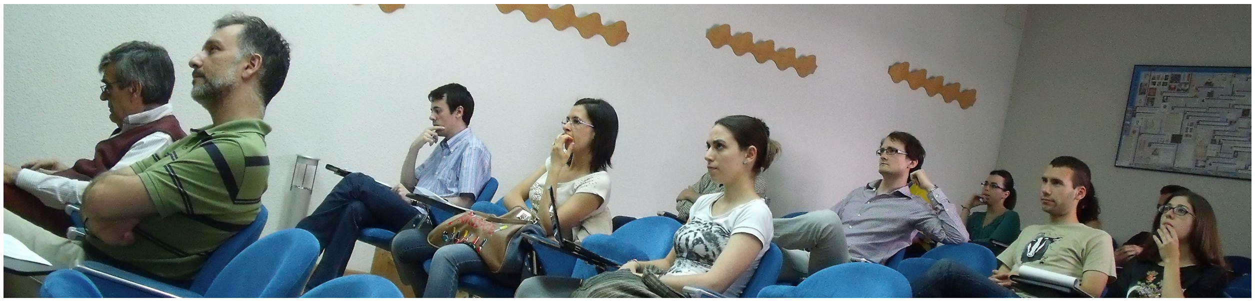
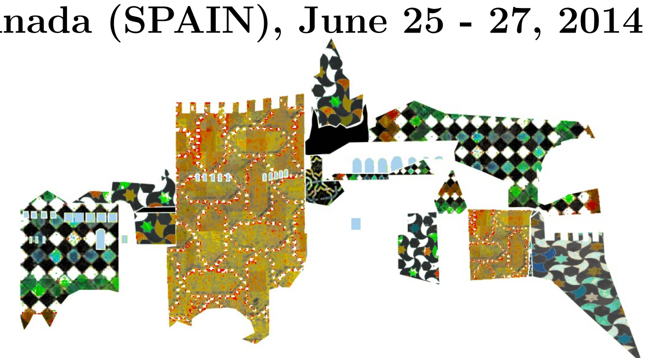
BIOMAT 2014



Complexity and Emergence in Social and Biological Systems

Book of Abstracts

Granada (SPAIN), June 25 - 27, 2014



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Contents

1. Stochastic multiscale models of competition between cellular populations

Tomás ALARCÓN
Centre de Recerca Matemàtica
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We present recent developments in the formulation, asymptotic analysis and numerical simulation of multiscale models of cell populations which account for stochasticity at different scales and help us to understand its effects on the growth of and competition within heterogenous cell populations.

2. What is a crowd for a mathematician?

Nicolla BELLOMO
Politecnico di Torino
Italy

Two lectures focus on the modeling, qualitative analysis, and simulations of dynamics of crowds viewed as large living systems. The approach is that of the mathematical kinetic theory for active particles.

2.1. From the Question "What is a Crowd?" to Mathematical Tools. The first lecture is devoted to a detailed analysis of the complexity features of pedestrian crowds and on the derivation of mathematical tools toward modeling.

2.2. Models, Mathematical Problems, and Evacuation Dynamics. The second lecture deals with a variety of topics, namely the study of initial–boundary value problems, derivation of macro–scale equations from the underlying description at the micro–scale, and simulations of the evacuation dynamics in normal and panic conditions.

3. Hydrodynamic Limits and Self-organization

Miroslaw LACHOWICZ
University of Warsaw
Poland

We discuss the importance of macroscopic limits (the so-called hydrodynamic limits) in the case of description of many interacting agents. We consider a class of kinetic models where the agents are characterized by their position and orientation with swarming interaction controlled by the sensitivity parameter. These statement leads to various interesting mathematical problems. In the limit the type of equations changes and it may be related to singularly perturbed problems. In some case the macroscopic limits of the models are defined for solutions close either to the isotropic (solitarious) or to the aligned (swarming, gregarious) equilibrium states for various sensitivity parameters. The latter may be related to self-organization. In the former case the classical linear diffusion equation results whereas in the latter a traveling wave solution does both in the zeroth (Euler) and first (Navier-Stokes) order of approximations.

