Simulation of Agent-rescuer Behaviour in Emergency Based on Modified Fuzzy Clustering

(Extended Abstract)

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ABSTRACT

Although there are various methods and models of agent's behaviour in emergencies, the problem of the synthesis of the optimal control systems, which can support best evolution strategies for agent-rescuers in emergency characterized by a high level of an uncertainty, is still needed. We developed the simulation of agent-rescuers behaviour in emergencies and proposed an effective modified fuzzy procedure for dynamical clustering of the crowd in order to define the optimal values of control parameters for agent-rescuers (such as speed of agents, time of waiting, distribution types of agents-rescuers between crowd clusters, etc.).

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search—*dynamic programming*; I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*intelligent agents, multiagent systems*

General Terms

Algorithms, Experimentation

Keywords

intelligent agents; fuzzy means clustering; crowd behavior

1. INTRODUCTION

In recent years, there has been a line of research (e.g., [1, 2, 5]) on human crowd behaviour in emergencies. Many works focused on the problem of the psychology and social aspects of the human crowd behaviour. For instance, in the pioneer work [6] the reasons of the formation and distribution of a human panic are described in detail. Many studies are based on the hypothesis that the personal behaviour significantly differs from the human behaviour in a crowd [7] because of such effects as the "crowd crash" and the "crowd turbulence" [1] which can be caused by a panic, rumors and the reaction of the growth of crowd density. There has been a line of research of Dirk Helbing [5, 6, 7] in which the author investigated the pedestrian crowds in normal and evacuation situations. Helbing in his work [6], published in Nature, firstly reconstructed some important phenomenons such as formation of traffic jams, involvement of new people in a panic and others with the help of mathematical modeling. Further, the discrete choice models of pedestrian walking behavior based on Helbing's results was created and described in the work [3].

This research focused on the problem of designing the crowd simulation system for agent-rescuers, based on the suggested modified fuzzy clustering algorithm of the crowd dynamics in emergencies, estimating of the probability of best evacuation routings, and forming optimal dynamics of agent-rescuers (number of agents, speed, routes, etc.).

2. SIMULATION OF AGENT BEHAVIOUR

The developed simulation model is based on the earlier developed phenomenological model of human crowd behaviour suggested in works [1, 2]. The dynamics of agent-rescuers are described by the systems of ordinary differential equations for each agent-rescuer and for each usual agent with simulating of the attracting process of usual agents toward agent-rescuers and evacuation exits. The model was implemented in the *AnyLogic* simulation system.

The main problem is trying to maximize the number of evacuated agents. To reach this purpose, optimal control parameters (waiting times, number of agent-rescuers, speeds of agent-rescuers, and types of distributions between crowd clusters) should be set.

PROBLEM A. *The need to maximize the number of evacuated agents through the set of control parameters* $\{K(t), s_k(t), \tau_k(t), g_c\}$*:*

$$\max_{\{K(t),s_k(t),\tau_k(t),g_c\}} \left[\sum_{t=t_0+1}^{t_0+T_{ev}} \sum_{i=1}^{I(t)} st_i(t) - st_i(t-1) \right]$$

under different constraints having a clear sense.

Here, t – the simulation time, $t \in [t_0, t_0 + T_{ev}]$ (t_0 – the start time); T_{ev} – the limit of evacuation time); $i = \overline{1..I(t)}$ – indexes of usual agents; $st_i(t) \in \{0, 1\}$ – the status of the i^{th}-agent ($st_i(t) = 1$ – the i^{th}-agent is evacuated, else $st_i(t) = 0$); $K(t)$ – the number of agent-rescuers, which are required for the evacuation of agents, $\bar{K}$ – the maximum number of agent-rescuers in the system (resource limit); $g_c \in \{1, 2, 3\}$ – the control parameter, which defines matching between the c^{th}-crowd cluster and the appropriate group clusters having the fixed distribution type (one of three possible) for the

Appears in: *Proceedings of the 15th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2016), J. Thangarajah, K. Tuyls, C. Jonker, S. Marsella (eds.), May 9–13, 2016, Singapore.*

destination of agent-rescuers as well as the strategy of the distribution of agent-rescuers between clusters; τ_k – waiting time of the k^{th}-agent-rescuers in crowd clusters and on exits.

