Paper presented at PED 2010, NIST, Maryland USA, March 8-10 2010

Introducing Emotion Modelling to Agent-Based Pedestrian Circulation Simulation

C. Hollmann, P. J. Lawrence and E. R. Galea

Fire Safety Engineering Group, University of Greenwich
London, SE10 9LS, UK
Corresponding author: C.Hollmann@gre.ac.uk

Abstract In agent-based pedestrian circulation models, the simulation of the pedestrian-environment interaction is mostly achieved by imposing on each agent a predefined list of goal locations which the agent visits in turn. However, in reality human behaviour in complex environments is highly dynamic and fixed plans are often changed and adjusted according to emergent conditions and the person's individual interpretation of these events, in particular the amount of time available to achieve all the desired tasks. In this paper we present a prototype emotion model implemented within the buildingEXODUS evacuation and pedestrian dynamics software which enables simulated agents to react to perceived time pressures by modifying their behaviour. The model is demonstrated using a circulation scenario within a rail terminal.

Introduction

Pedestrian circulation modelling tools have been developed with the intention to simulate human behaviour in various environments under normal usage conditions. Most of these models consider the physical movement of agents through a complex building layout and impose a set of goals on each agent which requires the agents to visit certain features within the structure, e.g. retail outlets, catering outlets, ticket offices, etc. The agents visit each location in turn, perhaps spending an arbitrary amount of time 'engaged' in activities at each location, often not taking into account external factors which may impact the viability or desirability of undertaking the prescribed activities. However, external influences such as congestion or time limitations may have an impact on the agents' short and long-term planning with regard to achieving their goals, and therefore need to be addressed within the simulation.

It is well known that emotions, motivations and feelings have a direct impact on human decision making as individuals attempt to cope with emergent events [1]. As a result the modelling of emotions has been introduced into areas such as computer graphics [2] and agenda scheduling [3]. There have also been approaches to introduce emotions into simulated human decision making associated with emergency evacuation [4] and pedestrian circulation [5]. Emotion modelling is used to augment the agent's context awareness and hence their capability to evaluate the current situation, come to a conclusion and take appropriate actions. In this paper, we present a basic emotion model with the aim to enhance the simulation of pedestrian behaviour in multi-purpose environments. The model has been incorporated into the existing agent-based evacuation and pedestrian dynamics simulation software, buildingEXODUS [6]. Here we provide a brief overview of our prototype emotion model and demonstrate its capabilities in a pedestrian circulation scenario within a large rail terminal.

The Emotion Model within buildingEXODUS

The new prototype emotion model monitors the time available for each agent to complete a set of assigned tasks and the estimated time required to complete those tasks. As the available time decreases the agent might have to decide to increase their movement speed and if necessary drop some or all of the assigned tasks while attempting to complete the critical assigned tasks. Within buildingEXODUS, pedestrian circulation movement is primarily determined by a list of tasks assigned to each agent (the *Itinerary*) which the agent completes as part of the simulation. Within the new prototype, these tasks are assigned to different categories: ***Compulsory Tasks***, these are tasks that must be completed e.g. 'purchase a train ticket'; ***Time Critical Tasks,*** these are tasks which must be completed at a particular time e.g. 'board the train before 17.45' and ***Elective Tasks***, these are tasks which are completely voluntary and while desirable to complete are not essential e.g. 'purchase a newspaper'. The agent's behaviour is therefore mostly governed by those tasks which are compulsory or time critical.

Table 1: Behavioural responses triggered by the agent's individual time evaluation.

Time Assessment	Urgency State	Physical Behaviour	Itinerary Adjustment
$ERT_1 \leq AT$	0	Continue as normal	-
$ERT_2 \leq AT < ERT_1$	1	Escalate speed + drive, Reduce patience	-
$ERT_3 \leq AT < ERT_2$	1	Escalate speed + drive, Reduce patience	Drop least important elective task and reassess situation with new itinerary
$AT < ERT_3$	1	Escalate speed + drive, Reduce patience	Drop all remaining unessential tasks and reassess situation with new itinerary

In the prototype version of the emotion model, a new personal parameter has been introduced which reflects the agents' attempt at fulfilling their assigned itinerary within the given constraints: the ***Urgency***. If the agent estimates that they have sufficient time to complete all of their assigned tasks, their Urgency is 0. As soon as they perceive that they have insufficient time to complete all of their remaining tasks their Urgency is increased to 1. The agent parameters drive, patience and walk speed have been modified to allow agents to vary these parameters according to their state of urgency. In addition, the tasks on the agents' itinerary have been prioritised, reflecting not only the compulsory, time critical and elective nature of the tasks, but also a ranking within each category. The task ranking determines the order in which the agents can drop their elective tasks if required. At dynamic time intervals, the agent calculates the amount of time remaining until their next critical time task i.e. the ***Available Time (AT),*** as well as estimates the amount of time that is required to complete all the remaining tasks i.e. the ***Estimated Required Time (ERT).*** Three threshold ERT's are determined (ERT_i) which are based on the individual agent's walk speed (slow or fast walk), perceived congestion considerations and appropriate safety or comfort factors. The agent then classifies their AT with respect to the ERT thresholds and adjusts their state of urgency and behavioural response as shown in Table 1.

