Interactive Visualization of Large-scale Evacuation Simulation using GPU Computing

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Introduction

Evacuation simulations are designed and used for estimating crowd movement in buildings or urban environments in the event of a disaster. Agent-based simulations are particularly suitable for modeling each person's evacuation behavior by following a set of simple individual rules. Moreover, real-time simulation tools are effective for interactively analyzing crowd behaviors. However, computing data for and visualizing massive crowds in real time is a computationally intensive task. This complexity was reduced in previous research by employing special data structures, such as mesh models or network models. Additionally, researchers have significantly increased computational performance by adapting existing CPU-oriented algorithms to parallel processing architectures. A promising new parallel architecture uses commodity graphics processing units (GPUs) having many cores, offering the performance benefits of parallel processing at a low cost.

In this study, we describe our novel approach to the real-time visualization of crowd flow using a large-scale, agent-based evacuation simulation that is suitable for execution on GPUs.

Large-scale Evacuation Simulation

The evacuation simulation uses an agent-based system. Namely, an evacuee is modeled as an agent. The modeling of each agent's behavior consists of (1) the route choice model: setting a destination and calculating the route, and (2) the crowd walking model: approaching the destination and avoiding collisions with other agents and obstacles. In our research, we implemented the shortest route choice model and the social force model.

Conventional methods implement agent-based modeling using CPU-oriented algorithms. The social force model that we implemented previously was also calculated using a CPU, and the agents were rendered on the GPU only after they updated their position. However, the use of GPUs for general purpose computing has become a new area of research in the recent years. In our new simulation, the social force model operations were executed on a GPU using CUDA technology, which is a parallel-processing architecture for GPUs with many cores. In particular, one thread is allocated per agent to calculate the social forces on that agent. Although CPUs can only concurrently execute one thread per core, CUDA can run tens of thousands of threads simultaneously. Thus, the GPU's computational power is sufficient for updating the modeled behavior of massive crowds in real time.

Interactive Visualization

Interactive visualization is effective for interactively analyzing evacuation behaviors in the trial-and-error stage of creating an evacuation plan. In this study, we visualized the evacuation simulation on a high-definition immersive projection display (CAVE), which contained a cluster of high-performance graphics PCs and high-definition projectors, in order to provide the user with an evacuation experience. This interactive visualization on a CAVE offers the following advantages: Such a virtual experience, in which the participant escapes from a disaster by interactive operation, contributes to that individual's disaster prevention education. It is also possible to recreate a participant's evacuation behavior in order to model the behavior characteristics for the evacuation simulation.

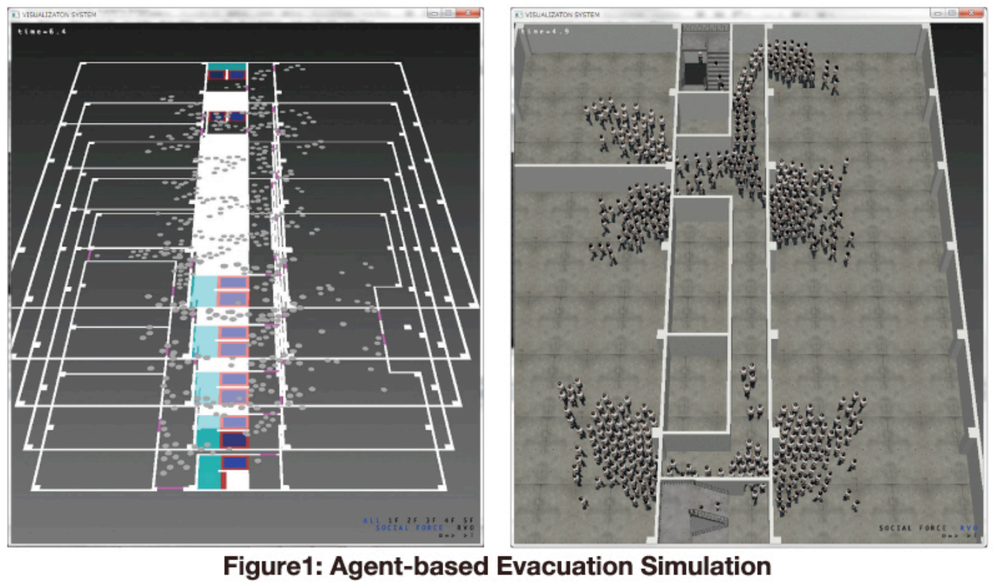

Figure1: Agent-based Evacuation Simulation

Figure2: Large-scale Evacuation Simulation using GPU computing

Figure3: Interactive Visualization on a CAVE

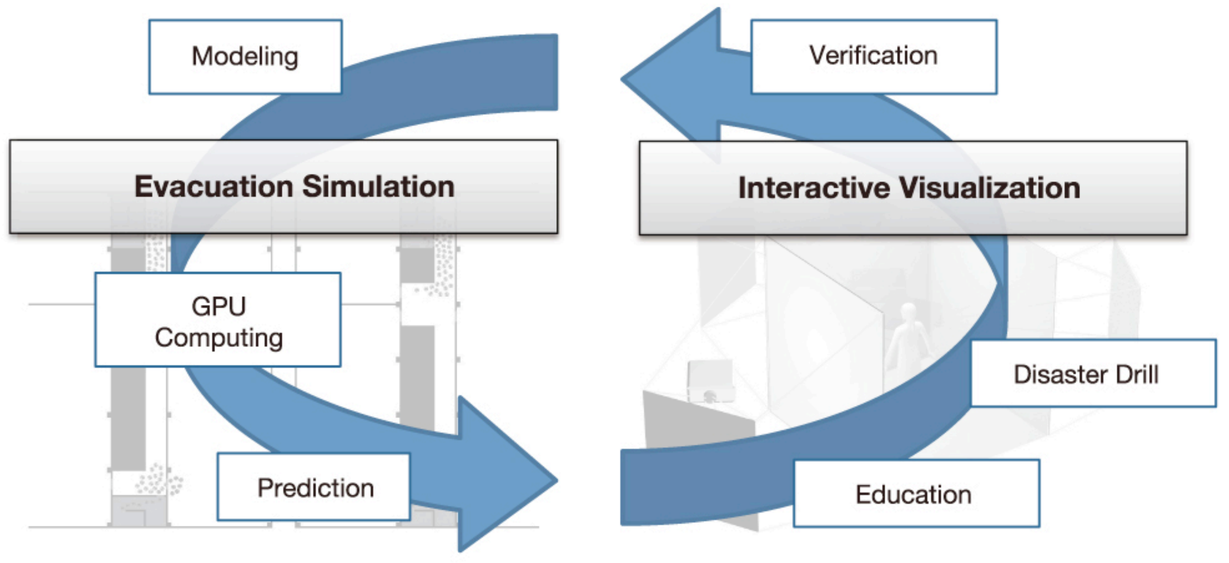

Figure4: Evacuation Simulation and Interactive Visualization

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