Crowd Behavior Modeling: From Cellular Automata to Multi-Agent Systems

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1 Scope of the chapter

The aim of this chapter is to introduce the current researches focused on the modeling and simulation of crowds of pedestrians. Research efforts on this topic are aimed, on one hand, at improving the scientific investigation of crowd related phenomena and, on the other, at the exploitation of the developed models and simulators to support designers and decision makers in their activities by providing them the possibility to envision the behaviour of crowds of pedestrians in specific scenarios.

2 Subject of the chapter

Crowds of pedestrians are complex entities from different points of view, starting from the difficulty in providing a satisfactory definition of the term ‘crowd’. “(Too) many people in (too) little space” (Kruse, 1986) is a pedestrians crowd definition aggregating several disciplinary interpretations, and the range of this definition sites its fuzzy borders in the traditional opposition between humanistic and scientific cultures. The range of individual and collective behaviours that take place in a crowd, the composite mix of competition for the shared space but also collaboration due to, not necessarily explicit but shared, social norms, the possibility to detect self-organization and emergent phenomena they are all indicators of the intrinsic complexity of a crowd. The relevance of human behaviour, and especially of the movements of pedestrians in built environment in normal and extraordinary situations (e.g. evacuation), and its implications for the activities of architects, designers and urban planners are apparent (see, e.g., Batty, 2001 and Willis et al., 2004), especially given recent dramatic episodes such as terrorist attacks, riots and fires, but also due to the growing issues in facing the organization and management of public events (ceremonies, races, carnivals, concerts, parties/social gatherings, and so on) and in designing naturally crowded places (e.g. stations, arenas, airports). Computational models of crowds and simulators are useful instruments supporting architectural designers and urban planners in their decisions by providing the possibility to envision the behaviour/movement of crowds in specific designs/environments, to evaluate what-if scenarios with reference to specific metrics and criteria.
3. The contribution of the chapter

The contribution of the present chapter is related to different elements that will be discussed in the chapter, and in particular:

- The current state of the art in crowd modeling approaches, that range from a physical representation of pedestrians (viewed in terms of particles subject to forces generated by points of reference/interest of the environment and by pedestrians themselves), to a discrete modeling of the environment in terms of a lattice in which pedestrians are viewed as particular states of a cell, in a cellular automata approach, to a situated agent based approach, that provides a clearer separation between the model of the environment and the active entities that inhabit it, acting and interacting according to their perceptive capabilities and behavioural specification;

- The detailed description of a specific situated agent modeling approach based on the Situated Cellular Agents model (Bandini et al., 2006) applied to crowds of pedestrians, with the description of its application to a paradigmatic case study. The elements of the model will be formally introduced and applied to represent specific elements of a typical crowding scenario (physical environment in which pedestrians are situated and pedestrians themselves, plus mechanisms for the interaction among these situated entities and between them and the environment);

- The description of a framework for the execution of SCA based models and three-dimensional visualization of the dynamics generated by the simulator. A simulation project, in fact, often requires the production of results that must be used by decision makers that might not be experts of the specific application domain. In this specific case, the possibility to envision crowd dynamics in different elaborated scenarios represents a useful feature, especially in a participated decisions scenario (see, e.g., Dijkstra et al., 2003).

4. Future research on crowd modeling and simulation

Future research on this topic provides several trends mainly focused on:

- Data acquisition, validation and verification techniques: the current landscape on approaches to data acquisition about crowds of pedestrians is changing due to the growing availability of localization technologies (GPS, RFID, UWB). However, proper methodologies for the acquisition of data to characterize crowds of pedestrians in complex situations are still missing, and this situation makes it difficult to devise proper validation and verification techniques that go beyond the typical paradigmatic cases (see Helbing et al., 2002);

- Integration of psycho/sociological considerations in crowd models: most models of pedestrian behaviours disregard differences among individuals that make up a crowd. The integration of psycho/sociological considerations on human behaviour (such as the inclusion of emotions and their effects influencing pedestrian movement) could provide an improvement to the expressiveness of crowd models that could also extend the range of applications, towards the modeling of consumers’ behaviours in shopping spaces (Dijkstra et al., 2007).
References


