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Advances in Understanding Human Complex Systems

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Abstract: This paper seeks to comprehensively offer a concise critical overview of the recent exciting advances in understanding human complex systems. The presentation and analysis here refers to both theoretical and methodological interdisciplinary developments. On the one hand, theoretical advances radically transform our conventional vision of society, as well as the old content of modern sociological and organizational conceptions, such as leadership, unpredictability and uncertainty. On the other hand, methodological advances mainly focus on agent-based modeling as a smart and effective way of incorporating agential heterogeneity in the systematic study of human social behaviour. This ultimately entails the ongoing dynamic interplay between determinism and unpredictability, between order and chaos. Human complex systems exist somewhere in-between.

Key words: Chaos, Knowledge and Epistemology, Scientific Methodology, Leadership, Complexity and Emergence

INTRODUCTION

For all Newtonian and Cartesian cosmologies, there is a purely harmonic and deterministic universe governed by absolute (Euclidean) geometric principles and invariant objective meta-laws.

However, it is now generally accepted (almost as a common norm!) that we do live in a complex, irreversible, fluid and rapidly changing social world, which is overwhelmingly characterized by the radical absence of stability, unity, homogeneity, permanence and predictability.

Contemporary "networked" and "virtualized" society is full of diversity, fragmentation, ambivalence and turbulence. This sharply opposes to the "old", "received" or "traditional" positivist paradigm according to which we inhabit a (more or less) stable, linear and orderly world, where organization and change are fully predictable and can systematically be explained and understood in a neutral, disinterested, "context-free" and "value-free" way (as Max Weber assertively maintained).

In sum, old assumptions and beliefs are being strongly destabilized and challenged. Everywhere we look, a rule or norm is somehow changing. Leadership, for example, once seen as a direct extension of management and included getting control over things or, at least, keeping things under control, has significantly changed.

It now involves less managerial and more ethical and dynamic activities like mutually shaping organizational cultures, setting meaningful goals, seeking autonomy, increasing diversity and freedom, cultivating common visions and values, producing knowledge and motives, facilitating communication, empowering others, boosting existential and competitive intelligence, and enhancing "meta-reflexivity" or "referential reflexivity" (May, 1999) – that is, a kind of reflexivity *upon* actions (rather than *within* actions), achieved by constitutive practice outside the daily routines of a community.

This is also connected with a radical shift in our way of thinking about (and living/working in) human complex systems, away from Newton's mechanical determinism (in fact, the mechanical metaphor is now falling like flies!).

Modernist linear thinking inevitably leads us to naively consider human organizations as strictly law-dependent, impersonal, static and predictable. And if they do not possess these "iron" properties, it is just because of lack of information, miscalculation, misjudgment or, simply, bad leadership.

Advances in theory:

Since the early 1990s, the social sciences began to go "complex", with a significant array of relevant publications. Some innovative "popular" books within this field include Kauffman's *The Origins of Order*,

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Casti's *Complexification*, Arthur's *Increasing Returns and Path-Dependence in the Economy*, Nicolis' *Introduction to Non-Linear Science*, Luhmann's *Social Systems*, Krugman's *The Self-organizing Economy*, Jervis's *System Effects*, Rescher's *Complexity*, Holland's *Emergence*, Byrne's *Complexity Theory and the Social Sciences*, Kelly's *New Rules for the New Economy*, Cilliers' *Complexity and Post-modernism*, and Hayles' *How We Became Posthuman*.

The social world is nowadays seen as an open, non-linear and dynamic turbulent system, spontaneously self-produced, self-evolved and self-organized, within a continual flow of extremely rapid changes, an "infinite flux" (Gilles Deleuze).

The communicative system of Society, as Niklas Luhmann repeatedly and reflexively observed, has indeed "no centre and no head. Representation of the social totality is impossible and so is steering. The world may be adrift like a ship without moorings, but given that there is and can no longer be a captain on board to coordinate and steer the operations of the different subsystems, the rhetorics of anxiety of the critical theorists only show the superfluity of their normative mode of thought and their incapacity to come to terms with the hypercomplexity of modern societies" (Vandenberghe, 1999).

This novel analytical stance is consistently and creatively adopted by the new science called "Chaos" (originally developed and flourished within the field of physics).

The science of Chaos (Gleick, 1987) is the systematic study of non-linear processes, within dynamic turbulent systems. Examples of such systems are: the global economy and the global crisis, wars and armed conflicts, human beings and social organizations, the stock market, science and technology, the Olympic Games, football games and other sport events, the weather systems, the internet, World Wide Web, Web 2.0, journalism and journalism 2.0, etc.

