Fast Breaking Comments

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Marcello Delitala & Abdelghani Bellouquid answer a few questions about this month's fast breaking paper in the field of Mathematics.

From •>>December 2006

Field: Mathematics

Article Title: Mathematical methods and tools of kinetic theory towards modelling complex biological systems
Authors: **Bellouquid, A;Delitala, M**
Journal: MATH MODEL METHOD APPL SCI
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✔ Update...

- **January 1, 2007:** This paper has also been named the New Hot Paper in Mathematics for January 2007.

ST: Why do you think your paper is highly cited?

This paper provides a contribution to a further development of the mathematical kinetic theory for active particles, which is a general mathematical approach to deal with the modelling of large systems of interacting entities.

Dealing with the inner complexity of biological systems, which exhibit features and behaviors quite different from those of inert matter, requires new mathematical methods. The substantial difference with respect to the classical kinetic theory is that the microscopic state of the interacting entities is characterized, in addition to geometrical and mechanical variables, e.g., position and velocity, by another variable, called "activity," which models the ability of the entities, called "active particles," to express functions which characterize living systems.

The method is developed in different fields of life sciences, e.g., biology, social systems, traffic modelling, politics, and behavioral economics. The number of mathematicians interested in this new and attractive research field is constantly growing. This may explain why the paper is highly cited.

"The mathematical kinetic theory for active particles develops methods to derive evolution equations for the one particle distribution function over the microscopic state of the particles."

ST: Does it describe a new discovery, methodology, or synthesis of knowledge?

The mathematical kinetic theory for active particles develops methods to derive evolution equations for the one particle distribution function over the microscopic state of the particles. The derivation is based on suitable balance equations in the elementary volume of the space of microscopic states. A key role is exerted by interactions at the microscopic level, which may be short or long range and may include proliferating or destructive events.

The paper develops a general method, related to the above approach, to model large systems of interacting cells in a living system. Specifically, two types of interactions are considered: mechanical interactions, which regard cellular movements, are assumed to be "long range type," since cells feel the reciprocal presence even at long distance, while biological interactions are assumed to be "short range type," since biological functions are exchanged due to contact and binding phenomena between cells.

The technical difficulty is that the activity of an active particle has the ability to modify the interacting rules of classical mechanics in addition to the ability of generating destruction or proliferation of cells. No doubt the application of models to real biological phenomena generates highly complex mathematical problems. Indeed, this is a great attraction for applied mathematicians.

ST: Could you summarize the significance of your paper in layman's terms?

Modelling of multicellular systems and processes takes many forms, depending on the spatio-temporal scale and detail one wishes (or is able) to capture. At one extreme, all individuals (for example cells or biomolecules) are assumed to have identical states, and all spatial information is lost. At the other extreme, there are individual based-models in which each element may represent an individual with assigned characteristics (for example, age or size) which can vary from one individual to the next.

Between these extremes, there are many modelling levels. In this paper, we deal with the modelling at the mesoscopic level with methods of mathematical kinetic theory for active particles; microscopic information defines the interacting rules of the active particles, and the macroscopic behavior of the system can be recovered as momentum of the distribution function. In this way one can begin to address the crucial issues of modelling at different scales (multi-scale modelling).

The paper proposes a general mathematical framework, and is able to generate different models which can describe different aspect of the biological system under study. In general, different systems of the "living" world (e.g., biological and socio-economic systems) may share the same mathematical framework, and, from it, specific models may be obtained by a proper specification of the interacting populations, their "functions," and the rules of interactions between them.

ST: How did you become involved in this research, and were any problems encountered along the way?

I decided to deal with the topics of this paper during my Ph.D. training at Department of Mathematics of Politecnico of Turin. My supervisor, Nicola Bellomo, introduced me to a research project which he had undertaken some years before, with the collaboration of a leading expert in immunology, Guido Forni of the University of Torino.

In my Department, I had a scientific encounter with Abdelghani Bellouquid, a mathematician now at the University Cadi Ayyad, Ecole Nationale des Sciences Appliquèes, Safi, Maroc, with whom I wrote various papers on these topics. Our efforts have been resumed in a recently published book: A. Bellouquid and M. Delitala, *Mathematical Modelling of Complex Biological Systems - A Kinetic Theory Approach* (Birkhäuser, Boston, 2006).

ST: Are there any social or political implications for your research?

The analysis of multicellular systems with reference to the immune competition, i.e., the topic of this paper, may contribute to a deeper understanding of the immune competition against aggressive diseases, while the analysis of the movement of cells may contribute to the understanding of pattern formation phenomena, including angiogenesis. One of the most significant applications is the struggle against cancer, which has reached the second place (after cardiovascular disease) in the league of fatal diseases.

Mathematical models derived from the framework of the kinetic theory of active particles may contribute to understanding the complexity of the immune system competition and possibly even focus the attention of biologists toward specific phenomena which are not being observed in current research, thus motivating new experiments.

The goal is the gradual enhancement of experimental analysis by means of new methods and tools generated in a collaborative context with the mathematical sciences.

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