The Emotion Model applied in a Station Scenario

A comprehensive rail station geometry has been developed in buildingEXODUS to demonstrate the functionality of the emotion model in a complex multi-purpose environment. The demonstration case geometry comprises two floors and thirteen platforms as well as a variety of retail and catering outlets which can be visited by the agents to accomplish elective tasks prior to boarding the required train. In this example we examine an off-peak station scenario involving about 7,750 agents and a total simulated time period of approximately two hours. Here we use the term ***Foot Passengers*** to represent those agents who arrive at the station via an external access point and leave the station on their assigned trains and ***Train Passengers*** to represent those agents who arrive at the station by train. A foot passenger's itinerary comprises a compulsory route i.e. an access point, by which the agent enters the geometry; a ticket office, where the agent purchases a ticket and a platform with an assigned train departure time. In addition to these compulsory and time critical tasks, foot passengers are assigned a random number of up to two elective tasks which they may want to undertake while at the station.

Table 2. Average percentage of foot passengers who have skipped none, one or two of their initially assigned number of elective tasks.

Number of elective tasks initially assigned	Skipped no elective tasks (%)	Skipped one elective task (%)	Skipped two elective tasks (%)
One task	78	22	-
Two tasks	50	8	42

To evaluate the impact of the prototype emotion model upon the agents' behaviour, we examine for each individual agent the proportion of the agent's elapsed time which the agent has spent in an urgent state i.e. the ***Urgency Ratio***. The average Urgency Ratio for a foot passenger was 14%, ranging from 0 to 65%. The large range clearly indicates that the individual agents experienced highly variable conditions. Furthermore, while on average 45% of the foot passengers did not enter an elevated urgency state, approximately 25% of the foot passengers spent more than 25% of their elapsed time in the station in an urgent state. Of those foot passengers assigned one and two elective tasks, 78% and 50% dropped none of their tasks respectively (see Table 2). To further assess the impact of the prototype emotion model the simulation was repeated with the emotion model disabled. We find that the agent's ability to alter their assigned itinerary has a strong influence on the foot passengers' punctuality, with no agents missing their assigned train when the emotion model is active and an average of approximately 22% of foot passengers missing their initially assigned train when the emotion model is deactivated. These results also demonstrate that only 22% of the foot passengers in fact needed to become urgent in order to catch their assigned train. The fact that 55% of the foot passengers entered an elevated urgency state indicates that a large number of agents were "rushing" needlessly – as is often the case in reality!

Conclusions

This work has introduced a prototype emotion model into agent based circulation simulation and demonstrated its impact on time critical behaviour which on the surface appears to produce realistic behaviours. However, further work is required to; assess the model, introduce refinements to the urgency escalation parameter, introduce fuzziness into the ERT, provide more representative safety factor distributions (optimistic as well as pessimistic safety factors) and to the modelling of short and long term planning and decision making behaviour.

References

1. R.J. Dolan. Emotion, Cognition, and Behavior. *Science*, 298(5596):1191–1194, (2002).
2. W. Shao and D. Terzopoulos. Autonomous pedestrians. *Graphical Models*, 69(5-6):246–274, (2007).
3. T. Gärling, R. Gillholm, and W. Montgomery. The role of anticipated time pressure in activity scheduling. *Transportation*, 26:173–191, (1999).
4. X. Pan, C.S. Han, K. Dauber, and K.H. Law. A multi-agent based framework for the simulation of human and social behaviors during emergency evacuations. *AI & Society*, 22(2):113–132, (2007).
5. J. Dijkstra, J. Jessurun, B. de Vries, and H. Timmermans. Agent Architecture for Simulating Pedestrians in the Built Environment. In *Fourth International Workshop on Agents in Traffic and Transportation at AAMAS-06. Hakodate Japan: ACM*, pages 8–16, (2006).
6. Galea, E.R, Sharp, G., Lawrence, P.J., Holden, R.: Approximating the Evacuation of the World Trade Center North Tower using Computer Simulation, Journal of Fire Protection Engineering, Vol 18 (2), 85-115, (2008).