Chapter 7.18
Two Informational Complexity Measures in Social Networks and Agent Communities

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ABSTRACT

Several informational complexity measures rely on the notion of stochastic process in order to extract hidden structural properties behind the apparent randomness of information sources. Following an equivalence approach between dynamic relation evolution within a social network and a generic stochastic process two dynamic measures of network complexity are proposed.

INTRODUCTION

Most of the statistical social network analysis methods rely on a fixed network structure. Earlier methods of dyadic statistical analysis manage to provide quantification on degrees of mutuality between actors and triadic analysis does a step forward allowing validation of theories of balance and transitivity about specific components of a network. Each of these constitutes a subset of a more general *k-sub graph analysis* based on *k-sub graph census* extracted from the network architecture. Some sort of frequency analysis is done over these censuses from which probabilistic distributions can be evaluated. More recent single relational statistical analysis additionally allows the validation of statistic models through parametric estimation. Looking further for positional assumptions of groups of actors, stochastic block model analysis measure the statistical fitness of defined equivalent classes on the social network (Carrington, 2005) (Wasserman, 1994). All of these tools assume some sort a static network structure, a kind of snapshot of reality, over which statistical measuring is done and some degree of confidence is evaluated against real data. It is not of our knowledge any method of providing some sort of analysis on the dynamic structure of social networks in which the set of relations evolves over

a certain amount of time. The method we propose has the purpose of allowing a probabilistic informational based evaluation of each actor's inner complex motivated behaviour on the process of relation change inside his network. The evaluation is supported on the measurement of the *Entropy Density* and after of the *Excess Entropy* over the stochastic relational changing. Measuring the evolution of this interplay complexity measure can provide some insights into each actor degree of inner structure pertaining to the specific kind of relation that the network is supposed to represent. *Entropy Density* and *Excess Entropy* are theoretical measures and for practical purposes only estimative can be obtained. The study of estimative computation for entropy is still subject to intense research in the Physics community. As the measurement only approaches the real relational entropy of each actor, it can be considered within the context of the set of members of the social network an absolute measure as the same estimate bias is applied to the community as an all.

NETWORK DYNAMICS AND INFORMATION

The complexity of the information that may be extracted from observations of a source, as a phenomenological observation of its behavior, without any prior knowledge of the source's internal structure, may reveal missed regularities and structural properties hidden behind the apparent randomness of the stochastic process that the source generates. This information can provide useful clues in order to predict the source future behavior or its characteristic properties. In social network dynamics each actor generally performs some sort of action, communication acts; exchange of capital or economic goods or any other possible social interplay or attribute for which a well defined time limit and intensity can be pinpointed in time. This definition can generally be extended and even applied to objects as for example a correlation of goods purchased by each

client of a supermarket. The agent that determines the dynamic nature of a network is primarily Time. Topologically a network that evolves as the one depicted in *Figure 1* is completely defined as a set of graphs, each constituted by a set of nodes and link, eventually tagged with some intensity attribute, that have been established during a defined time slot *T* of the interval of observation. The sequence of the *n* time slot started at time t_0 pretend to report the dynamical relational evolution that the network is supposed to represent. There are some approaches to dynamic network that take into account possible resilience of links as an intensity attribute. In fact, the process of time partitioning can be tricky, dynamic features that appear relevant at some time slot durations can in fact be insignificant look at other time spans. There exist ways to circumvent this problem taking into account the kind of relation the network represents. For example normalizing the duration of the interplay through an inverse exponential function of time slot duration can avoid some dependence on value of *T*.

Having a dynamic network and coding the combination of all the established links that each node performed during each time-slot, we obtain a relational stochastic process for that particular node. This process will symbolically represent the node relational evolution within the community. The extraction of informational quantities from this process is straightforward.

INFORMATIONAL MEASURES OF COMPLEXITY

Given a symbolic process $\vec{S} \equiv \cdots S_{-2}, S_{-1}, S_0, S_1, S_2 \cdots$ of random variables S_{T_i} that range over an alphabet A, taking sequence values $\cdots s_{-2}, s_{-1}, s_0, s_1, s_2 \cdots \in A$, the total Shannon entropy of *length-L* sequences of $\vec{S}$ is defined as (Cover, 2006):

$$H(L) = \sum_{s^L \in A^L} Pr(s^L) \log_2 Pr(s^L)$$

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