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Patterns preceding critical transitions in socio-economic systems

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We consider hierarchical dissipative complex socio-economic systems and one of their most important features: *persistent reoccurrence of abrupt overall changes*, called here "critical transitions". Our studies include the following critical transitions: in economic systems – starts and ends of economic recessions and episodes of a sharp increase in the unemployment rate, called here "Fast Acceleration of Unemployment" (*FAU*); in socio-economic urban systems (megacities) – surge of the homicides in a megacity.

Our study is a "technical" analysis that is a heuristic search of phenomena preceding critical transitions. We use the methodology of *pattern recognition of infrequent events* developed by the artificial intelligence school of I.M. Gelfand for a study of rare phenomena of highly complex origin, that, by their nature, limit the possibilities of using classical statistical or econometric methods. Our goal is to identify by an analysis of macroeconomic indicators (in the case of economic systems) or of statistics of several types of less severe crime (in the case of megacities) a robust and rigidly defined prediction algorithm of the *"yes or no"* variety indicating at any time moment, whether a critical transition should be expected or not within the subsequent months. The pattern recognition approach has been successfully applied also in seismology and earthquake prediction, geological prospecting and in many other fields including its application to prediction of the outcome of American elections.

Considering the five recessions in the USA since 1962 to 1996 we have found that each of them has been preceded by a specific pattern of 6 economic indexes, which

are defined at the lowest (binary) level of resolution. This pattern was present during 6 to 14 month before each recession and at no other time, suggesting a hypothetical prediction algorithm. The algorithm is exceedingly robust: the retrospectively diagnosed alarms remain about the same after variation of its adjustable numerical parameters, and of other non-unique decisions, involved in its determination. The last recession, which began in 2001, was predicted in advance. Another algorithm has been formulated for predicting the end of an American economic recession by means of analysis of the same macroeconomic indicators within the recession period. It indicates up to 6 months long time interval, during which recession will end. First application of the algorithm to out of sample data (not used in its development) is successful: it predicted that the last recession, started in April 2001, would end between July and December 2001 and that recession indeed ended in November 2001.

Considering unemployment in France between 1962 and 1997, we have found a specific "premonitory" pattern of three macroeconomic indicators that may be used for algorithmic prediction of *FAU*s. Among seven *FAU*s identified within these years six are preceded within 12 months by this pattern that appears at no other time. The application of this algorithm to Germany, Italy and the USA yields similar results. The first advance prediction, for the USA for early 2000, has been successful.

We analyzed statistics of several types of crime in Los Angeles over the period 1975-2002. Our analysis focused on how these statistics change before a sharp and lasting rise ("a surge") of the homicide rate. The goal was to find an algorithm for predicting such a surge by monitoring the rates of different crimes. The results may be summarized as follows: episodes of a rise of burglaries and assaults simultaneously occur 4 to 11 months before a homicide surge, while robberies decline. Later on, closer to the rise in homicides, robberies start to rise. These changes are given unambiguous and quantitative definitions, which are used to formulate a hypothetical algorithm for the prediction of homicide surges. In retrospective analysis we have found that this algorithm is applicable through all the years considered despite substantial changes both in socio-economic conditions and in the counting of crimes. Moreover, it gives satisfactory results for the prediction of homicide surges in New York City as well. Sensitivity tests show that predictions are stable to variations of the adjustable elements of the algorithm.

Decisive validation of our findings requires experimentation in *advance prediction*, for which these studies set up a base. Particularly encouraging for this further research is the wealth of yet untapped possibilities: we have used so far only a small part of the data and mathematical models that are currently available and that are relevant to dynamics of complex socio-economic systems.