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Parallel real time computation of large scale pedestrian evacuations

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ABSTRACT

Usually, modeling of the evacuations is done during the planning and authorizing process of office buildings or large scale facilities, where computing time is not an issue at all. The collaborative Hermes project [1] aims at improving the safety of mass events by constructing an evacuation assistant, a decision support system for heads of operation in an actual evacuation. For this, the status (occupancy and available egress routes) of a facility is constantly monitored with automatic person counters, door sensors, smoke sensors, and manual input from security staff. Starting from this status, egress is simulated faster than real time, and the result visualized in a suitable fashion to show what is likely to happen in the next 15 min. The test case for this evacuation assistant is the clearing of the ESPRIT Arena in Düsseldorf which holds 50,000–65,000 persons depending on the event type. The on site prediction requires the ability to simulate the egress in ≈2 min, a task that requires the combination of a fast algorithm and a parallel computer. The paper will describe the details of the evacuation problem, the architecture of the evacuation assistant, the pedestrian motion model employed and the optimization and parallelization of the code.

1. Introduction

A number of accidents in recent mass events (Tembisa, South Africa, July 6, 2010 with 10 severely injured, Love Parade in Duisburg, Germany, July 24, 2010 with 21 dead, and Bremen, Germany, September 27, 2010 with 20 injured, 1 severe) have again made it clear that the high density of pedestrians occurring in large events poses a risk even without any aggressive behavior of the participants. If need arises to clear a large facility rapidly – because of a fire, a bomb thread or another reason – the danger is much more imminent than in normal operation, so proper guidance to safe (non jamming) egress routes is highly important. However, security staff often lacks the necessary information. In all three incidents mentioned above there are claims that police action actually contributed to the accident.

To contribute to the improvement of the situation, the Hermes project was started in 2008 in order to evaluate the potential of crowd movement simulations for predicting dangerous situations. An evacuation assistant system will give security staff and police a sound base for decisions to open or close some pathways or guide the crowd in some direction. The first step to this goal is a monitoring of the present situation – automatic counting of people as they enter or leave areas and checking the status of doors and pathways. At present, estimation of crowd numbers is usually done by sight, and numbers differ widely depending on who does the estimate. This information then enters the central part of the evacuation assistant, a program running on dedicated hardware and calculating constantly a 15 min prediction of an evacuation starting from the present situation. To be useful, this calculation must not take more than a few minutes, otherwise it would often come too late for security action. Finally, the results of the status monitoring and especially of the simulations have to be visualized in a suitable way so that decision makers can rapidly grasp the important aspects of the situation and are not flooded by irrelevant details. Obviously, simply visualizing the process of the evacuation in real time as is often done in the planning of a facility is not fast enough.

The time requirements for the simulation are a severe problem, so a moderately parallel computer is employed and much effort will go into making the calculation fast enough. Details will make up the main part of the paper.

2. The architecture of the evacuation assistant

The concept of the evacuation assistant will be tested in summer 2011 in the ESPRIT arena in Dsseldorf. This is a multi-purpose facility for sports (mostly football), concerts and other events. The grandstand of the arena has 51,500 seats (Fig. 1), about half of them in the lower and in the upper part. In events that do not need the soccer field for stage space, up to 14,000 people can be placed on the field. The lower grandstand has 26 portholes and four large exits in the corners, the upper grandstand has 32 portholes and a