4. Modelling collective cell motion in biology

Philip MAINI
Oxford University
United Kingdom

There are many examples of collective cell migration in biology: cells can move in a coordinated manner as sheets of tissue; the can move as individuals responding to chemical cues; they can move in high density waves. In these lectures we will consider examples of each of these, with applications in early development and in cancer. We will consider three different mathematical modelling frameworks, each chosen appropriately for the particular example. We will show that all of these models, in their simplest form, reduce to the common coarse-grained framework of a reaction-diffusion system, where the nonlinear diffusion coefficient at the coarse-grained level incorporates the modelling assumptions at the microscopic level.

5. Pattern formation

Hans MEINHARDT
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Germany

3.1. Biological pattern formation: local self-enhancement and long range inhibition as the driving force. During development of higher organisms there are many situations in which structures emerge in systems that were initially almost devoid of any structures. An example is the generation of the major body axes - head-to-tail and the back-to-belly. Axis formation is a very essential process during development of higher organisms on the way from the fertilized egg to the final organism with all its complexity. Together with Alfred Gierer I proposed that that pattern formation can be accomplished by reactions that are based local self-enhancement and long-range inhibition. Organizing regions, gradients periodic structures and stripes can be generated in this way. Corresponding models are provided as partial differential equations; simulations will illustrate that the models reproduce faithfully the observed dynamic behaviour. Comparison with molecular data will show how these theoretically predicted reactions are actually implemented to initiate the major body axes and how it is achieved that these axes obtain an orthogonal orientation relative to each other.

3.2. Models for regeneration: reconciling pattern formation and growth. Many biological systems show a surprising ability to regenerate lost parts. Many of these regeneration phenomena can be regarded as an extreme case of self-regulation after a perturbation. Therein tissue growth is a challenging problem since with increasing distances the communication via diffusion or related mechanisms becomes less and less efficient. Moreover, pattern-forming reactions have the tendency to switch into symmetric and periodic patterns during growth. However, multiple organizer formation would be a catastrophe for a developing organism, leading to malformations like Siamese twinning. Obviously, supernumerary organizers are reliably suppressed under normal conditions. It will be shown that different organisms found different solution to allow growth without formation of supernumerary organizing regions and to maintain nevertheless the possibility to regenerate organizing regions if needed. In the freshwater polyp Hydra a long-lasting feedback of the pattern on the ability to generate this pattern leads to a graded competence and to a strong dominance of the first established organizer. In Planarians, which need regeneration for asexual reproduction, the spontaneous organizer formation is generally suppressed but wounds are used to trigger organizer regeneration. Thus, organizers can only regenerate at the appropriate positions. In insect limbs and many other systems, cells respond to morphogenetic signals by a stepwise, irreversible and unidirectional change in their determination: cells maintain their once obtained differentiation even if the signals fade away due to growth. However, after cutting, e.g., a juvenile insect limb, the signal is rebuild, causing a reactivation of the unidirectional determination change in the remaining limb stump. All these mechanisms allow stretching the size window in which regeneration is possible. It will be shown that growth to even larger sizes requires switching off the pattern-forming reaction. This is an important safety mechanism to avoid malformation due spontaneous organizer formation. In a sloppy saying, the price we have to pay for becoming larger than a few millimetres is that we can no longer regenerate a head as Hydras or Planarians can do and we are unable to regenerate a lost limb as it is observed in amphibians.

3.3. If patters destabilize themselves: generation of highly dynamic patterns by self-quenching of newly generated patterns. The mechanisms listed above generate spatial patterns that are essentially stable in time. However, in several biological systems highly dynamic patterning systems are involved that never reach a stable steady state. The permanent formation and retraction of protrusions of chemotactic cells or growth cones is one example. The localization of the division plane of a growing E.coli bacterium precisely to the centre by an out-of-phase oscillation is another. It will be shown that this is achieved by reactions in which patterns, shortly after their generation, become destabilized. Maxima either start to move into an adjacent position or they disappear and reappear at a different position. By modelling it will be demonstrated that these mechanisms allow permanent dynamic adaptation to changing conditions although usually non-linear reactions have a substantial hysteresis. In this way the systems remain flexible and are able to adapt to new situations. The permanent destabilization of just established patters plays a dominant role in the generation of the pigment pattern on tropical sea shells. Since molluscs can enlarge their shell only at the growing edge, these patterns are usually time records of a one-dimensional pattern-forming process. Having a complete time record of a highly dynamic system provided the opportunity to decode the underlying mechanism. Comparing actual patterns including their re-establishment after perturbations will illustrate the power of the models. Although only few components are assumed, the models reproduce the enormous diversity of different patterns as observed; minor changes in the parameters or in the actual interactions are sufficient.

