November 3-6, 2016 ~ Portland, Oregon

Hosted by Portland State University and the University of Oregon

This conference theme considers the role played by academic urban planning programs in practice and in place. Urban planning is unique and important because as a field it grapples with the study of real problems in real places; professional degree programs train those who will not only study but act. At the 2016 conference, participants will be especially encouraged to reflect on the relationships of planning programs with practice and/or place and how our pedagogy engages these relationships. We encourage participants to engage with challenging questions for our field and our departments, to dialogue with one another and to bring additional voices into the room –practitioners, community members, and students. We see the conference—the key gathering of planning academics in conversation—as an opportunity to build the conversations about what urban planning in the academy is and means, how it is important to universities, and what it means to the places we inhabit and serve. Some areas to explore include:

- SCHOLARSHIP - Planning research is often applied, place-based, and 'just-in-time' based on unfolding events. Is this kind of research a competitive advantage for planning as compared to the traditional social science disciplines? How are planning scholars making the knowledge from this kind of research useful for practitioners as well as introducing it into the scholarly literature on relevant issues?
- PEDAGOGY - While some disciplines are just now exploring the concept, community-engaged teaching and learning have been a long tradition in planning departments using studio and project courses to educate professionals. What pedagogies are planning programs articulating for community-engaged teaching? How are planning programs working effectively with communities in authentic, non-exploitive ways that produce real benefit? What can planning programs do to model this for our universities?
- PLANNERS, PRACTITIONERS - Being engaged scholars, working with practitioners and studying practice are critical to teaching future professional planners. How do planning programs reflect practice in our pedagogy? How do we adapt the teaching of planning to reflect current and anticipated needs for new skills and knowledge? What mechanisms do we use to respond to practitioner needs and address perceived rifts between academic and practicing planners?
- IMPACT - Measuring the impact of our programs is becoming increasingly important in our own universities and in (re)accreditation. How can we gauge the extent to which university planning programs affect practice? How can we assess planning schools' contributions beyond our scholarship, through engagement and the activities of our alumni?

AGENT-BASED SIMULATION FOR CROWD FLOW ANALYSIS

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ABSTRACT

The research discusses experiential outcome in the application of crowd simulation technology to analyze the pedestrian circulation in the public space to facilitate design and planning decisions. The paper describes how to connect space design with agent-based simulation (ABS) for various design and planning scenarios. It describes the process of visualizing and representing pedestrian movement, as well as the pathfinding and crowd behavior study.

An ABS consists of a large number of agents, which controlled by simple localized rules to interact with each other within a virtual environment, thereby formulating a bottom up system. The concept of the ABS has been widely used in computer science, biology and social science to simulate the swarm intelligence, dynamic social behavior, and fire evacuation. The simulation consists of interacting agents which can create various complexity. In terms of spatial modeling, agents can be defined as autonomous “physical or social” entities or objects that act independently of one another (Batty 2007). As the basic element in a self-organizing system, the most popular behavior of an agent is movement. “The agent-based system with motion behavior mechanisms can be influenced by the other steering behaviors, at any moment; this is, to change the agent’s location and orientation” (Baharlou, Menges 2013). Many research projects have been done to examine how agents “sense” the landscape and “walk” through it, such as the study on shopping malls and pedestrian flows by Sehnaz Genai (Genai 2008), as well as the migration pattern by Batty in the Sugarscape exploitation. The external rules also were used to evaluate the purposive movement of agents in Clayton and Yan’s panic evacuation simulation (Clayton, Yan, 2013).

This paper describes research on using local interactions to generate passenger flow analysis. An ABS is used to optimize the pedestrian flow and construct the micro-level complexity within a simulated environment. We focus on how agent-driven emergent patterns can evolve during the simulation in response to various design iterations. The research extends to the agents’ interactions driven by a set of rules and external environment. Our research method includes data collection, quantitative analysis, and crowd simulation on two train stations and surrounding areas in Beijing-Tianjin-Hebei Metropolitan Region, and Xuzhou, China. By proposing a mix-use program with the local public transportation system, the new development is integrated with the existing urban infrastructure and public space. Through the multi-agent simulation, we evaluate the crowd flow, total travel time, density, and public accessibility. Based on the result of ABS, we discussed whether various space design methods can improve pedestrian flow efficiency and passenger experience, as well as shortening transfer time, and reducing congestion.

