Macroscopic modelling and simulations of crowd dynamics

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Growing population densities combined with easier transport lead to greater accumulation of people and increasing number of life threating situations due to accidents and panic. Modern designs of walking facilities follow optimal requirements regarding flow efficiency and pedestrians comfort and security.

We consider two macroscopic models of crowd dynamics describing the evolution of the density of pedestrians in two space dimensions. The first one, introduced by Hughes [1], consists of a scalar conservation law closed with a speed-density relation. The second, proposed by Jiang et.al. [2], is a higher-order model given by the Euler equations for isentropic gas dynamics with relaxation source term and closed with a phenomenological law for the acceleration of pedestrians. Both systems take into account that pedestrians seek to minimize the path length towards their destination but temper their estimated travel time by avoiding high densities. This is obtained by coupling the above equations with the eikonal equation with a density dependent running cost function. The gradient of its solutions indicates the desired direction of motion of pedestrians.

The models were developed to describe the behaviour of a crowd in a two-dimensional walking facility where interpersonal distances are much smaller than the size of the domain. We approximate the solutions by a finite volume scheme on unstructured triangular meshes using the multidisciplinary software Num3sis and study the models numerically.

We first provide a comparison between the two models regarding their ability of reproducing complex dynamics of crowd motion such as formation of stop-and-go waves and clogging at bottlenecks. Then we consider only the second order model and analyze the dependence of the behaviour of its solutions on some of the parameters of the system. In particular, we focus on the effect of the strength of the internal repealing forces. Finally, we study the optimization of the evacuation from a room through a narrow exit. Adapting the hypothesis of the inverse Braess paradox [3], we present some cases in which placing obstacles in front of the door prevents from blocking and decreases the evacuation time.

References

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