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Crowd Evacuation Modeling and Simulation Using Care HPS

Mohammed J. Alghazzawi[1], Ghazal Tashakor[1], Francisco Borges[2], and Remo Suppi[1]

[1] Universitat Autònoma de Barcelona, Cerdanyola del Vallès, Barcelona, Spain.
Malghazzawi,GTashakor@caos.uab.cat, remo.suppi@uab.cat
[2] Federal Institute of Bahia, Santo Amaro, Bahia, Brazil
franciscoborges@ifba.edu.br

Abstract

The problem of evacuating crowded closed spaces, such as discotheques, public exhibition pavilions or concert houses, has become increasingly important and gained attention both from practitioners and from public authorities. This kind of problem can be modeled using Agent-Based Model techniques and consequently simulated in order to study evacuation strategies. In this paper, we show the Fira of Barcelona evacuation model implemented with Care HPS. As a main contribution: i) we extend and added new partitioning approaches and other features in Care HPS to carry on this model; and ii) we figured out that crowd evacuation problem has bottlenecks in reality, such as exits, that required more deep optimization in code in order to decrease the total execution time. Finally, we draw some conclusions and point out ways in which this work can be further extended.

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Keywords: Crowd Evacuation, Agent-Based Model, Parallel and Distributed Simulation

1 Introduction

Modeling the movement and behavior of individuals in a crowd can help engineers to reduce the number of deaths that occur in buildings and public spaces. As the global population continues to grow exponentially, more people attempt to fit into cities that are growing at a slower rate.

Cases as the Hillsborough Stadium disaster (Sheffield, England in 1989) causing 96 deaths, the Love Parade disaster (Duisburg, Germany in 2010) causing 21 deaths or the Kiss disaster (Santa Maria, Brazil in 2013) causing 239 deaths show us how bad decisions and planning can lead to human harm. Evacuation management and planning then become a crucial issue.

Simulation allows us to have knowledge to take informed decisions that can predict the behavior. Decision Support Systems (DSS) have gained importance in the last years, and the usage of simulators allows predicting the behavior of a system according to a model and helping experts to take decisions.

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In crowd evacuations there are random patterns among the public, therefore we need statistically reliable results in order to predict with reliability. For that, it is important to use high performance computational solutions and tools. Care HPS [4] is an Agent-Based Model tool that helps to execute experiments in a parallel and distributed architecture.

Therefore, in this paper, we use as a case study Fira of Barcelona model based on the Helbing model [6]. Fira model, implemented in C++, and simulated using Care HPS [4]. We analyzed the behavior of the model and how this tool carry on crowd evacuation models. This gives us more statistically reliable results. The rest of the paper is organized as follows. We present related works where we show previous crowd evacuation models 2. Then we dedicate Section 3 to show the challenges of crowd evacuation simulation and to present Fira crowd evacuation model. Care HPS [4], tool used for implement and simulate the Fira of Barcelona model, is presented in Section 4. Then, the model experiments and the improvements on Care HPS are presented and discussed in Section 5; and finally, some conclusions are drown in Section 6.

2 Related Work

The modeling of movement patterns of human crowds at the exit point of an enclosed space is a complex and challenging problem. An analytic study of crowd dynamics through exits may provide useful information for crowd control purposes. Proper understanding of the evacuation dynamics will allow, for example, improvements of designs of pedestrian facilities.

There are three main reasons for developing computer simulations for crowd behaviors: firstly, to test scientific theories and hypotheses; secondly, to test design strategies; and finally, to recreate the phenomena about which to theorize [8].

In the area of HPC to solve crowd problems, GPUs have been used to implement the crowd dynamics algorithm and the rendering [3]. Also crowd turbulence phenomena integrated on GPU cards [2], The implementation is a hybrid model between Verlet integration method and Agent Based Model. MPI was used in city evacuations distributing the space and agents [7]. These tools are normally tested with hundreds of individuals. Many crowd evacuation models using agent based model simulated people behavior by deploying cloud services for high performance simulation [1].

In this literature study, we note the need for further contributions in parallel and distributed solutions to carry out models with thousands of people. Also, tools can easily change the environment characteristics in order to simulate better layouts of space for fastest evacuations.

3 Crowd Evacuation Model

Modeling has allowed the humanity to advance its knowledge and improve its day living. All modelling approaches differ on the focus of how to extract the natural characteristics of the reality and how to implement them. Each approach has pros and cons, and choosing one or another is always a trade-off. Simulators implement the ideas designed by models. Simulation allows us to interact with the model and generate results without interacting with the real system.