Keywords: agent-based simulation, pedestrian flow analysis, self-organizing

INTRODUCTION

There were many computational methods applied to simulate agents involving movement, including "the simple statistical regression, spatial interaction theory, accessibility approach, space syntax approach and fluid-flow analysis" (Batty, 2007). Michael Batty described the property of "Autonomy" and "the embedding of the agent into the environment" as the two key properties of agents in an agent-based system (ABS). An ABS consists of numerous agents, which follow localized rules to interact with a simulated environment, thereby formulating a bottom-up system. Since Craig Reynolds' artificial "bodies" and flock simulation, the concept of ABS has been widely used to study de-centralized system including human social interaction. In urban modeling, agents can be defined as autonomous "physical or social" entities or objects that act independently of one another (Batty 2007). ABS focuses on the agent's properties and processes used to respond to external changes, specifically how the agents can "sense" and "act" to form a complex system. The movements are usually based on simple rules such as separation, alignment, and cohesion. Computer scripts can be used to control agent's velocity, maximum force, the range of vision and other properties.

In the early research phase, we compared the bottom-up ABS with the Cellular Automation (CA) methods, as well as Space Syntax to exam the generation of agents, their spatial properties, and their interactions with the environment.

Compare the ABS with Cellular Automation

Cellular automation (CA) calculates cells' changing state through time, based on the state of neighboring cells and context. As two famous bottom-up systems, both CA and ABS compute the status of a changing object over time. However, it is important to understand the distinction between cells and agents. Batty describes agent as "mobile cells, which – objects or events that located with respect to cells but can move between cells." (Batty, 2007) However, the behaviors of CA are often unpredictable and lack purposive planning goals. It is difficult to use CA to add rules and other "purposive goals" to the system beyond context awareness. Similar to Betty's "global attraction surface" in his study on the agent's movement, we need a system to introduce "external force rules" to influence the agents' behavior.

Compare the ABS with Space Syntax

Space syntax is another method to study movement pattern and accessibility of a network based on lines, nodes, and connections. With its own "agent analysis" tool, space syntax does not actually measure the interactions among agents. However, space syntax provides fast feedback between geometric elements and its accessibility value within a grid of cells.

We studied the space syntax as a reference tool for the ABS. Through importing the DAAP building floor plan into space syntax analysis tool, we produced heat map to represent accessibility and spatial integration. The warmer color represents higher spatial integration values. We computed the integration value of each cell by the analysis tools in space syntax and visualized the values with colors. The qualitative values extracted from the space syntax analysis are imported into Grasshopper for further computing. In order to convert the space syntax result into a heat map representation, we created a data processing method to expand the color values automatically from paths to zones. However, it becomes obvious that the interactions among agents, complex social behavior cannot be simulated through space syntax, although it provided a fast way to visualize interactions between agents and environment.

We also researched several other commercial agent-based tools in the entertainment industry. Mass animation tool has been widely used to simulate the behavior of crowds, where the agents' movements are computed based on the interactions among themselves, as well as the interactions with the environment. We explored A* pathfinding an algorithm used to create the "cognitive agents", which can populate a spatial model and navigate through a "cell" based map. Different from the "reactive" agent in Reynolds' flock simulation, these "cognitive agents" have their artificial intelligence (AI). The agents have the ability to response to the changing environment and other agents' movement in real time and adjust their behavioral parameters. The AI agents can make decisions while evaluating the result generated in a real time environment. (Figure 1)These tools and methods allowed us to understand the autonomous, bottom-up ABS approach and compare the effectiveness of various agent related computations.

