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CROWD DYNAMICS: RESULTS AND PERSPECTIVES

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1. **Introduction.** The research about crowd dynamics has undergone a dramatic development in the recent years. This fast advancement made it rather difficult for researchers in applied mathematics to keep contacts with the variety of analytical and numerical techniques recently introduced, as well as with the new problems being considered. Indeed, *Crowd Dynamics* is of interest to disciplines ranging from pure mathematical analysis to operation research, from numerical analysis to computer graphics, from model theory to statistics. The variety of MSC classifications labeling the papers of this special issue testifies the broadness of the subjects covered hereafter and, hence, also of this whole field.

This special issue of *Networks and Heterogeneous Media* aims at bridging several different research directions of interest to applied mathematicians. Each of the present papers describes key problems of particular interest for the authors, points at the related most relevant techniques and includes the corresponding main results. The common spirit is to share, also with non specialists of the very same field, achieved results in their full depth.

2. **Contributions.** The reader will find in the subsequent pages a rather broad view of the present status of the research in crowd dynamics from the applied mathematics point of view.

Several approaches at different levels of abstraction are available. First, as is well known, modeling can be pursued at the microscopic, kinetic or macroscopic levels. The overview by Bellomo and Bellouquid underlines features that, at these different levels, are specific to groups of living individuals. Within the macroscopic approach, the available analytical techniques range from measure theoretic frameworks, as in the paper by Tosin and Frasca, to 1D systems of hyperbolic conservation laws, see the presentation by Appert–Rolland, Degond and Motsch. At the microscopic level, a prominent role is played by ordinary differential equations, whence the relevance of the force based models discussed by Chraibi, Kemloh, Schadschneider and Seyfried. All these modeling efforts aim at the description of various specific real situations. Relevant examples are congestion management, addressed by Maury, Roudneff–Chupin, Santambrogio and Venel, and evacuation planning, specifically considered by Göttlich, Kuhn, Ohst, Ruzika and Thiemann. A particular feature of pedestrian

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flows, namely stratification, is the subject of the paper by Kamareddine and Hughes. At the interface between theoretical works and real world we find other two research directions. First, *ad hoc* numerical methods, such as those presented by Berres, Ruiz–Baier, Schwandt and Tory, allow to efficiently transform equations into usable information, such as graphs and numbers. Finally, only the availability of reliable and large data sets allows the comparison between theoretical models and reality, and in this connection we refer to the work of Schadschneider and Seyfried for the procedural part, as well as to the work of Roggen, Wirz, Troster and Helbing for the technological part.

Necessarily, the above presentation of the following papers is too sharp. As the reader will see, none of the works below is strictly contained in a single research direction. Models need to be presented discussing both their analytical properties as well as the related numerical methods. Similarly, for instance, data need to be collected having in mind the testing of specific models.

The complete list of contributions is:

- C. Appert-Rolland, P. Degond, S. Motsch: *Two-Way Multi-Lane Traffic Model for Pedestrians in Corridors.*
- N. Bellomo, A. Bellouquid: *On the Modeling of Crowd Dynamics: Looking at the Beautiful Shapes of Swarms.*
- S. Berres, R. Ruiz-Baier, H. Schwandt, E. M. Tory: *An Adaptive Finite-Volume Method for a Model of Two-Phase Pedestrian Flow.*
- M. Chraibi, U. Kemloh, A. Schadschneider, A. Seyfried: *Force-Based Models of Pedestrian Dynamics.*
- S. Göttlich, S. Kuhn, J. P. Ohst, S. Ruzika, M. Thiemann: *Evacuation Dynamics Influenced by Spreading Hazardous Material.*
- A. M Kamareddine, R. L. Hughes: *Towards a Mathematical Model for Stability in Pedestrian Flows.*
- B. Maury, A. Roudneff-Chupin, F. Santambrogio, J. Venel: *Handling Congestion in Crowd Motion Modeling*
- D. Roggen, M. Wirz, G. Troster, D. Helbing: *Recognition of Crowd Behavior from Mobile Sensors with Pattern Analysis and Graph Clustering Methods*
- A. Schadschneider, A. Seyfried: *Empirical Results for Pedestrian Dynamics and their Implications for Modeling.*
- A. Tosin, P. Frasca: *Existence and Approximation of Probability Measure Solutions to Models of Collective Behaviors.*

3. **Future research.** Having completed the collection of these works, it is clear to us that this issue may serve not only as a bridge among the different research directions, but also as a source of hints for future research. The increase of this field has been so rapid that some chaotic development was unavoidable. All along this discipline, for instance, there are still models that lack *ad hoc* numerical methods and/or experimental testing, benchmarks comparing different numerical methods are often missing, standardized procedures to process crowd data are hardly universally accepted. While we wish that the production of all sorts of mathematical models continues, that the devising of better and more specific numerical methods proceeds, that the procedures and the techniques to collect crowd data keep improving, we also believe in the importance of works comparing the various results and of merging techniques at different levels of abstraction.

We conclude wishing a pleasant and fruitful reading,

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