We thus need to deeply revise the conventional ways of perceiving and conceiving the pluralized social universe. In such a messy context, leadership is no more a top-down phenomenon, an exercise of directly controlling outcomes and self-confidently predicting causes and effects. Traditional leaders must now realize the advent of new concepts and emergent paradigms.

Keeping these in mind, and immersed in innovative scientific efforts, complexity researchers systematically and methodologically explore the profound implications of local behaviors and actions for global structures and patterns, and conversely, the deep influence of global factualities on local discourses and individual choices (a dual, upward-downward, relational causality).

In this "relational" research setting, where change is omnipresent, the social, (dis)order, (dis)organization and (mis)understanding reflexively come from chaos, heterogeneity, autopoiesis, agonistic competition, irreducible diversity, mutual evolution and emergence.

In general, complexity research seeks to carefully identify, challenge and reconstruct some of the fundamental modes of thinking, living and working in contemporary human complex societies.

These "networked" societies are inherently chaotic systems – that is, *both* deterministic *and* unpredictable (this sophisticatedly reconciles the unpredictability of non-linear dynamic systems with a sense of *order* and *structure*!).

In other words, a chaotic system may appear completely random, but there is always an underlying generative "real" order, deeper mechanisms and hidden patterns, rules and norms, which patiently wait to be dis-covered and un-covered (*therefore, there is not such a thing as "luck"*).

But even if (positivist, essentialist or realist) social scientists someday arrive at the very final stage of "total knowledge" about these "hidden patterns, rules and norms", they will not be capable of predicting (Tsekeris, *et al*., 2008)!

To put it very simply, a human complex society (as well as any other non-linear dynamic system) can never be fully contained in any way – even by its own "creator" (in the case of a computer-simulated artificial society).

So, any ambitious, long-term planning is inescapably doomed to absolute failure. What is actually needed here, consequently, is to reflexively include ourselves, as *both* researchers *and* social actors, within this *inherent* general unpredictability (Katerelos, 2009).

But complexity theory comprehensively considers non-linear dynamic systems *in between*: they are *neither* absolutely simple *nor* completely random (encoding thus some, potentially useful, information).

As shown in Figure 1, this clearly signifies a constant cycling between chaos and order-creation (rather than order-translation). The "region of emergent order-creation" exists somewhere *between the edges of order and chaos*. Complexity permanently moves between pure determinism and pure chaos, between simplicity and randomness.

It is therefore not incompatible with the claim to (reflexive) objectivity. As far as "uncertainty" is theoretically concerned, science can and should return to its study "rather than the attempt to overcome it, and thereby, re-engage the centrality of questioning official knowledge. Researchers would be in a position to recognize their own biases and prejudices and, to the extent practicable, communicate those to the audience. They could be clear about their political objectives and offer a project for positive social transformation together with the now ubiquitous critique" (Van Heertum, 2005).

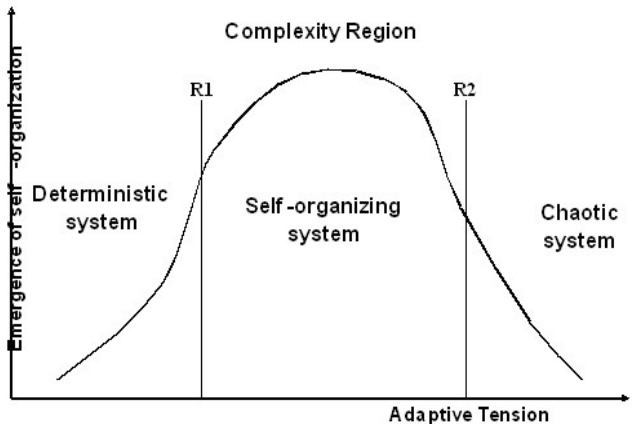

Fig. 1: The "Region of Complexity" (created by Renata Kaminska-Labbé, Catherine Thomas & Bill McKelvey)

Advances in Methodology:

Throughout the previous century, the highly static view of truth has been actively replaced by a dynamic, multi-dimensional and changing truth bounded by perspective, time and space.

To a large extent, this was due to the reflexive sensitization of modern science, from Biology to the Human Sciences, which gradually begun to self-consciously and self-critically look at itself and discover its own limits and weaknesses, especially since the first formulations of early 20th century Physics (e.g. Einstein's General Theory of Relativity, Heisenberg's Theory of Uncertainty and Prigogine's Theory of the Dissipative Structures).

Since the early 1980s, "computer simulation methodology" (Latin *simulare*, to imitate, to represent), which has been closely connected to the technology of computing, paves new scientific ways in a reflexive, interdisciplinary and boundary-breaking fashion.

