Dealing with Interaction for Complex Systems Modelling and Prediction

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ABSTRACT

The increasing complexity of problems in the context of system modelling is leading to a new epistemological approach able to provide a representation which allows from one hand, to model complex phenomena with the support of mathematical and computational instruments, and on the other hand able to capture the global system description. In this article is presented a methodology for complex dynamical systems modelling which is an extension of the supervised learning paradigm. The theoretical aspects of our methodology are introduced and then two different and heterogeneous case studies are presented.

Keywords: Complex Systems, Immunology, Interaction Pattern, Multi Agent Based Simulation, Prediction

INTRODUCTION

The marriage between biology and complex systems is unavoidable and mutually productive: on one hand the rationality and formalism defined to describe the complex system dynamics can enrich the biological research approach, and on the other hand, biology provides inspiration for theoretical extensions on the design and implementation of new instruments devoted to explain and predict complex system dynamics. The universe from the micro level up to the macro level is the result of interaction based dynamics: cells interact through interacting molecules, humans are interacting systems composed by interacting cells. Following this ideas the method presented in this work is not the result of a theorisation of dynamical systems, but a pure observation of living systems: from the biological, through cognitive, up to social systems which pose the concept of interaction as fundamental, recurrent, atomic and affecting the global system dynamics and aggregation. Systems consist of levels of network organization having dynamics derived by interaction within and between the entities at different levels. Intuitively, complexity is an...
emerging structural property of systems and it is the result of the interaction of aggregated and heterogeneous entities with different scope and functionalities.

We propose an elementary and foundational perspective in order to explore complex systems dynamics and behavior by focusing on interaction and its aggregation. The foundations of our modelling approach is grounded over Agent Based Simulation (ABS) field, and on data mining by defining, measuring and observing interaction between entities through networks of interaction and dependencies mining methods. On one hand, ABS, which is totally grounded on interaction among entities, allows to model complex phenomena in a distributed way by designing autonomous agents with certain attitudes (beliefs, desire, intentions, memory, learning, communication ability) at different levels of complexity. On the other hand the classification method presented in Nanni and Quattrociocchi (2007) provides instruments to classify and predict the global system behavior by focusing the entities description as dynamics on interaction and interaction variation during time, considering the effect of relations of dependencies and the bounds which they bring in a shared environment. According to our perspective, to study and explain the behaviour of a complex system we must concentrate on the interaction and interconnection concept defined as follows: (1) Interaction is the effect of two or more variables in a not-simply additive relation and (2) Interconnectivity means that all parts of the system interact and rely on one another. Now the dynamics of a complex system can be seen as a transformation, among entities’ interaction, of the system itself during time.

Methodology Background

In general, there are two fundamental approaches to implement a classification system over complex data: statistical and structural. Each approach employs different techniques within the description and classification tasks which constitute a pattern extraction system: Statistical classification draws from established concepts in statistical decision theory to discriminate among data from different groups based upon quantitative features of the data. The quantitative nature of statistical classification, however, makes it difficult to discriminate among groups based on the morphological (i.e., shapebased or structural) sub patterns and their interrelationships embedded within the data. This limitation provided the impetus for the development of a structural approach to classification. Structural Classification, sometimes referred to as syntactic pattern extraction due to its origins in formal language theory, relies on syntactic grammars to discriminate among data from different groups based upon the morphological interrelationships (or interconnections) present within the data. Structural classification systems have proven to be effective for data which contain an inherent, identifiable organization such as image data (which is organized by location within a visual rendering) and timeseries data (which is organized by time). The usefulness of structural classification systems, however, is limited as a consequence of fundamental complications associated with the implementation of the description and classification tasks. The description task of a structural classification system is difficult to implement because there is no general solution for extracting structural features, commonly called primitives, from data. The lack of a general approach for extracting primitives puts designers of structural classification systems in an awkward position: feature extractors are necessary to identify primitives in the data, and yet there is no established methodology for deciding which primitives to extract. The result is that feature extractors for structural classification systems are developed to extract either the simplest and most generic primitives possible or the domain and application specific primitives that best support the subsequent classification task. Neither scheme is optimal. Simplistic primitives are domain independent, but capture a minimum of structural information and postpone deeper interpretation until classification. At the other extreme, domain and application specific primitives can
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