Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 2 (2014) 618 – 623

Transportation Research Procedia

www.elsevier.com/locate/procedia

The Conference on Pedestrian and Evacuation Dynamics 2014 (PED2014)

A hybrid agent architecture for enabling tactical level decisions in floor field approaches

Luca Crociani [a], Alberto Invernizzi [a], Giuseppe Vizzari [a,*]

[a] *Complex Systems and Artificial Intelligence Research Center, University of Milano-Bicocca, viale Sarca 336/14, 20126 Milano, Italy*

Abstract

For a comprehensive modeling of pedestrian dynamics in real-world scenarios the consideration of tactical level decisions in addition to operational ones is necessary. This paper presents a hybrid agent architecture employing a Floor Field approach at the operational level but granting agents an abstract representation of the simulated environment. The paper briefly presents the environmental model and hybrid agent architecture based on the floor field approach, then a sample practical application in a simple case study is also presented to show how it allows specifying abstract behavioural *scripts* for different groups of agents.

© 2014 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

Peer-review under responsibility of Department of Transport & Planning Faculty of Civil Engineering and Geosciences Delft University of Technology

Keywords: pedestrian simulation; agent-based modeling; floor-field model; hybrid agents; environments for multi-agent systems

1. Introduction

The Floor Field approach to the modeling and simulation of pedestrian dynamics, first introduced by Burstedde et al. (2001), represents a viable option for the implementation of quantitatively validated simulation systems based on a discrete approach to the representation of the environment. However, a comprehensive simulation system for pedestrian dynamics in real-world scenarios requires the consideration of tactical level decisions in addition to operational ones, as discussed by Schadschneider et al. (2009), that are the main focus of the Floor Field approach. This paper presents a hybrid agent architecture essentially employing a Floor Field approach at the operational level but providing agents an abstract representation of the simulated environment for tactical level deliberation, a map automatically derived from an annotated CAD-like description of the environment in which the simulation must take place. This form of knowledge is essentially a labeled graph in which nodes are associated to regions and links represent connections among them; links and other relevant points in the environment are associated to static floor fields allowing agent navigation at the operational level. Considering, instead, tactical level aspects, agents are provided with a goal, a final target destination potentially enriched by intermediate steps and movement constraints; they initially autonomously inspect their knowledge and derive a plan indicating intermediate destinations, associated to specific static floor fields to be followed. The paper will briefly present the environmental model, including a base

* Corresponding author. Tel.: +39-02-64487865 ; fax: +39-02-64487839.
E-mail address: giuseppe.vizzari@disco.unimib.it

2352-1465 © 2014 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).
Peer-review under responsibility of Department of Transport & Planning Faculty of Civil Engineering and Geosciences Delft University of Technology
doi:10.1016/j.trpro.2014.09.103

CAD-like geometric representation from which both the abstract representation and a set of layers associated to static floor fields are automatically constructed. The tactical level extension of a previous agent-based model, also allowing the management of groups of pedestrians, introduced by Vizzari et al. (2013) will then be described to show how this level and the existing operational layer interact. Finally, a sample practical application in a simple case study is also presented to show how it allows specifying abstract behavioural *scripts* for different groups of agents.