The principal strategic aim of social simulation modeling is to obtain a better (deeper) theoretical *and* empirical understanding of complex social and human processes, as well as of our own (scientific) meta-theories and hypotheses, rather than to self-confidently and dogmatically make full predictions of the future – at least not beyond a relatively limited "predictability horizon".

In particular, no prediction can be decisively made if we do not seriously take into account this indispensable "predictability horizon" – that is, the "short time period during which above-chance prediction can occur in a chaotic system … *Hence, the question of prediction shifts from 'controlling accurate values' to 'controlling the error propagation of inaccurate values'*" (Katerelos & Koulouris, 2004). Of course, unpredictability is nothing but a research finding; it is not a mere axiom or an elegant theoretical slogan!

Agent-based modeling (variously called *artificial social intelligence*, or *multi-agent systems*) is an innovative branch of computer simulation and a promising quantitative method for computational social scientists, focusing on the modeling of human interactions within complex dynamic systems or organizations. It seeks to model the individual (and, particularly, the individual behavior) together with its unique heterogeneity, imperfections, weaknesses, limitations, idiosyncrasies and personal interactions.

Thus, according to this ground-breaking method, initially developed through John von Neumann's work on *cellular automata* during the 1940s, we build the model from "the bottom-up", mostly paying attention to micro-rules, and attempt to make sense of the emergence of macro-behaviors (e.g. levels of cooperation and conflict), macro-institutional structures and spatial patterns.

For example, William Sims Bainbridge (1997) smartly modeled the surprising spread of competing religious movements in a social network, following three simple rules:

(1) an individual will convert to a movement if a plurality of his associates already belong to it;

(2) an individual will tend to break ties to neighbors who belong to different movements from his own;

(3) members of one especially aggressive movement will tend to establish bonds with neighbors regardless of their affiliations, in what sociologists of religion call *outreach*.

Another characteristic example can be successfully provided by the careful methodological coupling between agent-based modeling and marketing. The valuable result here is *Agent-Based Marketing*, where a system (an artificial society or a virtual world) is strategically modeled as a collection of autonomous/heterogeneous decision-making "intelligent entities" (agents) – endowed with bounded rationality and embedded (endogenous or instrumental) reflexivity.

Each (individual or collective) agent roughly estimates and calculates its relative local situation and makes purposeful decisions, on the specific basis of a *set of rules*. We can then see that "even a simple set of rules that determine consumer behavior can exhibit complex market behavior patterns. Agent-based Marketing provides a natural description of systems and potentially allows description of all relevant elements of a market, including social networks, and captures emergent phenomenon" (see http://www.agentbasedmarketing.com/gpage3.html).

But given the various empirical problems with data collection, as well as the explicit inclusion of cognitive, institutional, and social processes in agent-based models, achieving good statistical performance is often not sufficient. In some cases, no data even exist to perform an elementary statistical analysis. Other criteria that can be used are (Janssen & Ostrom, 2006):

- Is the model plausible given our analytical understanding of the relevant processes?
- Can we adequately understand the reasons for which the model is doing so well?
- Did we eventually derive a better analytical understanding of our empirical observations?
- Does the behavior of the specific models coincide with the understanding of the relevant stakeholders about the system?

In his greatly influential *Generative Social Science*, Joshua Epstein perceptively argues that agent-based modeling could eventually allow us to successfully meet wholly new standards of scientific explanation and observe phenomena of interest in "artificial societies" inhabited by interacting (and inter-dependent) agents.

What actually counts as an "agent" here is a "computational entity that can act, somewhat in the manner of an animal or human being, sensing external events and doing things that affect the environment. Autonomous software agents can be either simple or complex, but even the simplest can produce complex effects when many of them interact in a multi-agent system" (Bainbridge, 2007b).

These "agents" are heterogeneous (*either* following different rules of action *or* possessing different resources that cause them to act differently), locally reflexive and boundedly rational, represented as mathematical or software objects.

In brief, agent-based modeling (and, more broadly, "new science") is developed on two simple assumptions:

1.All "agents" comprising social phenomena are not "*homogeneous*" and

2.Ceaselessly interact under *disequilibrium conditions* (or conditions "far from equilibrium").

The "New" Social Science, Complexity Science, and Agent-based Modeling usually refer to human societies characterized by emergent behaviors (reflexively resulting from everyday dynamic interactions and negotiations). Therefore, social systems cannot be reduced, fragmented or dis-integrated without losing their idiosyncratic identity, signature and purposefulness.

This novel methodological approach is directly opposed to *both* sociologism (over-emphasizing social factors) *and* psychologism (over-emphasizing psychological factors). As R. Keith Sawyer (2007) maintains, human societies are complex, non-linear and dynamical systems, and the best possible way to adequately understand them is by developing the concept of emergence.