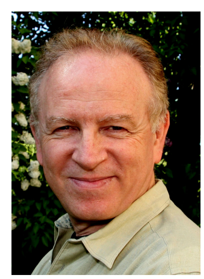
As I will show at different parts of my talk, there are several surprising parallels to mechanisms that lead to patterns in social systems.

6. Climate change: governance, cooperation and self–organization[1]

JORGE PACHECO
Universidade do Minho
Portugal

When attempting to avoid global warming, individuals often face a social dilemma in which, besides securing future benefits, it is also necessary to reduce the chances of future losses. In this set of lectures, I will review some of the approaches used so far to study this problem and predict governance measures designed to win this game that we cannot afford to lose. Subsequently, I shall introduce a simple theoretical approach to address the problem, in which the risk of failure plays a central role in individual decisions. The model developed can be shown tocapture some of the essential features discovered in recent key experiments, while allowing one to extend in non-trivial ways – and to regions of more practical interest – the insights from those experiments. Our results suggest that global coordination for a common good should be attempted by segmenting tasks in many small to medium sized groups, in which perception of risk is highand uncertainty in collective goals is minimized. Diversity in group size and in participants wealth may be beneficial, provided homophily is not an issue. Moreover, our results support the conclusion that sanctioning institutions may further enhance the chances of coordinating to tame the planets climate, mostly when risk perception is small, as long as they are implemented in a decentralized and polycentric manner.

7. Flocking and consensus in collective dynamics



EITAN TADMOR
Maryland University
U.S.A.

6.1. Agent-based models. We begin our discussion with a series of prototype models for self-propelled collective dynamics encountered in human and mobile networks and in biological organisms — opinion dynamics, flocking, swarming, bacterial self-organization driven by chemotaxis and phototaxis, etc. The dynamics of such systems is governed solely by interactions among individuals, or agents", with the tendency to adjust to their environmental averages through finite repulsion, alignment and attraction. This, in turn, leads to

[1]In coll. with V.V. Vasconcelos, F.C. Santos & S.A. Levin

the emergence of clusters, such as colonies of bacteria, flocks of birds, parties of people, etc. Natural questions which arise in this context are to understand when and how clusters emerge and what type of rules of engagement influence the formation of such clusters. Of particular interest to us are cases in which the self-organized behavior tends to concentrate into one cluster, reflecting a consensus of opinions or flocking as examples for concentration around positions intrinsic to the dynamics. We provide a concise review of current results of local and global models and conclude with open questions regarding the emergence of flocks/consensus and their relation to the propagation of connectivity.

6.2. Kinetic and hydrodynamic descriptions. Kinetic descriptions provide a particularly effective framework for studying the emergence of macroscopic clusters. We will give a concise overview on the passage from agent-based models to a mean-field limit, and show how the overall methodology carries over to a kinetic description and thereby can be cast into hydrodynamic equations. Questions which arise in this context include pattern formation, their phase transition, equilibrium, control, and its (meta-)stability.

In particular, we show that in analogy with the agent-based models, the presence of non-local alignment enforces strong solutions to self-organize into a macroscopic flock. When such strong solutions exist? we show that flocking hydrodynamics admit critical thresholds in the phase space of initial configurations which dictate the global regularity vs. a finite time blow-up.

8. Traffic flow on networks: A fully-discrete kinetic theory approach

Andrea TOSIN
Consiglio Nazionale delle Ricerche
Italy

In this seminar I will present a new approach to the modeling of vehicular traffic flows on road networks based on kinetic equations and centered around a modern view of traffic as a living and evolving complex system. While in the literature the problem has been extensively studied especially by means of macroscopic hydrodynamic models, to date there are still not contributions tackling it from a genuine statistical mechanics point of view. Probably one of the reasons is the higher technical complexity of kinetic traffic models, further increased in case of several interconnected roads. In the proposed approach such difficulties of the theory are overcome by taking advantage of a discrete structure of the space of microscopic states of the vehicles, which is also significant in view of including the microscopic granularity of the system in the mesoscopic representation.

Notes