Computer Simulation Approach to Interdisciplinary Research of Crowds Behavior in Regular and Emergency Situations

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Abstract: Behavior of massive assemblies of people – large crowds or dense (intensive) pedestrian flows occurring in confined spaces (public buildings, shopping malls, airport terminals, public transport stations, concert halls), or in the open grounds (squares, streets, sports arenas) – attracts growing attention as a specific pressing sphere of urgent diverse multidisciplinary scientific research. This is mainly due to the critically increasing number of extraordinary incidents such as natural calamities (devastating earthquake, hurricane), technogenic accidents (explosion, fire, sudden destruction, etc.) or anthropogenic hazards (acts of terrorism) – those that over past decades have inflicted large-scale casualties and loss of life among urban population around the world. Extensive consideration has been paid to design and introduction of preventive measures against such disasters. Practitioners of urban planning, architects, civil engineers, emergency responders, etc., are professionally in need of methods and tools to evaluate the degree of a facility safety, to foresee the possible consequences of public gathering places construction, to be able to predict the potential dangers, to estimate probabilities of pedestrian traffic congestions. Investigations in this vast sphere embrace many domains, among other including human physiology, psychology, sociology, anthropometry, empirical studies on human behavior, analytical methods of events prediction, and computer simulation methods and techniques. [6] – [10].

Keywords: Crowds behavious,Simulation,Anthropogenic hazards,anthropometry

I. SUBJECT MATTERS OF THE RXPOSITION

In this paper, we leave out of consideration all the above mentioned important approaches to the investigation of crowds and pedestrian flows behavior except the one mentioned last – the ways and means of computer simulation. The exposition concentrates on multi-agent approach to event-driven simulation of human behavior in crowds. Our particular scope of attention is passengers on subway metropolitan stations. As an example, we present here a simulation model of a certain typical metro station (Zvenigorodskaya) in Saint-Petersburg – Russia.

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(By tragic coincidence, while the presented model has been under development, on April 3rd, 2017 a bomb explosion triggered by a terrorist on a subway train approaching the nearby station has hit over a hundred passengers, 16 perished.)

II. CHOICE OF SIMULATION METHODS AND PLATFORM

Recently, a substantial variety of simulators to be used for modeling pedestrian and evacuation dynamics are available either on a commercial or an open-source basis. The choice much depends on requirements of a researcher.

For us, it is natural and advantageous to rely on the familiar *AnyLogic* platform [4] that has been initially designed and developed by a team of young researchers in a laboratory at Peter the Great Saint-Petersburg Polytechnic University.

There are three basic simulation modeling paradigms and corresponding methods and technologies:

- System dynamics simulation – SD (introduced by J. W. Forrester – MIT, 1956) [1]
- Discrete event simulation – DES (introduced by G.A. Gordon – IBM, 1960) [2]
- Agent-based simulation [3], [5].

The *AnyLogic* platform offers all three methods for use in any combination in a single tool. This unique feature allows for flexible *multi-method simulation* modeling.

Besides, it offers a rich *Pedestrian Library* for simulating flows of people in airports, stadiums, stations, shopping malls, etc.

III. THE MODEL

The modeled environment and location

The dynamic model represents stochastic movements of throngs of passengers (agents) arriving at the station on their ways to this or other destinations.

The modeled environment is a typical underground station. The general layout includes:

- the main subterranean floor with platforms on each side, with or without protection walls along the railway tracks

- escalators (one or two), with stairways (at least 2, usually 3 or 4), each stairway is under control by the escalator operator, can be stopped and is up/down reversible in case of emergency (simulated by model experiment user) [Fig.1]
- walkways (cross-passages) to/from adjoining stations on other lines – for transit passengers.

The REGULAR mode simulation of the subway station operation

In the REGULAR mode each passenger at any instant on the premises of the station is in one of the following states:

- is arriving at the underground floor via one of the existing ways of entry (descending on an escalator, getting out of just arrived train, coming to the floor out of the transit passage from another adjoining station)
- is leaving the platform (ascending on a way-out escalator, getting on board just arrived train, getting out of the underground floor along the transit passage to another adjoining station)
- is moving along the underground floor on a route towards individually chosen way-out facility or a platform
- is waiting on a platform for a train (standing or moving to a personally preferable position along the track)
- is idle (sitting on a bench, standing, waiting for somebody, or just moving around).

Trains arrive and depart with certain variable intervals (model calibration parameters). Intensities of incoming/outgoing passenger flows from/to existing escalators, passages and arriving trains are variable according to weekdays the time of the day (model calibration parameters).

For visualization, we employ 2D [Fig. 1], 3D graphic or VR [Fig. 2] presentation models.

The ALARM mode simulation of the subway station operation

The ALARM mode performs simulation of the orderly passenger's evacuation scenarios. The mode can be triggered at any moment during the model runtime by pushing the "ALARM" key on the model interface.

Passengers caught by an ALARM signal on the station floor and those arriving from all inbound directions start normal evacuation in accordance with the prearranged scenarios. Possible evacuation directions and means are way-out escalators, cross-passages, and trains.

The EMERGENCY mode simulation of the station operation

The EMERGENCY mode enforces simulation of urgent evacuation scenarios. The mode is triggered by simulated occurrence of dangerous or extraordinary events – such as explosions, fire, heavy smoke, gas fumes, or other accidents). The situation may be aggravated by the consequences of the throngs of people typical behavior in a rush, overcrowding with possible congestion, injuries, other possible damages, and panic. The passengers' evacuation dynamics in such circumstances is subject to behavioral deviations due to the well-known human factors of physiological, psychological, and sociological origin.

For visualization, we employ 2D [Fig. 1], 3D graphic or VR [Fig.3] presentation models.

The model output results

Collection of raw data that are being accumulated during the model runtime allows for displaying major statistical data in the form of dynamically drawn diagrams. The time-plots dynamically represent:

Arrival rates of passengers – persons/sec (p/s)

Egress rates of passengers – persons/sec (p/s)

The current size of the floor population – persons (p).

In "Alarm" and "Emergency" evacuation modes additional dynamic and final results are presented, including:

The initial size of the floor population at the start of the critical period – persons (p)

The current number of evacuees along each egress path (time-plots) – persons (p)

The total floor evacuation time – (sec).

IV. CONCLUSIONS

The results of experiments with multi-agent simulation models can be employed for a number of goals, such as:

Assessment of evacuation strategies Estimating the probability of jams, panic flight and stampedes in a crowd,Identifying obstacles and bottlenecks of evacuation plans, paths, and procedures.

However, the trustworthiness of the obtained results completely depends on the veracity of the original data, and assumptions accepted in the design of scenarios.

In order to develop reliable, consistent and real-world adequate model, rigorous model verification methods should be applied and strict calibration procedures must be carried out to validate the integrity and effectiveness of these methodologies.

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