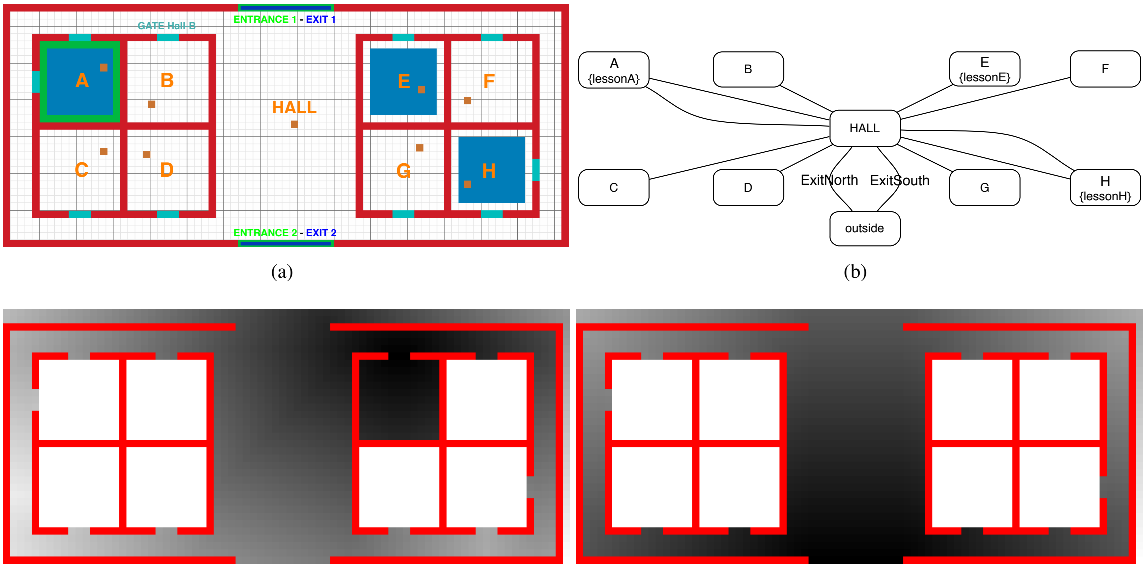
2. Environment

As discussed by Weyns et al. (2007), the environment of an agent-based system is "a first class-abstraction that provides the surrounding conditions for agents to exist and that mediates both the interaction among agents and the access to resources". An environment for agent-based systems can encompass both abstractions and mechanisms, for instance regulating the outcomes of agents' chosen lines of action, as discussed by Bandini and Vizzari (2007). Within this framework, for this particular application of an agent-based modeling and simulation approach, the environment does not only encompass a spatial representation of the simulated area, but also a set of abstractions and data structures (e.g. static floor field matrices) enabling agents' perceptions, deliberations and actions. In particular, for our purposes we need (i) a discretization describing the walkable area subdivided into cells of configurable size (e.g. 40 cm sided square cells); (ii) a similar discrete layer representing the effect of obstacles on the overall cell desirability; (iii) similar discrete layers representing the static floor field associated to a given point of reference/interest; (iv) a graph-like abstract representation of relevant sub-areas in the simulated space connected according to the reachability relationship.

In order to support an automated production of the above elements and related data structures, a spatial representation of the area in which the simulation must take place, in the form of a CAD-like file, is required: on the other hand, this kind of map is generally produced when planning the construction of a building or available to managers of a premise. In order to allow algorithms to actually explore this representation and make sense of it, the designer is required to produce some form of *annotation* in it, as exemplified in Figure 1(a). In particular, the sub-areas in which the environment is divided into must be constrained by *obstacles* (in red in the figure), or passages, *gateways* to another sub-area (in cyan), and they must contain a specific block indicating a label that will be associated to the area. Both gateways and these *label blocks* are annotations that do not influence the walkability of the associated cells. Additional annotations represent *start areas*, in which pedestrian agents can be created (either initially or even at later stages of the simulation), *end areas*, final targets of movements in which pedestrian agents actually exit the simulation, and *intermediate destinations* (also associated to labels, not shown in the figure) that pedestrians must reach at a certain point of a more articulated movement plan.

The construction of such a plan requires the possibility to explore and process a much simpler data structure, in particular an abstract map in terms of a graph-like commonsense representation of the environment, as discussed by Bandini et al. (2007). This structure, also exemplified in Figure 1(b), can be automatically derived by the annotated CAD-like representation employing an algorithm that cannot be reported here for sake of space. We want to emphasize here the fact that intermediate destinations (such as the one included in area A, labeled as "lessonA") are essentially included in the sub-area they are part of. Moreover, final exits are represented as annotated edges (ExitNorth and ExitSouth in the figure) leading to a vertex not associated to a sub-area in the CAD-like representation of the environment but rather related to the "outside" world. As we will discuss in the following section, this structure is particularly suited for simple path planning algorithms that can be employed in agent's tactical level.

Instead, for managing operational level tasks in the Floor Field approach, additional discrete grids containing gradient-like structures supporting agents' navigation of the environment are necessary. Examples of these data structures are shown in Figure 1(c) and 1(d), respectively related to the static floor fields leading towards the gateway between the sub-areas labeled as "Hall" and "E" and the southern exit of the scenario. Once again, the annotated CAD-like representation of the environment supports the automated generation of these layers, by means of a simple cellular automaton whose description is omitted here for sake of space. Please notice that, however, we chose not to extend the diffusion of the static floor field associated to an area or marker to all the discrete representation of the environment, but to limit this operation to the sub-areas that are in direct connection to the target in the abstract commonsense representation. This, on one hand, simplifies the environment set up phase (especially considering relatively large environments, in which it would not be practically feasible to do this) and, on the other, is sufficient



(a) (b)

(c) (d)

Fig. 1. Relevant elements of pedestrian agents' environment. (a) CAD-like representation of the environment. (b) Abstract commonsense representation of the environment. (c) Static floor field associated to the gateway between "Hall" and "A". (d) Static floor field associated to the southern exit.

since the agents will be provided with a tactical level behavioural model allowing them to generate plans requiring the perception of these fields only in these adjacent sub-areas.