3. MODIFIED FUZZY CLUSTERING

It should be noted that the convergence of the fuzzy C-means clustering algorithm was firstly showen in the work [4]. Additional internal restrictions and parameters were included into the standard fuzzy C-means procedure in order to take into account natural restrictions for the evacuation such as wall, obstacles, etc., which can isolate individuals from their clusters. Also, an initial partition matrix, as opposed to the standard implementation, is chosen not by chance, but based on the modification results of the agglomerative algorithm with Ward's distance.

The developed modified fuzzy clustering algorithm is implemented for each agent. This algorithm is used for recognition of the centers of clusters of crowd by agent-rescuers for the purpose of increase of efficiency of procedure of evacuation through the distribution of agent-rescuer between crowd clusters. The algorithm aims to minimize an objective function:

$$J = \sum_{c=1}^{C(t)} \sum_{i \in I(t)} (m_{ci})^w e^{B\frac{\alpha_{ci}}{\pi}} d(v_c, x_i),$$

where $c = \overline{1..C(t)}$ – indexes of clusters; m_{ci} – degree of belonging of i^{th}-agent to c^{th}-cluster; w – fuzzifier; v_c – c^{th}-cluster center coordinate; x_i – i^{th}-agent coordinate; α_{ci} – angle between the direction of i^{th}-agent movement and the direction from the i^{th}-agent to the c^{th}-cluster center; B – weight coefficient.

4. RESULTS OF THE SIMULATION

The results of the simulation are represented in the Figure 1 for the case study of emergency in the Domodedovo airport (Moscow, 2011 year). The *genetic algorithm* was applied for solving the main optimization problem. The combined chart reflects the dynamics of agent-rescuers and evacuated agents during the evacuation time, as well as the dynamics of crowd clusters, taking into account the sequence of their disappearing. It should be noted that the *verification of the developed simulation of agent-rescuers behaviour* was completed with the help of *video-data*, which were obtained from the Domodedovo airport after the emergency.

5. CONCLUSIONS

The simulation of agent-rescuers behaviour in emergencies using the developed fuzzy clustering algorithm and the suggested procedure of bypassing around dynamical obstacles for the optimal control of agent-rescuers behaviour was represented. The approach allows increasing the number of evacuated agents with the help of limited number of agent-rescuers in the condition of an appearance of dynamical obstacles.

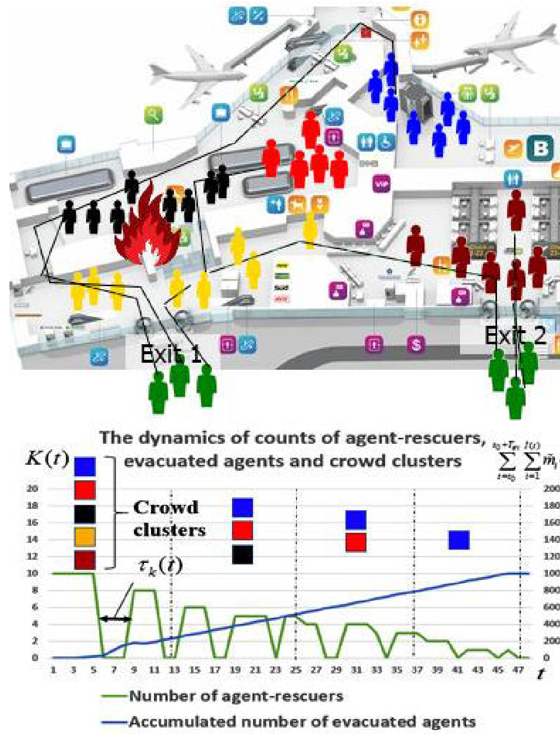

Figure 1: The results of the simulation and clustering.

Acknowledgments

The reported study was partially supported by RFBR, research project No. 15-37-20265 mol_a_ved.

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