay between levels. The Systems view of emergence was founded on:

- Holism; the whole is greater than the sum of its parts.
- A concern with feedback both positive and negative.
- A concern with boundaries and boundary conditions.

More recently the development of complex systems theory and its application to natural, social and cognitive phenomena has provided additional concepts upon which much current debate about emergence draws. Many of these concepts and methods have become widely used within the multi-agent modeling community (Castelfranchi, 1998a; Gilbert, 1995; Holland, 1998).

Within contemporary debate, and in contrast to the position taken by the British Emergentists who argued that irreducibility was the exception (Eronen, 2004), most real world systems are now argued to be non-linear (Kauffman, 2000; Kauffman, 1993, 1996; Stewart, 1990). It is non-linearity which contributes to these system’s capacity for novelty and unpredictability in principle, through the presence of deterministic Chaos (Lorenz, 2001; Williams, 1997) and/or equifinality. Equifinality as it is known within systems theory, or the principle of ‘wild disjunction’ as it is known in philosophy, refers to a system where a single high level property may be realized by more than one set of micro-states which have no lawful relationship between them (Richardson, 2002b, 2002a; Sawyer, 2001). As there is no a-priori basis by which the likely micro state can be determined, such systems are irreducible and unpredictable in principle.

Summary

The concept of emergence has led to the establishment of a number of general principles which describe the relationship between micro and macro phenomena, as well as some methods and techniques for identifying and exploring it. Specifically, we can conclude that there are systems which:

- are inherently analytically reducible (to which the concept of emergence does not apply);
- are analytically reducible in principle but difficult to reduce in practice and/or where an advance in science/knowledge is needed for reduction to be possible because the results were ‘unexpected’ (Chalmers, 2006) (to which the concept of ‘weak’ emergence can be applied);
- are not reducible in principle (to which the principle of ‘strong’ emergence is relevant).
Towards a specification of the Generative Processes
Particular to Human Social Systems

Our ontological starting position is that physics constrains chemistry; chemistry constrains biology and biology, sociality – in other words we advocate a form of naturalism. However, at each of these ontological levels, novelty occurs due to the emergence of unique macro-configurations within the space of possibilities allowed by the lower level. There is downward causation through the way in which higher order patterns change boundary conditions at lower levels and constrain the situation specific interactions that are possible. This suggests an instantaneous co-penetration of levels (synchronic emergence) and also a sequential one (diachronic emergence).

The nature of the micro agents (their characteristics and action potentials), the heterogeneity and the structure of their relationships will influence the range and type of macro structures which can emerge. So far, though, there is nothing here that is not true of any other natural system in which there is the presence of non-linearity. What, then, are the fundamental characteristics of human agents, and what effect might the range and type of action potentials have on emergent social structures?

Human agents are cognitive. Within the biological sciences human cognition is recognized as involving nervous system activity, where external perturbation on sensory surfaces results in a set of behavioral dispositions and responses to the environment. Like many animals, Humans form social systems by coordinating their behavior through reciprocal action. Unlike many other animals, Humans are capable of coordinating their coordination of action by way of language. The biologists Humberto Maturana and Francisco Varela developed a comprehensive theory of this process – the theory of autopoiesis (1980) and subsequently explored its implications for human social systems (Maturana, 1988a; Maturana, 1988b; Varela, 1981; Varela, 1987; Varela, Thompson, & Rosch, 1992). Elsewhere, we have argued that the theory of autopoiesis and its associated theory of enactive cognition is consistent with complex system ideas and that when combined with complexity, provides one possible pathway for understanding the substantive mechanisms of sociality (Goldspink & Kay, 2003b; Goldspink & Kay, 2003a). As a part of this work, we argued that social systems represent a distinct class of complex systems and that this difference was significant in terms of the range and type of emergent structures which it implied. From this, two systemic mechanisms suggest themselves as the generative source of emergent patterns which we commonly refer to as social structures – the first of these is pre-linguistic (and by definition non-reflexive) and the second involves language and hence is reflexive (Gardenfors, 2006).

