Chapter 15
Modeling a Multi–Agents System as a Network: A Metaphoric Exploration of the Unexpected

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ABSTRACT

The article presents an empirically oriented investigation on the dynamics of a specific case of a multi-agents system, the stock market. It demonstrates that S&P500 market space can be described using the geometrical and topological characteristics of its dynamics. The authors proposed to measure the coefficient R, an index providing information on the evolution of a manifold describing the dynamics of the market. It indicates the moments of perturbations, proving that the dynamics is driven by shocks and by a structural change. This dynamics has a characteristic dimension, which also allows for a description of its evolution. The consequent description of the market as a network of stocks is useful for the identification of patterns that emerge from multi-agent interaction, and defines our research, as it is derived from a system of measure and it is part of the logic of a defined mathematics.

INTRODUCTION

In the very first page of his highly regarded novel, One Hundred Years of Solitude, Gabriel Garcia Marquez writes that, when arriving at Macondo and discovering so many unknown objects, Aurelio Buendia had to point out these things because no words were defined for them. This metaphor of the process of metaphorisation is an apt description of the scientific process itself, as science points out to what it ignores: denotation generates connotation. Even when science is defined as a self-contained logic, as mathematics, it dares into the territories of the unknown and of the unexpected; the more rigorous, the more daring it ought to be.

Yuri Manin (Manin, 1991), in the paper “Mathematics as Metaphor”, commented precisely on this metaphoric quality of mathematics:

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Considering mathematics as a metaphor, I want to stress that the interpretation of the mathematical knowledge is a highly creative act. In a way, mathematics is a novel about Nature and Human-kind. One cannot tell precisely what mathematics teaches us, in much the same way as one cannot tell what exactly we are taught by “War and Peace”.

The epic “War and Peace” tells us much about Humankind, as the rigor of mathematics proposes to do. In each case, an exploration into the nature of evolution and change is at stake. The metaphors consequently produced, either as imaginary descriptions or as precise formal models, suggest new interpretations that therefore produce new meanings. Mathematics is semantics.

In particular, complexity - a metaphor of natural and social relations to be precisely analyzed by mathematical methods – defines an approach which is more insightful to understand dynamics than traditional determinism and positivism. In this article, we argue that this metaphor is powerful enough to suggest new methods to interpret the emergence of new patterns in the dynamics of the a multi-agents system.

Here, a stochastic geometry is applied to describe the structural change in the stock market for the last years. The description of the market as a network of stocks suggests evidence for a transition of regimes, measures its dynamics and provides a graphic description of the ongoing process.

**Structure Generation in Complex Systems**

The research on Complex Systems uses plenty of metaphorical developments where the interpretation of the mathematical knowledge (the creative process) gives place to at least two different (and apparently conflicting) perceptions of the system. The description of Complex Systems generally follows one of two strategies, describing the multi-agents system as:

A. **Simple systems with complex behavior:** They are simple systems because they are characterized by few degrees of freedom. Nevertheless the display unpredictable behavior: deterministic and yet apparently random. A rich literature has been based on this hypothesis. The mathematical tools are those used in non-linear dynamics, namely: ergodic invariants, measure theory, algebra and set theory.

B. **Complex systems with simple collective dynamics:** They are complex systems because they are characterized by having many degrees of freedom. Nevertheless their collective dynamics display patterns that can be observed at different levels. These patterns usually obey to Scale Laws, giving place to the emergence of simple structures that contrast to the huge amount of complexity that defines the individual components of the system. The mathematical tools are those above mentioned plus Graph Theory. When this is the strategy to approach a Complex System one, graph theory is used to characterize the emerging structures from a network modeling perspective.

Figure 1 provides a schematic description of the leading strategies to approach complexity. The arrows and the shaded circles indicate the route to be followed and the topics to be covered in this article.

For the interpretation of the apparently random financial market behavior, it is usual to compute some Ergodic Invariants (Lyapunov exponents, entropy measures) as an alternative to traditional modeling of stochastic processes. In the example here considered, we approach the stock market complexity from the Collective Dynamics perspective. To this end, a stochastic geometry technique is used to describe structural change. Due to their unpredictable behavior eluding so many established models, stock markets have been widely discussed as an example of complex
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