Additional layers are actually included in the agent environment to support the gathering of statistics about their dynamics, but also their interactions (in particular, the mutual perception of members of groups) and the management of conflicts (movement intentions are stored into one of these additional layers to support a simple identification and management of the conflicts by the environment itself).

3. Agent Architecture

Considering the above structure for the agent environment, it is clear that the information provided to agents' perceptions is sufficient to support basic operational level behaviour for pedestrian agents. In fact, whenever an agent knows where it's headed (i.e. can perceive the static floor field associated to that destination), the basic floor field model is sufficient to allow the agent to achieve its own movement goal. However, as mentioned in the previous section, the static floor fields is not spread in the complete discrete representation of the environment, so an agent must actually plan a course of action, implying a sequence of intermediate way-points associated to other static floor fields, leading to an area in which the target is finally perceivable. This particular reasoning requires a *hybrid* architecture of the agent, whose "body" component reproduces the pure reactive behaviour (i.e. the raw movement at operational level), while a "mind" is dedicated to this cognitive level reasoning, aimed at achieving a sequence of fields to follow in order to reach the final target. A schematic description of the devised agent architecture is shown in Figure 2: the operational level layer (denoted as body) is actually an implementation of the extension to the floor-field model described by Vizzari et al. (2013)[1] slightly modified to trigger the computation of tactical level choices (carried out by the layer denoted as mind) whenever it is necessary. An obvious condition for the activation of the tactical level is the fact that an agent has a final goal that is not immediately perceivable at operational level. For instance, in the sample environment introduced in the previous section, an agent situated in the sub-area "E" cannot perceive the floor field

[1] Additional details about the implementation are provided by Crociani et al. (2013).

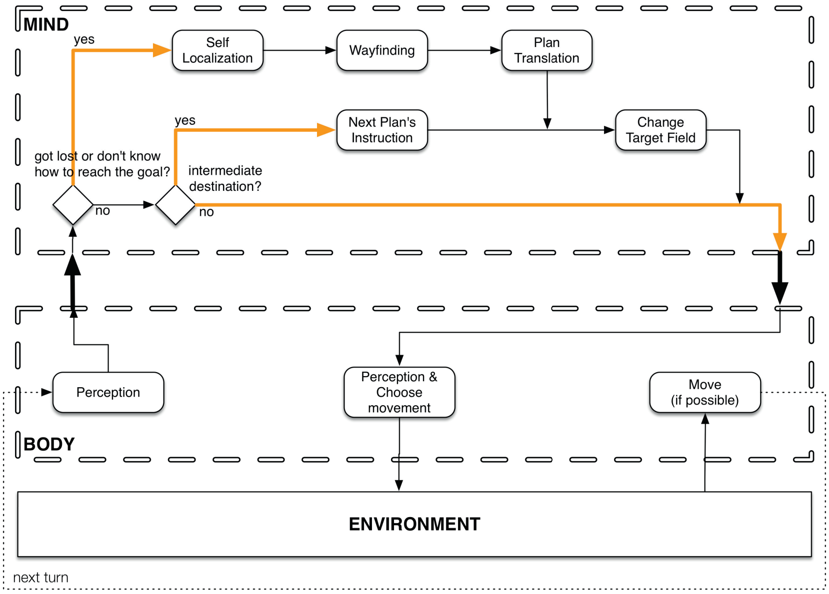


Fig. 2. Agent architecture

associated to the northern exit. Nonetheless, agents are provided with the spatial knowledge associated to the abstract commonsense representation of the environment, which is a data structure accessible by their tactical level. Therefore, since they are able to understand what is their current location in this structure, they can search for their goal in the abstract map and in particular the intermediate steps leading towards this goal. The result of this search operation (that employs state of the art graph search algorithms whose description is omitted for sake of space), leads to the construction of a plan in the form of a set of operating instructions as depicted in Figure 3 (for sake of simplicity and compactness, the example is not related to the above described environment but rather to a small apartment): the plan was constructed by an agent situated in a sub-area labeled “dining room” and with the goal of reaching the “balcony”. The intermediate steps are sub-areas labeled “corridor” and “bedroom”, each associated to a specific static floor field: the connection between edges among vertexes (associated to sub-areas) and a related static floor field layer allows the tactical level plan to be translated into an operational level focusing on the correct field leading to the current intermediate (or final) target.

The current implementation of the search algorithm represents a basic approach, that does not consider agent preferences (e.g. avoid stairs and use escalators), or the crowding conditions of the environment (e.g. when the most direct path is getting too congested, change the plan), but these extensions are currently being considered for extended search strategies.