Non-reflexive social emergence

The pre-linguistic mode operates through the mechanism of structural coupling between agents. Structural coupling will arise between biological (auto-epoietic) agents which have sufficient cognitive range (behavioral repertoire) if they are located in a common environment. Assuming that their phylogeny and ontogeny is such that they can co-exist through the process of recurrent mutual perturbation, each will adjust its structure so as to accommodate the other – their structures will become mutually aligned or structurally coupled. This process has been approximated in a simulation by Stoica-Kluver and Kluver (2006).

An observer may notice regularities in the resulting patterns of interaction and these may be labeled as ‘norms’ for example. These ‘norms’ represent mutual accommodations, and an observer might attribute to those accommodations some social ‘function’. The accommodations an agent makes to remain viable and to maintain its organization (i.e. which ‘satisfice’ the constraints and allow conservation of identity) based on its unique ontogeny (structure resulting from its history of interactions in a variety of domains).

Here the emergent structure can be seen to be ‘in’ (i.e. internalized within its own cognitive structure) each agent to the extent that each has had to make structural adjustments to operate in the shared domain. The structural adjustment each needs to make in order to persist will, however, be unique – in other words the structural accommodations each has made in order to contribute to the patterns we are calling ‘norms’ for example, will not be the same. The structure, then, can also be regarded as ‘in’ the network, as it is the intersection of these disparate agent structures which gives it its particular form at a particular time. As any agent could leave the domain and
have minimal effect on the resulting pattern, each agent’s ‘contribution’ will be relatively small. The pattern that is labeled as ‘norm’ can be thought about as like a hologram. The whole is in every part (agent) such that removal of parts (agents) reduces the resolution (coherence) but does not constitute loss of overall pattern. However, the loss of too many components may reduce the coupling to the point that the existing pattern de-coheres and transforms into something different. Each agent contributes to the pattern formation, so it is conceivable that the pattern will only be realized with some critical minimal number of agents present which have had a sufficient mutual history to have aligned their structures (become socialized within that context). As agents leave, the coherence may degrade until, beyond some critical point, it may de-cohere or take up an alternative ‘shape’ due to the influence of external perturbations (acting through the remaining agents as points of intersection of domains), or to the entry of new agents with different ontogeny.

Note that this emergence is consistent with that which we would observe between any complex natural systems – the emergent pattern is the product of local interactions only. This is relatively easy to model. While feedback from macro level to the micro is possible, it is only by means of effects of collective action on the environment and then the environment on the individual – i.e. downward causation. In natural systems, the local level interactions between agents are constrained by the existing structures of the agents and the state of their environment. With biological agents the system is open in that any emergent structure is possible as long as it remains consistent with the biological viability of the agents as living (autopoietic) entities. This biological constraint includes limits to environmental conditions conducive to life (i.e. not too hot or too cold, the need for energy, limitations to sensory channels, channel bandwidths and affective/psychomotor response capabilities etc). These are primarily a product of phylogeny (the evolutionary history of the organism at the level of the species) rather than ontogeny (the history of development at the level of the individual), and are therefore slow to change and not under the control of the emergent social system. As a consequence the basic dimensionality of the phase space of the social system does not change over the time frame of interest for understanding social systems. The dimensionality of the phase space is determined by the dimensions of variability possible by individuals – i.e. the plasticity of their nervous systems and by higher order dimensions which emerge from their interaction.

