Stochasticity in Multi-Agent Systems (SMAS)

A mini-workshop supported by the European Science Foundation
under the Programme STOCHDYN

Sigüenza, Spain, June 1 through 4, 2005

SCIENTIFIC REPORT

Summary

"Stochasticity in Multi-Agent Systems" (SMAS) has been a three days mini-workshop intended to strengthen the collaboration between researchers working on topics closely related to the goals of the STOCHDYN programme. The scientific objective of the mini-workshop was the study of agent-based models and their analytical description, with emphasis on the correct inclusion of the fluctuations and the non-trivial departures from evolutionary game theory expectations they give rise to. While the discussion had a substantial part of theory and computer simulations, there has been input from real-life problems, such as traffic planning and organization or queuing problems in industry, that has helped focused on results relevant for applications.

The format of the mini-workshop, with all the participants staying at the Parador de Sigüenza, has been very succesful, in so far as it allowed all-day-long interaction between participants and very lively and relaxed discussions, without the pressure of a very tight or formal agenda.

Scientific content

The workshop took place from the evening of June 1 to the morning of June 4. Every lecturer was given a one-hour slot for their presentation, organized in two sets of five talks, preceded and followed by general discussion. However, the actual lectures were longer because a lot of discussions took place already along the way, which was very stimulating both for lecturers and participants.

In order to focus the scientific discussion of the mini-workshop, a very brief introduction was presented by **Angel Sánchez**, who reviewed the goals of the mini-workshop and the main point to be discussed, namely the influence of fluctuations of diferent origins in multi-agent systems. Following that introduction, every lecturer presented his ideas on this common issue. Specifically, the topics discussed were:

Jens Christian Claussen, Institut fur Theoretische Physik, Universitat Kiel, Germany

- **Topic:** Nongaussian fluctuations arising from finite populations in evolutionary games (with Arne Traulsen)
- **Abstract:** What approximations are valid in multi-agent systems as they are investigated in evolutionary game theory? Usually an approach widely used in physics is to mimick deviations from an averaged or mean-field dynamics by Gaussian distributed noise, motivated for systems near to a thermodynamic equilibrium. But one is aware from other complex systems (like cellular automata [5] and networks [4]) that various slowly decaying distributions and correlation functions can emerge; widely applicable and tractable models still are rare and limited to special classes of systems. Within the framework of evolutionary game theory, the appropriate description of fluctuations is a fundamental unsolved problem in the

case of finite populations. The case of finite populations implicitely is assumed in many models of spatial game theory [3]. The Moran process recently introduced into this context [Nowak et al., Nature (London) 428, 646 (2004)] defines a promising standard model of evolutionary game theory in finite populations for which analytical results are accessible. In [1], we derive the stationary distribution of the Moran process population dynamics for arbitrary 2x2 games for the finite size case. Here a nonvanishing background fitness can be transformed to the vanishing case by rescaling the payoff matrix. As demonstrated for four representative cases, the finite size fluctuations can deviate significantly from a Gaussian distribution. Finally, the mean-field limit for infinte populations of this dynamics is obtained as the adjusted replicator equations [2].

- **References:**
  - [1] Claussen and Traulsen, Phys. Rev. E 71, 025101(R)
  - [2] Traulsen and Claussen, cond-mat/0409655
  - [3] Traulsen and Claussen, Phys. Rev. E 70, 046128
  - [4] Claussen, q-bio/0410024
  - [5] $1/f^a$ spectra generated by cellular automata: Phys. Rev. E, 70 (3), 032101, math.CO/0410429, nlin.CG/0410037 (Phys. Rev. E, in print).

- Cees Diks, Center for Nonlinear Dynamics in Economics and Finance, Universiteit van Amsterdam, The Netherlands
  - **Topic:** Agent based economic dynamics: asset pricing models and the roles of endogenous and exogenous noise
  - **Abstract:** We give an overview of agent based dynamic asset pricing models that are being developed to obtain insights into the properties of the price fluctuations observed in financial markets. We show how the aggregate market dynamics collapses into a low-dimensional dynamical system together with an endogenous noise term arising from details at the agent level. Because agents adapt their beliefs upon observing price changes, exogenous shocks (news) can easily trigger a sequence of endogenous events with prices reacting in a complicated way. It turns out that relatively simple behavioral assumptions on how agents update their beliefs can already lead to price sequences with volatility clustering and long memory.
  - **References:** Check author's web page http://www1.fee.uva.nl/cendef/whoiswho/showHP/default.asp?pID=6&selected=pi

- Max-Olivier Hongler, Ecole Polytechnique Fédérale de Lausanne, Switzerland
  - **Topic:** Multi-Agents System in Production Engineering
  - **Abstract:** Queuing problems are ubiquitous in industry and management. One approach that has been very succesful in the past is the use of multi-armed bandit problems to model the issues at stake in queuing. In particular, this technique allows to pinpoint very clearly the different regimes that arise in resource processing as a result of the fluctuations in the stages of the production chain. Consequences were drawn in terms of control of the queue.
  - **References:** Available at http://lpmwww.epfl.ch/users/mhongler/

