Procedia Computer Science

Volume 51, 2015, Pages 522–531

ICCS 2015 International Conference On Computational Science

The Multi-Agent Simulation-Based Framework for Optimization of Detectors Layout in Public Crowded Places

Nikolay Butakov[1], Denis Nasonov[1], Konstantin Knyazkov[1], Vladislav Karbovskii[1] and Yulia Chuprova[1]

[1] *ITMO University, Saint-Petersburg, Russia*

alipoov.nb@gmail.com, denis.nasonov@gmail.com, constantinvk@gmail.com, vladislav.k.work@gmail.com, yulyachuprova@gmail.com

Abstract

In this work the framework for detectors layout optimization based on a multi-agent simulation is proposed. Its main intention is to provide a decision support team with a tool for automatic design of social threat detection systems for public crowded places. Containing a number of distributed detectors, this system performs detection and an identification of threat carriers. The generic model of detector used in the framework allows to consider detection of various types of threats, e.g. infections, explosives, drugs, radiation. The underlying agent-based models provide data on social mobility, which is used along with a probability based quality assessment model within the optimization process. The implemented multi-criteria optimization scheme is based on a genetic algorithm. For experimental study the framework has been applied in order to get the optimal detectors' layout in Pulkovo airport.

Keywords: sensors, detectors layout, evolutionary computation, multi-objective optimization, crowd simulation, crowded environment, agent-based simulation, security, genetic algorithms

1 Introduction

Today facing crowded places is an ordinary practice in urban life. This usually happens, for example, at transport hubs (airports, stations). Crowded places are connected with several types of threats that have a large effect on public safety. Because of the large number of people crowds, they often become a target for terrorist attacks. On the other hand, the complex character of crowds and inability to check everybody allows smugglers to transport illegal cargo through crowded places. And the interactive nature of crowds with many contacts inside, leads to the propagation of infections.

Selection and peer-review under responsibility of the Scientific Programme Committee of ICCS 2015

doi:10.1016/j.procs.2015.05.278

In order to detect such threats, screening detectors are widely used. The main principle of functioning for such detectors is based on a sequential gathering of air samples. It takes some period of time, from tens of seconds to a half an hour (Gooding, 2006). A detector generates a signal of alert if an internal test gives a positive result. Such screening detectors usually are not as precise as individual checking. But they are less time consuming and can handle more people without causing queues. Due to economical reasons and installation limitations, it is usually impossible to cover the entire crowded place with such detectors. And there are also different types of detectors which can differ by some parameters like cost, detection precision, etc. Thereby, there is a need to choose detector types, and correct positions for detector placement. This determines a multi-objective optimization problem.

Pedestrian flows formed by people's movements have a great influence on different characteristics of the crowded place, which affects the performance of detectors layout. However, it is not enough to know only aggregated characteristics in order to find out optimal detector layout. Some goals of the detection system, which is being designed, may require more detailed information, e.g. the goal of identification of individual "threat carriers". Usually a single detector cannot solve the identification problem, as it has its latency and it is receptive to noise caused by a large group of people. In this case, an identification problem is solved on the level of a whole detection system.

This work is devoted to the detector layout optimization problem and contributes: an optimization framework architecture based on agent-based simulation; a formulation of multi objective combinatorial optimization problem based on quality assessment model which uses information about pedestrian flows and accounts the described types of detectors; a data structure optimization procedure which allows reducing time of optimization procedure spent dealing with massive simulation data; an experimental case study for Pulkovo airport (Saint-Petersburg).

2 Related works

The general problem of detector layout optimization has emerged in various fields such as gas leak detection, intruder detection, detection of threats in water, and detection of biological or chemical attacks. This problem is well known in the wireless sensor networks engineering area of research (Molina., Alba & Talbi 2008; Dhillon & Chakrabarty, 2003). Works in this area are focused on the network's topology, observable natural phenomena coverage, and don't take into account aspects connected with crowd dynamics and crowd simulation. Another related area is tracking people with a system of video cameras (Qian & Qi, 2008; Jin & Bhanu, 2012).

The most widely accepted approach to solve the task of detector layout optimization within the crowded place is based on aggregated information about such a place, and geometric principles. Particularly, Kiekintveld & Lerma (2011) consider detecting biological weapons. Their approach is based on a natural idea to place more detectors in areas with more population and fewer in areas with fewer people. They try to optimize coverage of important zones based on geometrical principles. The work assumes presence of data about population density, which may be unknown in advance. The model of detectors is not oriented to take into account features such as time of sample gathering. Also, visiting several sensors does not influence the optimization process directly, and some features like different velocity of threat spreading in different directions can be ignored. Väkevä(2007) have proposed to use risk-based analysis for detector placement which is aimed at event detection. The authors (Nie, Batta, Drury & Lin, 2007; Stolkin, Vickers & Nickerson, 2007) use similar approach to ours, which is focused on the calculation of probability of an agent interception based on several measurements performed by independent detectors. In the work (Nie, Batta, Drury & Lin, 2007) the model assumes the presence of only the one suicide bomber, and detectors work in an instant mode. Otherwise, our model is targeted to deal with the cumulative probability of detector's activation which