**Reflexive Social Emergence**

Our sensory surfaces are designed to detect difference in some dimension of the world and our cognitive apparatus is thus geared to make distinctions. Once our cognitive complexity exceeds a critical threshold (Gardenfors, 2006) these distinctions can be represented in language. Maturana and Varela (1980) describe language as involving the co-ordination of the co-ordination of actions – i.e. language provides a meta process by which agents orientate themselves within a world. Structural coupling can arise purely through behavioral coordination of action (as discussed above), but it can also take place in and through linguistic exchange – the mutual co-ordination of co-ordination of behaviors. This gives rise to a consensual linguistic domain characterized by a more or less shared lexicon. This process has been simulated using both shared referents and simple structural coupling in the absence of objective referents (Gong, Ke, Minett, & Wang, 2004; Hutchins & Hazlehurst, 1995; Steels, 1997, 1998; Steels, 2005; Steels & Kaplan, 1998; Steels & Kaplan, 1999), as has the emergence of a rudimentary grammar (Howell & Becker, n.d; Vogt, n.d).

The advent of language radically increases the behavioral plasticity of agents and has significant implications for the dimensionality of the phase space and of the resulting higher order structures it can generate and support. This is because language makes possible the emergence of domains of interaction which can themselves become the target for further linguistic distinction and hence new domains. In other words, language allows the agent to make distinctions on prior distinctions (to language about its prior language or to build further abstractions on prior abstractions). This supports the possibility of infinite recursion and infinite branching (there are no doubt biological constraints on this in humans). Furthermore, a capacity to distinguish (label or categorize) processes supports reification and this simplifies the cognitive handling of processual phenomena and allows the resulting reifications to be treated by the agent in the same manner as material objects.

These capabilities greatly expand the structural flexibility of the agents: they can now invent shared epistemic worlds. The phase space of agent cognition is now based primarily on constraints of ontogeny rather than phylogeny and is hence under the influence of the agent/s. Language makes possible a further major qualitative difference in natural and human social emergence. Humans (and possibly some other primates, cetaceans and elephants)\(^1\) have developed sufficient cognitive capacity to become self-aware and as such exhibit reflexive behavior. This occurs when the agent is capable of distinguishing ‘self’ and ‘other’ i.e. the agent can entertain the notion of ‘I’ as a concept and treat that concept as an object. The advent of this capacity for reflexive identity also supposes the existence of a range of conceptual operators that act on

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\(^1\) It is important to note that we can infer the existence of threshold effects here but cannot precisely specify the critical points of complexity at which self-awareness and language becomes possible. The ability for language is of course evident in species other than humans, but the degree to which their linguistic plasticity involves or enables reflexivity in the system is a subject for further research.
identity – identity construction and maintenance becomes a part of the agent’s world creation. This gives rise to what Gilbert has called second order emergence:

second order emergence occurs when the agents recognize emergent phenomena, such as societies, clubs, formal organizations, institutions, localities and so on where the fact that you are a member or a non-member, changes the rules of interaction between you and other agents. (Gilbert, 2002: 6).

In other words, agents can now notice the patterns that arise as they interact with others and distinguish those patterns in language. For example, with the EMIL project which is concerned to understand the emergence and self-regulatory role of social norms, a reflexive agent can notice an emergent pattern of social behavior and explicitly denote it as a ‘norm’. While this denotation may be idiosyncratic (i.e. based on the necessarily limited perception of the individual agent), the agent can nonetheless act on the basis of this denotation. Once distinguished and ratified within a domain, agents can decide (on the basis of rational as well as value based or emotional criteria) how to respond – they can choose to ignore the norm or to behave in ways they believe will limit the reoccurrence of the behaviors that are outside the agreed/shared patterns of the group. Once a pattern has been distinguished in language it can make the transition to a rule – a formally stated, linguistically explicit requirement with stated conditionals and possible resources to maintain it. This suggests, for example, that an agent can form hypotheses about the relationship between a macro structural aspect of the social system in which it is a participant and then act on that hypothesis, potentially changing the structure which it participates in generating. This gives rise to a feedback path between macro and micro phenomena that is not present in any other natural phenomena.