- Henrik Jensen, Department of Mathematics Imperial College London, UK
  - **Topic:** The Tangled Nature model: community structure, species area relation and species diversity as a consequence of interaction and evolution
  - **Abstract:** We present a review of the attempt within the Tangled Nature[1,2] model to understand the effect of evolution and interaction on ecological and evolutionary observables. We report on the relation between the interaction structure in genotype space and the resulting Species Abundance Distribution. Ecological relevant SADs are only obtained if the genotype space allow for a potential high connectivity between species[3]. We also study the relation between the degree of genotype interaction and species diversity. Furthermore we include spatial degrees of freedom to investigate the Species Area Relation from an evolutionary perspective. Comparison with observed SARs is favourable and suggests that evolution may be a fundamental factor in understanding the observed power law-like SARs. The model has been generalised to include a conserved resource for which all existing

types have to compete. This allows us to study, from an evolutionary perspective, the relation between community structure and availability of the conserved resource. Finally, we turn to a different type of model in which the livelihood of the agents is determined through rounds of zero-sum games. We describe the emergent ecological structure in which moderation turns out to be the clever strategy[4].

- **References:**
  - [1] K. Christensen, S. A. di Collobiano, M. Hall, and H. J. Jensen, **Tangled Nature: a model of evolutionary ecology.** J. of Theor. Biol., vol. 216,73 (2002).
  - [2] M. Hall, K. Christensen, S. A. di Collobiano and H. J. Jensen, **Time dependent extinction rate and species abundance in the Tangled Nature model of biological evolution.** Phys. Rev. E. vol. 66, 011904 (2002).
  - [3] P. Anderson and H.J. Jensen, **Network Properties, Species Abundance and Evolution in a model of Evolutionary Ecology.** J. Theor. Biol. 232/4 , 551-558 (2004).
  - [4] D. Eriksson and H.J. Jensen, **Darwinian selection in a locally unstable Boolean Network**. J Stat. Mech.: Theor. Exp. P09001 (2004).

- Esteban Moro, Universidad Carlos III de Madrid, Leganés, Spain
  - **Topic:** Mesoscopics of the stock market
  - **Abstract:** During the last years much attention has been devoted to unravel the so called "stylized" facts of the stock market fluctuations. On the other hand, microscopic modelization in terms of collectivities of agents has become a potential approach in understanding the origin of those stylized facts. However no empirical study of the behavior of actual stock market agents exists that could validate the basic assumptions of those models. Here, we present the first study of a stock market (the Spanish IBEX35) in terms of the actions of firms and brokers that trade in that market. Our study allow us to identify the two new and basic ingredients of the mesoscopic description of the stock market, namely, the distribution of wealth in the society and the network of market relationships among the set of agents. The importance of these findings when explaining the stylized facts of the stock market and its possible modellization as the aggregate outcome of the agents actions is is discussed.

- Kai Nagel, Institute for Computational Science, ETH, Zurich, Switzerland
  - **Topic**: Application of multi-agent simulation to real world traffic systems
  - **Abstract:** The traditional approach to real word traffic simulation has been developed during the last thirty years and has reached its limits in forecasting traffic conditions, yielding only an accuracy of about 30 %. A completely new approach is needed and therefore we suggest a multi-agent simulation with individual agents artificially generated in terms of their daily schedule. We discuss issues related to traffic monitoring and feedback and specifically we show how fluctuations are relevant in some time scales as to render any attempt to pass information to drivers useless or even counter-productive. Connections to game theory are drawn and issues on software engineering are also commented upon.
  - **References**: Check http://www.vsp.tu-berlin.de/publications and in particular, check papers number 3 and 11. Or, as short version, paper number 6.

- Juan M. R. Parrondo, Universidad Complutense, Madrid, Spain
  - **Topic:**Collective effects in paradoxical games
  - **Abstract:** We will present a review of the so-called paradoxical games or Parrondo's paradox, where two losing gambling games become winning when alternated. Our presentation will focus on collective effects. In particular, we will discuss in detail the case of an ensemble of players that must decide which game will be played in each turn. Some counter-intuitive phenomena occur. For instance, a blind strategy, such us deciding at random, can perform better than a majority rule or even a short-range optimization.

- **References:**
  - Brownian motion and gambling: from ratchets to paradoxical games. J.M.R. Parrondo and L. Dinís. Contemporary Physics 45, 147 (2004).
  - Feedback control in a collective flashing ratchet F. Cao, L. Dinís y J.M.R. Parrondo. Physical Review Letters 93, 040603 (2004).
  - Optimal strategies in collective Parrondo games. L. Dinís y J.M.R. Parrondo. Europhysics Letters 63, 319 (2003).