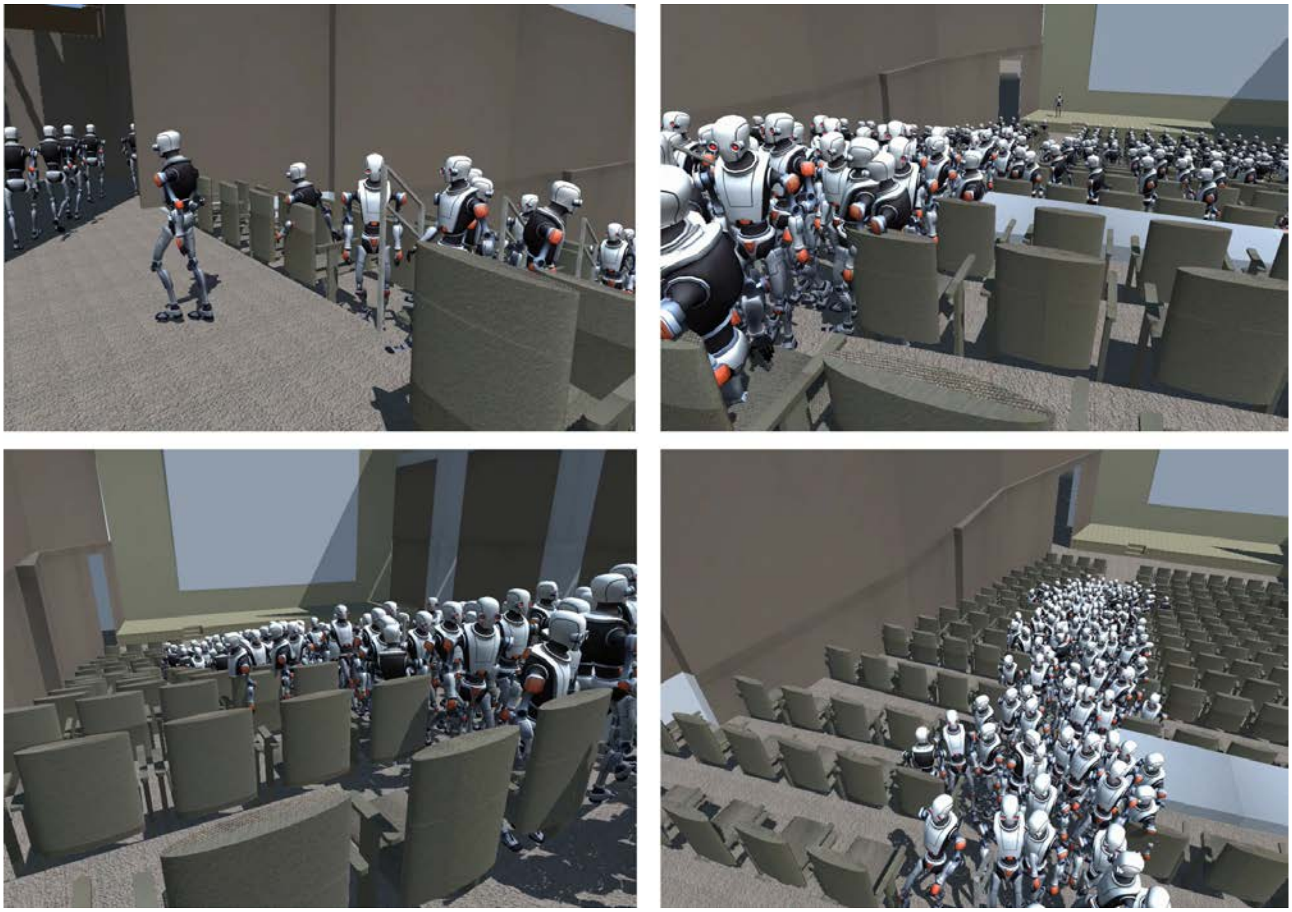

Figure 1. Evacuation simulation and crowd behavior study. AI-controlled avatars evacuate from lecture hall in DAAP building. University of Cincinnati (UC). By Laura Kennedy, University of Cincinnati.