4. Example application

The example application of the hybrid agent model is related to the previously described environment; in particular, it is a rough representation of a building including a set of lecture halls (labeled from “A” to “E”), all of which reachable from a central hall (actually including a surrounding corridor), with a northern and southern exits.

Within this scenario, exploiting the previously described tactical level extension, it is relatively simple to model different groups of pedestrian agents associated to different groups of students, having different timetables. For instance we could define three groups (Green, Yellow and White agents) whose tasks in the environment are the following:

Green $[A \rightarrow lessonE \rightarrow Exit\{0.5\, North; 0.5\, South\}]$

Yellow $[EntranceNorth \rightarrow lessonA \rightarrow lessonH \rightarrow Exit\{0.5\, North; 0.5\, South\}]$

White $[EntranceSouth \rightarrow lessonA \rightarrow lessonH \rightarrow Exit\{0.5\, North; 0.5\, South\}]$

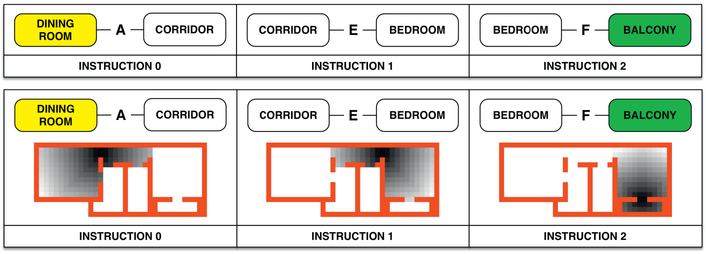


Fig. 3. Operating instructions

The green agents, in other words, are already in the environment at the beginning of the simulation, in particular in lecture hall “A”, then they have to move to the sub-area in which “lessonE” takes place (i.e. lecture hall “E”) and finally they must leave the environment, half of them through the northern exit and the other half through the souther one. Yellow and white agents, instead, enter the simulation area respectively through the northern and southern entrances, then move to the sub-area where “lessonA” takes place (lecture hall “A”), then they have to move to “lessonH” (lecture hall “H”) and finally leave the environment, also splitting equally between northern and southern exits.

Some screenshots of this simulation are shown in Figure 4. In particular, in Figure 4(a) green agents are exiting hall “A” and moving towards hall “E” (using both exits of hall “A”), while yellow and white agents are moving to hall “A”. In Figure 4(b) the three groups have reached the respective destinations and, later on in Figure 4(c), the green group leaves the environment while the yellow and white groups move towards lecture hall “H”. Finally, in Figure 4(d), both groups are reaching their final lesson before leaving the environment. The fact that agents from the same group employ different paths to reach the same movement target may depend, on one hand, on the nature of the static floor field layer, but also on the fact that, at the tactical level, they may choose different intermediate steps (e.g. there are two gateways leading from the main hall to lecture hall “A”).

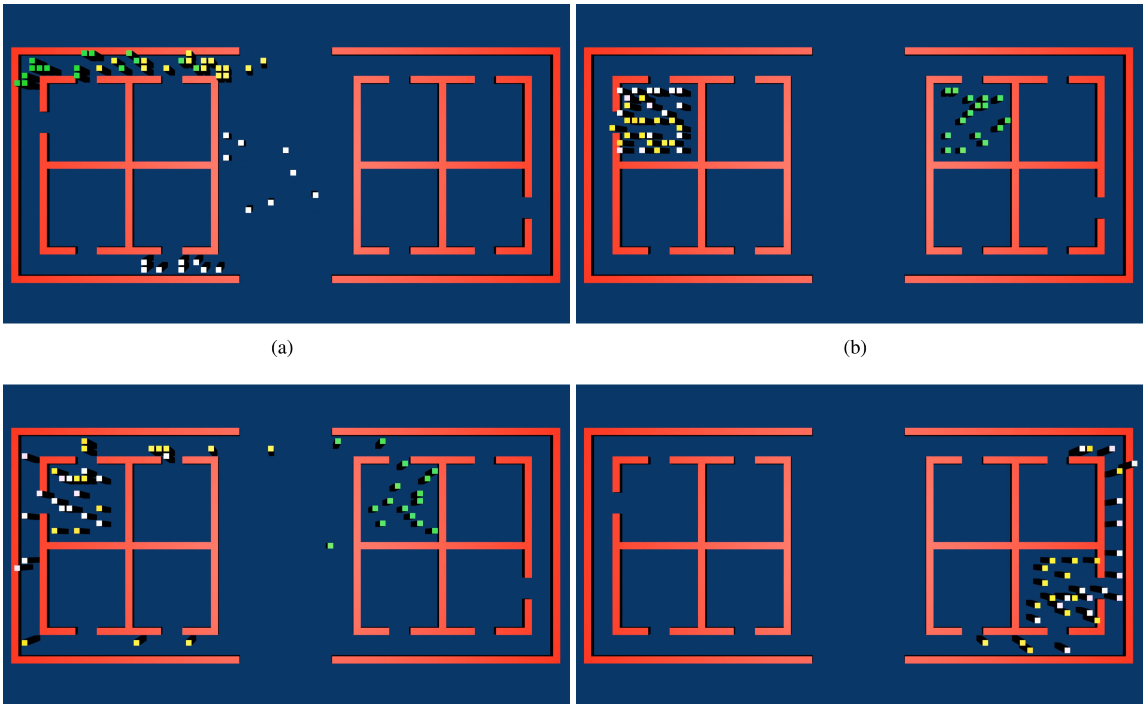
Finally, it must be noticed that the modeler is not forced to precisely and extensively define the path followed by the agent groups, which will plan according to the tactical level knowledge and then actuate at operational level, exploiting the already implemented floor field based system.