In our case model and simulator have mainly the purpose of provide knowledge of potential problems also analyze theories and simulate them. Moreover, one of the main final goals is to provide a decision support system where the complexity of the model and the performance is hidden to the final user by integrating the crowd evacuation model with Care HPS tool.

Our present model is a discrete time model able to handle thousands of agents, whereas the model recovers ideas from Cellular Automata to be computationally efficient. This model reproduces crowd phenomena in *Salón del Manga*, which is the building 2 of Fira de Barcelona. And it can hold almost a hundred thousands of people. This environment has different zones and obstacles, which make the evacuation more complex.

The model is divided into two sub-models, agent and environmental intelligence. And the agent move between cells approaching to the exit, while there can be only one agent per cell, and when agents achieve the exit, they are released. The model is described by a set of attributes, which are (A1: Stopped, A2: Moving, A3: Evacuated, N: Approaching the exit, E: Exit reached, F: Free patch), and transitions between states are determined by the attributes of the model. The algorithm used for the environment sub-model is the potential field algorithm, which provides the shortest path and support obstacle avoidance feature. This algorithm is a recursive algorithm that visits the cells in breadth search giving higher values every time.

The model and Care HPS tool implemented in C++ programming language, To test the model with Care HPS, we distributed the simulations using MPI, while the simulator were executed for several configurations with 0-64 OpenMP threads and 2-64 cores, also we used different partitioning strategies.

4 Care HPS

Care High Performance Simulation (HPS) [4], is a scientific instrument that enables researchers to: 1) develop techniques and solutions of high performance distributed simulations for agent-based models; and, 2) study, design and implement complex agent-based models that require HPC solutions. Care HPS was designed to easily and quickly develop new agent-based models. It was also designed to extend and implement new solutions for the main issues of parallel and distributed solutions.

Care HPS act as a tool that allows the development of studies in different approaches for several problems in these areas. This means that new approaches can be verified without changes in its kernel or huge programming efforts. In Care HPS, users can attach their ABM and HPC solutions to the kernel of Care HPS by using interfaces. The user might implement their ABM, partitioning, communication, synchronization and other HPC solutions, then attach their solutions to the kernel of Care HPS.

As examples of use, user can test to see which partitioning technique offer the best performance for a specific ABM; or, user can analyze and study a new proposed algorithm of synchronization using ABMs which require different computational characteristics.

In this paper we explore Fira crowd evacuation model over Care HPS.

5 Experiments

In this section, we will present the experiments conducted over Fira of Barcelona model.

The first experiment was carried out for 15000 and 39000 agents, and, it was executed using one MPI processes and n threads were created. We used the hybrid strip partitioning, This partitioning is one of the partitioning available in Care HPS, where we use MPI and OpenMP threads to simulate agents behaviors.

The best execution time found was with eight threads for both number of agents. Where the simulation time for 15K agents was 1317 seconds and the simualtion time for 39K agents was 5587 seconds with 8 threads. As we note, the total execution time increased and it occurs

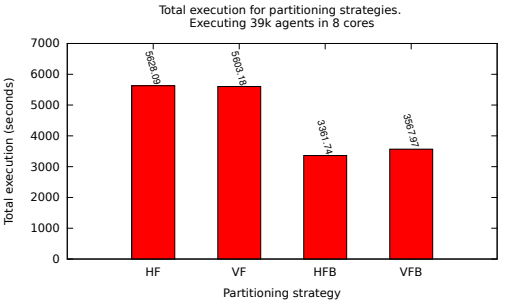

Figure 1: Partitioning strategy analysis.

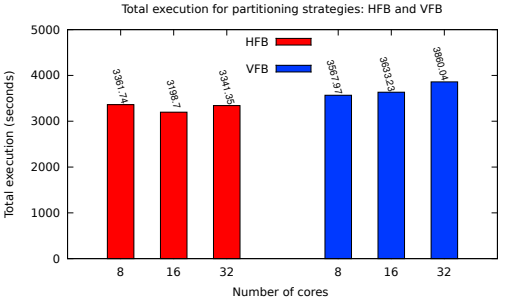

Figure 2: Partitioning strategy analysis better total execution time.

because the model has a limited number of exits and all agents look up for these exits. Therefore, increasing the number of cores does not decrease the execution time, because of the access to exits is sequential and computing of the stopped agents is not too high.

Also we found the best speedup with 8 and 16 cores and the best efficiency we obtained are for 2, 4 and 8 cores. As we notice from these results, the model can not take advantage of increasing the number of cores because of the reason noted at first experiment. Regardless of eight cores bring the lowest total execution time.

