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An investigation on human dynamics in enclosed spaces☆

Marcello Trovati*,[a], Eleana Asimakopoulou[b], Nik Bessis[a]

[a] Department of Computer Science, Edge Hill University, UK
[b] Hellenic National Defence College, Greece

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ABSTRACT

In this article, we introduce a method for analysing specific dynamical properties associated with the movement of people on a two-dimensional (compact) space. We focus on a variety of features defined by the topology and dynamics of the system to investigate human dynamics in enclosed spaces. This can potentially have significant applications within systems defined by human behaviour, particularly relevant to disaster management, internet of things (IoT), and big data analytics.

1. Introduction

Human behaviour typically exhibits complex features, which have been investigated via various models and simulation techniques, where the aim is to determine the most important factors in the time and the way of reaching a specific target, such as exiting a room [1].

In this article, we propose an investigation of the dynamical properties of systems defined by the movement of people over a two-dimensional (compact) space. Our approach is based on the properties of the network generated by specific parameters linking the different individuals, such as the mutual distance and leadership properties exhibited by some of them, which might influence the followers–leaders structure.

In particular, the choice of following a specific individual depends on global and local topological, as well as dynamical properties associated with the corresponding network, such as the connectedness of the different nodes and how this changes over time. Such properties have a direct impact on the overall behaviour of the system.

1.1. Applications to IoT, big data and disaster management

Internet of things (IoT) has been attracting increasing attention from the research community [2,3]. In particular, the interconnections among devices, buildings, sensors, etc. enable the collection and exchange of an enormous quantity of data, creating significant opportunities, as well as new challenges. Therefore, when IoT is integrated with big data technology, this can identify new trends and actionable information, which can be used in a variety of contexts and applications [4,5]. In particular, disaster management is an important application, where IoT sensing and communication technologies can be utilised to monitor and gather data, even in the absence of any existing infrastructure [6].

The method proposed in this article can be used to investigate and assess human movement in enclosed spaces, by analysing the dynamical and self-organising properties of the corresponding system. Throughout this work, we assume that a suitable IoT

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* Corresponding author.
E-mail address: trovatim@edgehill.ac.uk (M. Trovati).

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framework, gathering relevant information regarding the positions of the corresponding individuals, is in place and fully functioning. The novelty of this article stems from its integration of various theoretical techniques with specific applications. In particular, the former allow a more comprehensive description of such systems, which has not previously been fully exploited. Furthermore, this work is part of a wider line of inquiry aiming to create a model based on a topological and algebraic framework. This will enable the identification and assessment of the macro and micro properties of the system, by using an efficient and agile computational approach. Furthermore, the mathematical formalism utilised in this research can be extended to integrated theoretical approaches currently developed in other contexts [7]. This will have important applications within disaster management, big data analytics, as well as various IoT scenarios.

The article is structured as follows: Section 2 discusses the current research in this field, and Section 3 introduces the main concepts and definitions used in this context. Sections 4 and 5 discuss the components of the model and the simulation results, respectively. Finally, Section 6 concludes the article and discusses future research directions.

2. Related work

In [8], a model predicting the emergence of self-organisation phenomena is introduced. The authors investigate the combination of pedestrian heuristics with body collisions potentially creating crowd turbulence, based on an integrated assessment of simultaneous interactions between multiple individuals.

In [9] a method for investigating realistic models of crowd dynamics is proposed, which considers an agent-based approach combined with non-homogeneous and asynchronous cellular automata. The authors argue that this approach enables the modelling of pedestrians' dynamics in various and complex environments. In [10], via the utilisation of exosomatic visual architecture, the authors show the feasibility of behavioural models where movement rules are based on Gibson's principle of affordance [11]. More specifically, they apply agents defined by such rules to a built-environment scenario, via the variation of specific parameters, such as destination selection, field of view, and steps taken between decision points.

The properties related to the behaviour of ants and pedestrians are investigated in [12], where the pheromone left by preceding ants creates a trail, which is followed by other ants. In a similar manner, pedestrians attempt to follow other individuals in a crowded environment to optimise efficient and safe walking. The authors propose a stochastic model, which integrates this type of behaviour based on local update rules. In particular, the relation between the ant trail model and the floor field model for studying evacuation dynamics of pedestrians is investigated, based on a two-dimensional generalisation of the ant trail model, where the pheromone is replaced by footprints. Their evaluation demonstrates that small perturbations will sometimes avoid congestion and hence allow safe evacuation.

A method for identifying human behaviour in a social network is introduced in [13], which is based on Markov chains trained on a specific number of models of normal human behaviour from social network data. This is subsequently, integrated with an activity detection framework, to identify unexplained activities on the basis of the normal behaviour models.

In [14], the authors discuss a model for the social interactions of pedestrians to enhance the prediction of their destination. An investigation of the phenomenon of the leader–follower behaviour is also provided, which is defined as the adjustment of an individual's motion to follow a leader.

In our proposed method, specific dynamical properties are emphasised, which can be easily expanded to address the interactions in human behaviour. These, in turn can be utilised to build a more robust theory based on topological and algebraic properties, as discussed in Section 1.

3. Main definitions and assumptions

In this work, we consider an enclosed two dimensional space, such as a room, where a group of individuals move based on specific rules, aiming to eventually leave through one or more exits. In particular, their mutual relationships create a complex system, which evolves over time and is highly dynamic by nature. Fig. 1 depicts an example of such scenario.

As discussed in Section 2, there is extensive research on this topic, and it has been demonstrated that IoT provides a framework to

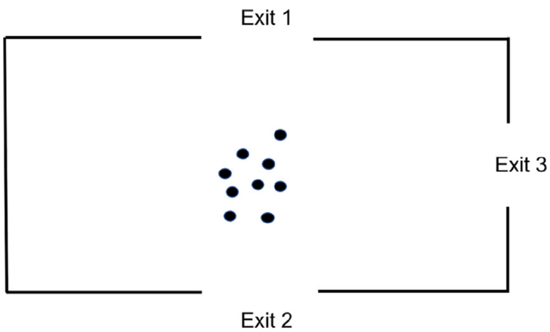

Fig. 1. An example of the scenario described in Section 3.