Towards a More Efficient Evacuation of Crowds by Means of an Optimal Location of Exit Doors

Lino J. Alvarez-Vázquez[1,*], Néstor García-Chan[2], Aurea Martínez[1], Carmen Rodríguez[3] and Miguel E. Vázquez-Méndez[4,5]

[1] Departamento Matemática Aplicada II, EI Telecomunicación
Universidade de Vigo, 36310 Vigo, Spain
e-mail: lino@dma.uvigo.es, web page: https://gscpage.wordpress.com

[2] Departamento Física, CUCEI, Universidad de Guadalajara, Guadalajara 44430, Mexico

[3] Departamento Matemática Aplicada, Facultad Matemáticas
Universidade de Santiago de Compostela, 15782 Santiago, Spain

[4] CITMAGA, 15782 Santiago de Compostela, Spain

[5] Departamento Matemática Aplicada, EPSE
Universidade de Santiago de Compostela, 27002 Lugo, Spain

ABSTRACT

Effective crowd evacuation in emergencies is a key public safety priority. Modelling and analysis of crowd dynamics have been a very active study area in traffic engineering in recent decades, both from a numerical and an analytical viewpoint [1, 2]. Nevertheless, optimal control and optimization of these evacuation processes have been much more sparsely addressed within the scientific literature.

In this work we introduce a novel framework, based on optimal control techniques of partial differential equations, to automate the optimization of locations for a given number of exit doors at gathering places, so that the evacuation of crowds takes place in a safer and faster way.

Our proposal is based on the use of optimal control techniques for a formulation of the problem within a framework of partial differential equations. In particular, we consider a reformulation of the classical Hughes system with a suitable set of initial/boundary conditions for modeling the flow of pedestrians (characterizing their density and walking velocity), which constitutes the state system of the optimal control problem. The objective function to be optimized in our problem corresponds to minimizing the number of pedestrians left inside the place at the end of the evacuation process. Moreover, we also need to include some constraints on the control (the location of the exit doors) since not all possible door positions are admissible for geometric, organizational, or security reasons.

To solve the constrained optimal control problem numerically, we propose a full discretization of the problem, with a space semi-discretization via the finite element method over a family of triangular meshes of the domain under study, and a time semi-discretization via the Euler algorithm. Finally, for the resulting discretized minimization problem, we propose its optimization by means of any derivative-free algorithm, due to the hard numerical difficulties involved in the possible computation of the gradients of the cost functional. In our case, we have chosen the classical Nelder-Mead algorithm and a controlled random search procedure.

Several numerical examples, corresponding to two different scenarios for a real-world study case posed on Plaza de la Liberación in Guadalajara (Mexico), are presented and discussed to assess the effectiveness of our approach [3].

This research was funded by Ministerio de Ciencia e Innovación (Spain) under grant TED2021-129324B-I00, by Sistema Nacional de Investigadores (Mexico) under Grant SNI-52768, by Programa para el Desarrollo Profesional Docente (Mexico) under Grant PRODEP/103.5/16/8066, and by CONACyT/Ciencia de Frontera (Mexico) under Grant 217556.

REFERENCES

[1] N. Bellomo and C. Dogbé, "On the Modeling of Traffic and Crowds: A Survey of Models, Speculations, and Perspectives", *SIAM Revue*, Vol. **53**, pp. 409–463, 2011.

[2] B. Maury and S. Faure, *Crowds in Equations: An Introduction to the Microscopic Modeling of Crowds*, World Scientific, Singapore, 2019.

[3] L.J. Alvarez-Vázquez, N. García-Chan, A. Martínez, C. Rodríguez and M.E. Vázquez-Méndez, "Optimal Location of Exit Doors for Efficient Evacuation of Crowds at Gathering Places", *Axioms*, Vol. **11**, 592, 2022.