5. Conclusions and Future Developments

The paper has shown an extension of a floor field model to encompass tactical level tasks and information. We introduced a particular structure of agents’ environment allowing them to perceive and act at the operational level, but also deliberate at tactical level: environmental data structures are automatically generated starting from an annotated CAD-like environment description. The hybrid agent architecture, including a simple reactive operational level able to trigger deliberation activities of the tactical level whenever it is necessary, has also been introduced. A sample application illustrating how this approach allows specifying simple behavioural scripts for relatively complicated agent’s plans has finally been described. Future works are aimed, on one hand, at supporting the possibility to enrich the abstract commonsense spatial representation for allowing tactical level reasoning about information like estimated distances, level of crowdedness of visible areas or passages, additional relevant information (e.g. a certain area is a steep ramp or staircase, which would hinder the movement of elderlies or persons on wheelchairs). Moreover, we are also going to extend agents’ behavioural specification to allow the coordination of group path planning and the definition of area activities, in the vein of Was and Lubaś (2014).

Acknowledgements

This work was partly supported by the ALIAS project (“Higher education and internationalization for the Ageing Society”), funded by Fondazione CARIPLO.



(a) (b) (c) (d)

Fig. 4. Application in a university building scenario. (a) Green group leaves hall "A" while yellow and white ones move towards it. (b) All groups reached their intermediate targets. (c) Green group leaves the environment, while yellow and white ones move towards hall "H". (d) Yellow and white groups have almost completed their movement towards hall "H".

References

Bandini, S., Mosca, A., Palmonari, M., 2007. Common-sense spatial reasoning for information correlation in pervasive computing. Applied Artificial Intelligence 21, 405–425.

Bandini, S., Vizzari, G., 2007. Regulation function of the environment in agent-based simulation, in: Weyns, D., Parunak, H.V.D., Michel, F. (Eds.), Environments for Multi-Agent Systems III, Third International Workshop, E4MAS 2006, Hakodate, Japan, May 8, 2006, Selected Revised and Invited Papers, Springer–Verlag. pp. 157–169.

Burstedde, C., Klauck, K., Schadschneider, A., Zittartz, J., 2001. Simulation of pedestrian dynamics using a two-dimensional cellular automaton. Physica A: Statistical Mechanics and its Applications 295, 507 – 525.

Crociani, L., Manenti, L., Vizzari, G., 2013. Makksim: Mas-based crowd simulations for designer's decision support, in: Demazeau, Y., Ishida, T., Corchado, J.M., Bajo, J. (Eds.), PAAMS, Springer. pp. 25–36.

Schadschneider, A., Klingsch, W., Klüpfel, H., Kretz, T., Rogsch, C., Seyfried, A., 2009. Evacuation dynamics: Empirical results, modeling and applications, in: Meyers, R.A. (Ed.), Encyclopedia of Complexity and Systems Science. Springer, pp. 3142–3176.

Vizzari, G., Manenti, L., Crociani, L., 2013. Adaptive pedestrian behaviour for the preservation of group cohesion. Complex Adaptive Systems Modeling 1.

Weyns, D., Omicini, A., Odell, J., 2007. Environment as a first class abstraction in multiagent systems. Autonomous Agents Multi-Agent Systems 14, 5–30.

Was, J., Lubaś, R., 2014. Towards realistic and effective agent-based models of crowd dynamics. Neurocomputing (in press).