- Anxo Sánchez (coordinator), Universidad Carlos III de Madrid, Leganés, Spain
  - **Topic:**Fluctuation effects in evolutionary game theory
  - **Abstract:** Very generally, evolutionary game theory assumes that in a multi-agent system where players play a game, evolution is governed by the fitness accumulated in round-robin tournaments (equivalently, in a mean-field approach). If this assumption is lifted, highly counterintuitive results arise, which have implications in different fields.
  - **References:**
    - **Altruistic behavior pays, or the importance of fluctuations in evolutionary game theory**
      Angel Sánchez, José A. Cuesta and Carlos P. Roca, Proceedings of the 8th Granada Seminar in Computational Physics, AIP Proceedings series.
    - **Altruism may arise from individual selection.**
      Angel Sánchez and José A. Cuesta, Journal of Theoretical Biology, in press.

- Maxi San Miguel, IMEDEA, Palma de Mallorca, Spain
  - **Topic:** Consensus and noise
  - **Abstract:** The role of Noisy Dynamics in mechanisms of consensus formation are explored in the Voter model and in Axelrod's model of dissemination of culture. Complex netorks of interaction are considered.
  - **References:**
    - Global culture: a noise induced transition in finite systems, Physical Review E 67, 045101 R (2003) (Klemm, K., Eguíluz, V.M., Toral,R., San Miguel, M.)
    - Globalization, polarization and cultural drift. J. Economic Dynamics and Control 29, 321-334 (2005) (K. Klemm, V.M. Eguíluz, R. Toral and M. San Miguel)
    - Conservation laws for the voter model in complex networks. Europhysics Letters 69, 228-234 (2005) (K. Suchecki, V. M. Eguíluz and M. San Miguel)
    - Voter model dynamics in complex networks: Role of dimensionality, disorder and degree distribution cond-mat/0504482 (K. Suchecki, V. M. Eguíluz and M. San Miguel)
    - Presentations, papers and related material can be found in here.

- Christian van den Broeck, University of Hasselt, Belgium
  - **Topic:** The call of the wild
  - **Abstract:** We show that wild fluctuations, which have no significant effect on individual behavior, can completely dominate the properties of a collective system. We also show that transient instability of single individuals can induce collective instabilities which are typically reentrant, e.g., they disappear when the collective interactions become too strong.

Other Participants:

- Saúl Ares, GISC, Universidad Carlos III de Madrid, Spain
- Roger Filliger, groupe "QuaDeStra", Ecole Polytechnique Fédérale de Lausanne, Switzerland
- Bai Li, University of Nottingham, United Kingdom.
- Carlos P. Roca, GISC, Universidad Carlos III de Madrid, Spain

In summary, the scientific content of the mini-workshop was as planned, an exchange of ideas between researchers from different fields but with the common aim of understanding how

fluctuations act on multi-agent systems and modify the corresponding emergent phenomena. A large majority of the presentations were of the appropriate level as to provide everybody with a common background to make fruitful discussions possible. The whole range of phenomena that goes from game theory to evolution models through basic stochastic differential equations was considered, and the close relations between all these approaches were made clear in a very coherent and consistent manner.

Impact and results

One of the main issues addressed at the workshop is the relevance of fluctuations in multi-agent systems irrespective of the real problem they are applied to. The relationship among the different approaches presented was extensively discussed (the ample slots of time available and the atmosphere provided by the Parador de Sigüenza were most suitable to this end) and some new ideas and possible collaborations have arisen from these discussions. In this respect, the mini-workshop has been extraordinarily fruitful in providing a common language for all the participants to discuss and establish collaborations.

From the theoretical viewpoint, the mini-workshop has made clear the importance of gaining further insight on the time scales involved in the problem that one intends to model as a multi-agent system. As discussed during the sessions, some progress has already been made, but the participants concluded that it is necessary to carry out further research on the issue. The fact that data from measurements (e.g., in traffic or in economics) are available and may be used to assess this issue was a highlight of the conclusions, and it is hoped that collaborations along these lines will soon be established.

An additional important result of the mini-workshop was the get-together of the researchers themselves. A very nice atmosphere was established and the common goals of the different individual projects were placed in a much wider context. Future contacts will take place to deepen this connection so it may develop into a common European-level project. It is clear in this respect that the collaborations that may arise from the mini-workshop will have an impact towards strengthening the European Research Area in a very active field of research.

Final program

Wednesday June 1

20 Arrival and welcome
21:30 Dinner

Thursday June 2

9:30 Sánchez (introduction and lecture)
10:45 Coffee
11:15 Diks
12:30 Hongler
13:30 Lunch
15:30 Hongler (cont'd)
16:30 Coffee
17 San Miguel
18 Discussions
21 Dinner

Friday June 3

9:30 Claussen
10:30 Coffee

11 van den Broeck
12 Nagel
13:30 Lunch
15:30 Moro
16:30 Coffee
17 Jensen
18 Parrondo
19 Discussions
21 Dinner

Saturday June 4

9:30 Final discussion and closing.