From the Mathematical Theory of "Living" Systems to Behavioral Crowd Dynamics

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This Lecture is devoted to the development of mathematical tools for the modeling, qualitative analysis and simulations of crowd dynamics viewed as a living, hence complex systems. The presentation is proposed in three steps: i) Detailed analysis of the complexity features of living systems focused on crowd behavior; ii) Derivation of models and simulations based on methods of the kinetic theory with interactions described by theoretical tools of game theory; iii) An overview of challenging analytic problems.

Part I: This introductory part of the presentation aims at providing an effective answer to the following question: *Do complex living systems exhibit common features and which are the analytic and computational tools able to capture these common features?* As known, it is very difficult to understand and model these systems based on the sole description of the dynamics and interactions of a few individual entities localized in space and time. In fact, interactions are not additive and their modeling should take into account the ability of the interacting entities to develop specific strategies based on the states and localization of all interacting entities.

Part II: Based on the preliminary analysis of Part I, some specific models are derived according to the following hallmarks: 1. The overall system is subdivided into *functional subsystems* constituted by entities, called *active particles*, whose individual state is called *activity*; 2. The state of each functional subsystem is defined by a suitable, time dependent, probability distribution over the microscopic state, which includes position, velocity, and activity variables; 3. Interactions are modeled by games, more precisely stochastic evolutive games, where the state of the interacting particles and the output of the interactions are known in probability; 4. Interactions are nonlinearly additive and nonlocal; 5. The evolution of the probability distribution is obtained by a balance of particles within elementary volume of the space of the microscopic states, where the dynamics of inflow and outflow of particles is related to interactions at the microscopic scale.

Subsequently various simulations are developed to enlighten the predictive ability of the model focusing on segregation phenomena and evacuation dynamics in conditions of danger.

Part III: This final part focuses on analytic problems, the following challenging topics are presented: The good position of the initial boundary value problem and the derivation of macroscopic (hydrodynamic) equations from the underlying description delivered by kinetic theory methods.

Bibliography

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