This pays attention to *multiple levels of analysis* (individuals, interactions, and social groups), with a special dynamic focus on the particular, detailed ways in which group phenomena "emerge" from daily "performative" communication processes among individual members.

While empirical sociologists often downplay the huge importance of emergence, social simulations appear to tackle many substantive methodological problems. Social statisticians conventionally use a very rigid language (which does not really interpret or explain anything!), while qualitative researchers variously describe the richness of personal experience and social settings *in a highly ambivalent and non-generalizing way*.

In social simulations, according to Gilbert and Troitzsch (2005), statistical analysis is neither "ungrounded" at the individual level and ethnography, nor is unable to generalize, because of the potential communicative or behavioral complexity of contextual social interaction.

They also avoid strong "methodological individualism" and perceptively involve agents in shared representations of social rules and social structures, while their so-called *demonstrative power* clearly communicate us the "processual" nature and character of complex social phenomena *in a very simple and understandable manner*. This "power" is vividly depicted in Figure 2, where dynamic social interactions (social groupings and de-groupings) are simulated by the HESIOD model (see http://www.hesiodproject.net).

In the wider context of human complex systems, the vast "multiplicity of feasible research methodologies would permit a range of overlapping research studies, adjudicating between alternative theoretical propositions and thereby connecting the currently isolated schools of thought" (Bainbridge, 2007a).

Of course, techniques and methods in cyberspace (e.g. social simulations, agent-based modeling, social network analysis, cyberethnography etc) do not only change the way we do sociology (or social science in general), but also the very substance (object) of the modern sociological enterprise or "project".

That means, according to the central epistemological rationale of the constructivist (anti-foundationalist/anti-objectivist/anti-essentialist) sociology of scientific knowledge (see e.g. Woolgar, 1988), including the e-sociology of scientific knowledge, the very practice of these techniques and methods is performative; it is more or less constitutive of (and for) what increasingly counts as "normal" social scientific activity.

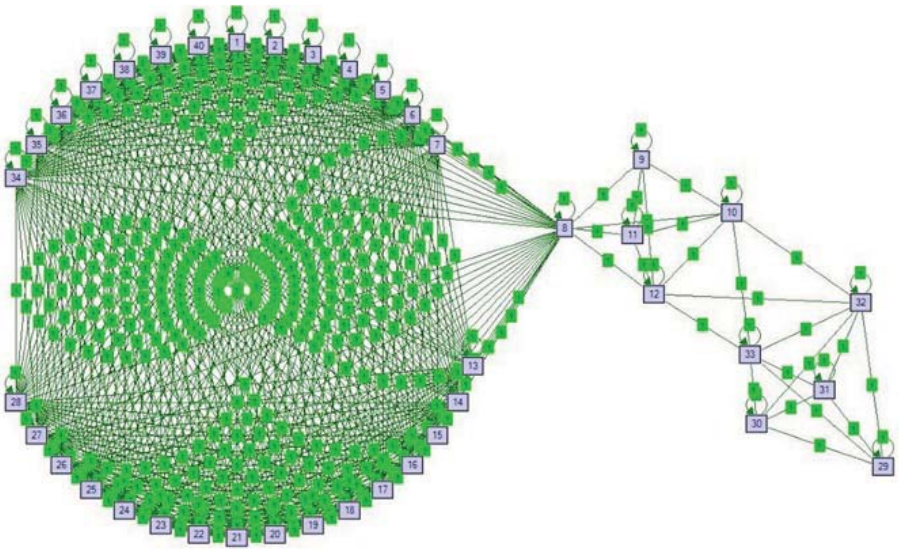

Fig. 2: A computer simulation vividly showing the emergent social system dynamics in low stability conditions. It explicitly indicates how the members of society become grouped and de-grouped over the course of time.

Conclusions:

It is thus concluded that "social equilibrium" is just a theoretical state. But it is also something *undesirable*. Equally undesirable is a predictable, stable and homogenous human world. This would probably be a very hopeless, colorless, dull and boring world: A completely grey social universe! In addition, there is indeed a small degree of optimism about the future, by focusing upon *possibilities rather than limitations*.

The future dynamic evolution of human complex systems can be coarsely projected up to a certain time horizon (*predictability horizon*), but it cannot be fully predicted with certainty and precision in the long run. Namely*, predicting the future could be rather considered as an irresolvable riddle*.

The interdisciplinary discourse of unpredictability might eventually provide new exciting insights into contemporary academic discussions around the intimately dialectic cycles of micro/macro, emergence/social causation, reproduction/transformation, structure/action and theorizing/experiencing relations, vividly demonstrating the inherently undecidable and often surprising character of social and organizational dynamics (Tsekeris, *et al*., 2008).

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