Simulation of crowd evacuation requires fast single execution to be able to execute many times and return reliable data. Therefore, in the next experiment, we executed the model in two MPI processes and we used several partitioning approaches available in Care HPS [5, 4] in order to create separate memory context and evaluate the best partitioning approach for this type of model. Figure 1 presents the total execution time for four strip partitioning approaches: HF - it creates partitions with horizontal cut, VF - it creates partitions with vertical cut. HF and VF take into account the position of object in the environment and avoiding that an object becomes shared with different MPI processes.

Both approaches HFB and VFB were included in Care HPS after analyses preliminary data of simulation. These data showed that some cores was getting idle because the partitioning approaches HF and VF were creating partition with size completely different, while one of them is very huge and the another one is too small. It happened because of these partitioning tried to find empty space between the obstacle in order to avoid sharing the objects. Therefore we observed that these built in partitioning approaches were not appropriated for Fira model. Thus, we included these new two approaches in Care HPS to carry out this type of model.

Figure 1 shows the total execution time for 39000 agents executed at 8 cores using different partitioning approaches. The proposed approaches HFB and VFB give better execution time. With aim of analyzing more these approaches, we executed the Fira model with in 8, 16 and 32 cores using hybrid partitioning and simulating 39000 agents. As result, we obtained 3198.7 seconds as the best execution time for HFB approach and 3567.97 seconds as the best execution time for VFB approach. These time were obtained by executing in 16 (HFB) and 8 (VFB) cores. It means that the speedup and efficiency for HFB is 7.62 and 47.60%. On the other hand, VFB approach presents 6.83 and 85.35% as speedup and efficiency. Therefore, taking into account the parallel computing measures future optimization of model must be conducted over VFB strategy and execution using 8 cores. In spite of HFB approach with 16 brings lower total execution time.

6 Conclusions

In this paper we presented an evacuation case study using Care HPS. The aim of the paper is to show how Care HPS can be useful for this type of problems. Simulation of evacuation has two main requirement: i) faster execution in order to get reliable data through many executions of same model; and ii) it requires easiness to re-configure the environment in order to change the position of obstacle and the exits in the reality. This reconfiguration can help decision makers to decide according to the time required to evacuate a certain number of people.

For improvement the performance of this model, we implemented the following features in Care HPS: i) support rectangle object to represent the obstacle of Fira; ii) we changed the strip partitioning to divide the environment without considering the position of object and create same partition size, therefore we proposed two new partitioning approaches in Care HPS; Also iii) support creating "N" static threads.

Through the experimentation, we found the best partitioning strategy and number of cores for a huge number of agents 39000 in Fira model using Care HPS. Also, we figured out that crowd evacuation problem has bottlenecks in the reality. It occurs because of agents dispute the few exits, same way that occurs in the reality. When this behavior is modeled, it must be implemented as a sequential access therefore it avoids a better gain of execution time when the solution is parallelization.

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References

[1] Remo Suppi Albert Gutierrez-Milla, Francisco Borges and Emilio Luque. Crowd evacuations saas: an abm approach. In *International Conference on Computational Science*, volume 51, pages 473–482, 2015.

[2] Remo Suppi Albert Gutierrez-Milla, Francisco Borges and Emilio Luque. Crowd turbulence with abm and verlet integration on gpu cards. In *International Conference on Computational Science*, volume 80, pages 2428–2432, 2016.

[3] A. Bleiweiss. Multi agent navigation on the gpu. *GDC*, (9), 2008.

[4] Francisco Borges, Albert Gutierrez-Milla, Emilio Luque, and Remo Suppi. Care hps: A high performance simulation tool for parallel and distributed agent-based modeling. *Future Generation Computer Systems*, 68:59 – 73, 2017.

[5] Francisco Borges, Albert Gutierrez-Milla, Remo Suppi, and Emilio Luque. Strip partitioning for ant colony parallel and distributed discrete-event simulation. *Procedia Computer Science*, 51(0):483 – 492, 2015. International Conference On Computational Science, {ICCS} 2015 Computational Science at the Gates of Nature.

[6] Illales Farkas Dirk Helbing and Tamalas Vicsek. Simulating dynamical features of escape panic. *Nature*, (407), 2000.

[7] Masaki Fujioka Hiroyuki Kobayashi, Yutaka Ishimoto and Kenichi Ishibashi. A multi-agent evacuation simulator to design safe cities for high quality of life with computer clustering. In *SICE Annual Conference*, 2007.

[8] K Dauber X Pan, C S Han and K H Law. A multi-agent based framework for the simulation of human and social behaviors during emergency evacuations. *AI and society*, 2007.