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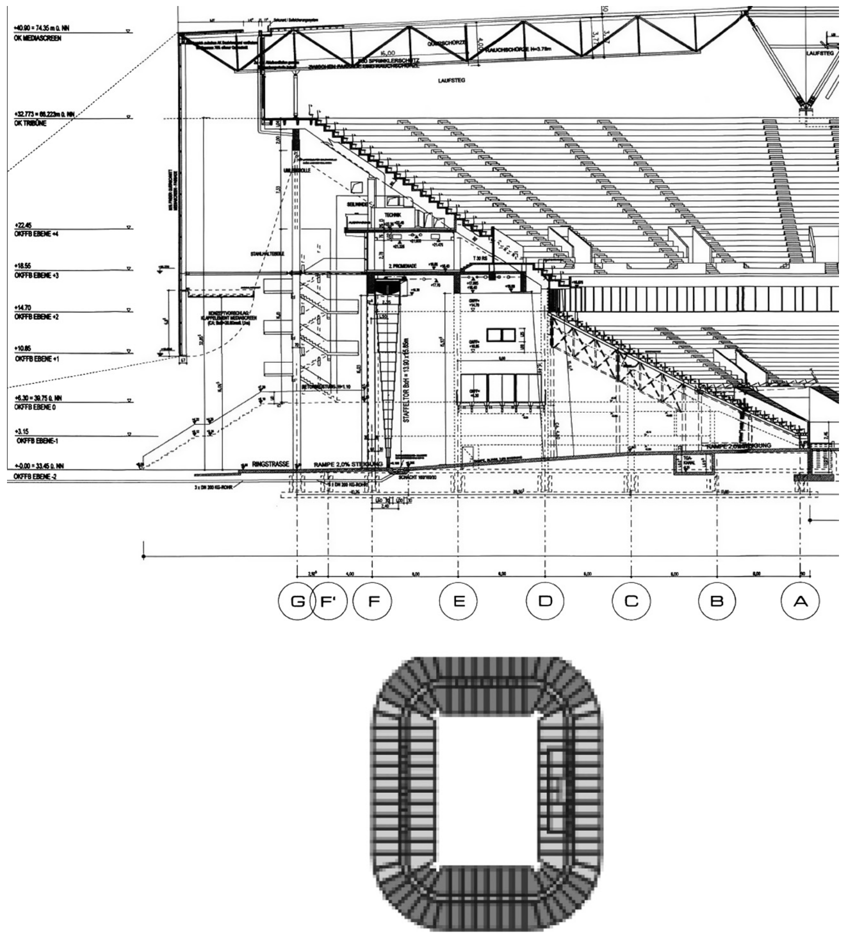

Fig. 1. Cut of part and schematic top view of the ESPRIT arena.

number of exits at the top that are not used in normal operation and will probably not be used by many persons in emergency unless they are forcefully directed there. The central area has three very wide exits at the sides which lead directly outside through wide corridors. The portholes from the grandstands lead to a ring shaped hall (lower $\approx$20 m wide, upper $\approx$10 m wide, top $\approx$5 m). The lower hall has doors directly to the outside area, the upper ones to outside staircases. These halls have rolling gates that separate radial sections. In the halls are plenty of fixed and movable service stands which are obstacles to free movement, so the way from the portholes to the outer door is usually not straight and streams from different portholes may merge and partially cross each other. Streams for upper and lower grandstand do not mix inside the building, so they can be considered independently. Once people have reached the outside area, there are wide passways leading down a slope away from the building, and the slope itself is not too steep to be used by persons with at least normal mobility. Therefore everybody in the outside area is considered to be in safety during an evacuation. The area for the test of the evacuation assistant is about half of the lower grandstand and part of the upper grandstand. The limits are placed such that mixing of the pedestrian stream from the test area with those from the other area can be expected to be minimal. Of course, a testing of the entire facility would be much better, but the budget does not allow a full instrumentation. If the evacuation assistant proves helpful enough, further installations will follow.

The first step for the evacuation assistant (Fig. 2) is the monitoring of the present status. For this, all doors in the test areas as well as those leading into it are equipped with infrared based person counters, such that the number of persons in any area is known at any time. Absolute accuracy is neither possible nor necessary, first tests show an error rate about 3%, which will be improved by tuning. In some events, especially pop music concerts, counting persons in the area optically is not possible because the spectator area is dark and vision may be further hindered by smoke from the stage. A second set of sensors monitors the opening and closing of the doors. Further, the smoke sensors that are now connected to a central display will also be connected to the evacuation assistant; an area filled with smoke will not be considered a possible egress route unless this is specified manually by the operation management. Finally, the security staff distributed in the facility can report any unusual conditions to the operation management which is able to enter information manually.

All this information is collected in a front-end computer of the evacuation assistant and processed for display. It is further used to define an egress route for every person which is based on choosing the nearest visible exit. A macroscopic network model is used to get a quick overview and improve the routing. As main task, a microscopic egress simulation is being run constantly to predict how the egress would work starting from the present situation. This simulation is run on a parallel cluster with 25 Nehalem nodes, each having two processors with six cores. At present, this calculation takes about 4 min with potential for further optimization. The goal is 2 min. The results of the simulation are transported back to the front-end, where they are processed for various modes of display. There will be a global display giving time averages of densities, fluxes, and speeds which is supposed to be active constantly. From this, the operation management can zoom in to