The recognition that agents possessing this cognitive complexity form the components of a social system sets up a distinct class of emergence. This is on the basis that reflexive agents will display qualitatively different behaviors from non-reflexive through the ability to modify their own sets of behavioral change triggers. For agents which have linguistic capability, the two processes (linguistic and non-linguistic) intertwine or even become one and would not be able to be empirically disentangled. Their respective influences will only be able to be examined through simulations or by comparing agents with different (phylogenetic) capabilities (i.e. different species).

The Role of the Observer

Another significant implication of the relationships described above is the observer dependant nature of emergence in social systems. In human social systems every agent is an observer and it is the process of observation and the associated distinction-making which is the reflexive engine of emergence. In natural systems, the agents of the system are unable to observe and distinguish linguistically or to distinguish external structures as separate from themselves hence the process of observation has no impact on the dynamics of the system or the way in which emergence takes place. To some extent we can see an acknowledgement of this effect in methodological discussions within ethnography, action research (Carr & Kemmis, 1986) and grounded theory (Corbin & Strauss, 1990). In each of these methodologies the impact of the researcher on the social system under study is acknowledged and seen as part of the process. The view being proposed here is that any agent that becomes a part of the system being observed has the potential to influence that system. An agent can become a part of the system simply by being itself observed or conceived as observing by those who constitute the system. In other words, the effect of the entry of a new observing agent is to change the system boundary so as to include that agent. The boundary is itself an entity of ambiguous status – it is an epistemic distinction albeit one based on potentially ontological markers. The most elegant handling of this concept we have encountered in the context of emergence is that of Alex Ryan (2006). In most social theory, positing the observer as a necessary part of the system removes any ontological privilege and threatens either infinite recursion or paradox. Based on the position advocated here, a degree of both may well be fundamental to the type of system being described (Hofstadter, 2007).

Implications for emergence

Complex systems demonstrate a capacity to give rise to complex macro patterns as a result of local interactions between agents in highly connected webs. This local interaction can often be characterized as involving some signaling between agents. As we have seen above, in human social systems, this signaling behavior takes on a qualitatively different form. This has three key implications for our understanding of emergence that to date have largely been ignored by the literature.

1. Social systems will display an increased range of emergent possibilities: the reflexive nature of social systems implies that a greater range of emergent structures should be expected and they will be subject to more rapid change.

2. Dimensions of phase space are non-constant: As the agents in the social system define and redefine the phase space as a function of their reflexive distinctions they will create and change the dimensions of that phase space, in order to support their own viability in that space.

3. Phase space comes under control of the system and is dynamic: The dimensionality of the phase space
associated with ontogenetic parameters is derived through the self-distinguishing characteristics of the agents and can be influenced by their situated behavior.

**Conclusion**

In this paper we have argued that the notion of emergence as it is currently discussed in the literature fails to consider that alternative generative mechanisms, and hence forms of emergence, apply to different classes of phenomena. Complex systems, artificial life and artificial societies currently model bottom up emergence and systems where top down influence operates only indirectly by downward propagation of constraint, not by more direct feedback. We have argued that this is not adequate for an understanding of human social systems. We have set out two mechanisms present in human social systems – non-reflexive and reflexive; suggested a suitable theoretical frame from which they may be considered – that of autopoiesis; and examined some of the implications these alternatives may have for the behavior of systems which support them.

We have argued that autopoietic human agents display a qualitatively different range of behavioral possibilities brought about by their distinctive (biological) properties, primarily an advanced nervous system which supports the development of language and a capacity for reflexive self-awareness. These broadened behavioral capabilities, in particular language, imply that the process by which emergence occurs in social systems is fundamentally different to that which is observed in other systems populated by non-linguistic agents.

We suggest that this framework may support a more focused research program that doesn’t unnecessarily mix different classes of system under the same conceptualization. At the same time we acknowledge the possibility for yet further classes of emergence to be identified due to a current lack of understanding within the literature on the threshold points between system classes as they relate to emergence. We suspect, for example, that the locutionary, illocutionary and perlocutionary aspects of language identified by linguists may imply different mechanisms.

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