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Survey of detection techniques, mathematical models and simulation software in pedestrian dynamics

C. Caramuta, G. Collodel, C. Giacomini*, C. Gruden, G. Longo, P. Piccolotto

Dipartimento di Ingegneria ed Architettura, Sezione di Strade, Trasporti e Topografia, Università degli Studi di Trieste, via A. Valerio 6/2, 34127 Trieste, Italy

Abstract

The study of pedestrian dynamics has become in the latest years an increasing field of research. A relevant number of technicians have been looking for improving technologies able to detect walking people in various conditions. Several researchers have dedicated their works to model walking dynamics and general laws. Many studies have developed interesting software to simulate pedestrian behavior in all sorts of situations and environments. Nevertheless, till nowadays, no research has been carried out to analyze all the three over-mentioned aspects. The remarked lack in literature of a complete research, pointing out the fundamental features of pedestrian detection techniques, pedestrian modelling and simulation and their tight relationships, motivates the draft of this paper.

Aim of the paper is, first, to provide a schematic summary of each topic. Secondly, a more detailed description of the subjects is displayed, pointing out the advantages and disadvantages of each detection technology, the working logic of each model, outlining the inputs and the provided outputs, and the main features of the simulation software. Finally, the obtained results are summarized and discussed, in order to outline the correlation among the three explained themes.

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* Corresponding author. Tel.: +39-040-558-3582; fax: +39-040-558-3580.
E-mail address: cristian.giacomini@dia.units.it

1. Introduction

The increase of global population and the resulting widespread urbanization have often involved the expansion of congested areas and the possible uprising of transport problems: the need of making mobility more eco-friendly, urban design more suitable for walking people, as well as the management of crowded areas, the design and integration of transport terminals within the urban context, safety and security of people.

The need of facing these problems and, at the same time, the development of a society which is more careful towards environmental safeguard, inhabitant health, easier accessibility and, in general, towards a better living quality, have brought to an inversion of tendency in urban design. In fact, from now on, technicians have focused their attention on the pedestrian point of view, managing to highlight the difficulties and necessities of walking people. Consequently, various adaptations of infrastructures have been defined, which facilitate pedestrian mobility, with the aim of satisfying transfer demand.

In order to achieve all those goals, in the latest decades, detection and tracking technologies have been improved, walking dynamics have been analytically modelled and simulation software have been developed.

In Section 1 the three topics are briefly described; in Section 2 the pedestrian detection and tracking techniques are deeply analyzed, focusing on their way of operation. In particular, the provided outputs are explained through some real applications. In Section 3 the main mathematical models of pedestrian dynamics are illustrated, stressing the required inputs in order to describe those phenomena. Section 4 deals with the most referenced pedestrian simulation software, evaluating the needed inputs and the given outputs. Finally, the conclusions highlight the relationship among the three themes.

2. Focus on the issues

The need of analyzing pedestrian mobility requires a deep knowledge of several aspects of the modelling process, as data acquisition, model definition and software simulation.

The lack of data about walker behavior is one of the greatest problems that researchers have to face. It is known that detecting and tracking human beings is very difficult: as a matter of fact, while walking, pedestrians keep on changing their shape; moreover, people have several peculiar features and they often move in crowded places. These complexities have brought to the development of many detection and tracking technologies, providing more precise and autonomous methods. The main used detection techniques are video and RGB+D cameras, GPS devices, laser scanners, pressure sensors and localization sensors. These technologies have been analyzed in order to highlight their pros and cons and the outputs they provide, referring to different application fields.

The main reference studies about detection technologies are the following: in [1] detection methods have been evaluated with the aim of providing a classification based on established criteria.

The authors of [2] have analyzed pedestrian passive detection technologies used at unsignalized intersections.

[3] introduces some methods for pedestrian detection, in order to simplify the choice of the best technique for planning.

The aim of representing pedestrian behavior has led studiers to develop various models, that can be classified into two categories: the macroscopic and the microscopic ones. As already confirmed by previous works, the firsts define pedestrians in an aggregated way, so that the smallest representable entity is the flow. The latter consider each pedestrian individually, as an agent interacting with other moving subjects and the environment.

In the macroscopic field the two main models are the continuum and the fluid-dynamic ones.

From the microscopic point of view, many models have been carried out, like the social force model, the utility maximization one, the magnetic force one, the cellular-automata one, benefit- cost one, the queue one, discrete-choice one and agent-based one.

In the modelling field, Teknomo et al. have focused their attention on the state-of-art about microscopic models in various papers [4,5,6].

Also Shiwakoti et al. have dealt with both microscopic and macroscopic pedestrian modeling, in order to present an overview of the main models useful under emergency conditions [7].

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