ABS FOR CROWD SIMULATION

ABS allows a complex movement pattern to emerge from the simple interaction among agents. Each agent can "sense" its neighbors and "react" to them by modifying its location, velocity, shape or other attributes. ABS for crowd behavior simulation is established in the same relational model and computational strategy from the early physiological field. Some of the emerging methods in the crowd simulation involve utilizing ABS to generate realistic crowd dynamics that respond to the crowd's visibility in the environment, and even social influence. All of these simulation methods modeled the interaction of agents, despite model the path directly. In another word, we can understand the dynamics of crowd movement better by not modeling them at the global level but instead simulating the local interactions among these components and automatically construct the movement patterns at the relational level. (Figure 2)

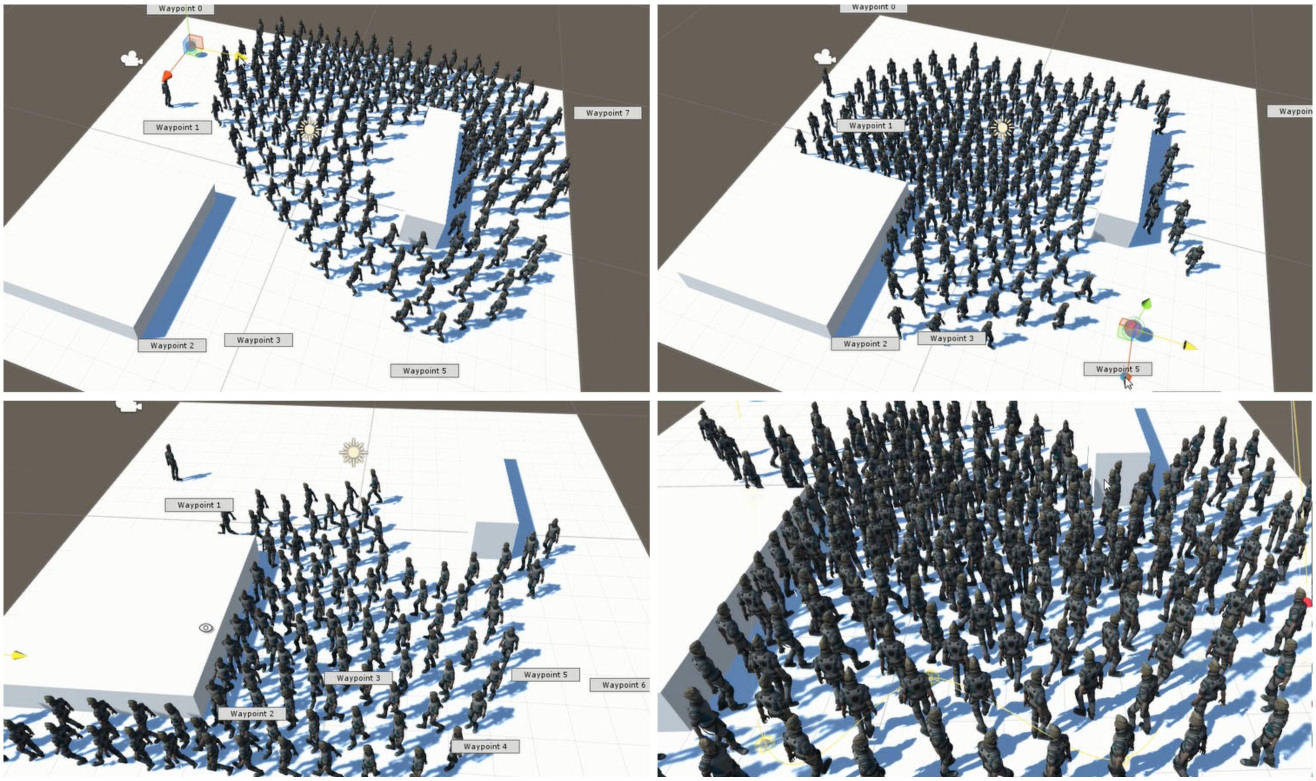

Figure 2. A large number of agents are chasing a flying target (top-down goal), as well as interact with each other, and the environment locally. By Ming Tang.

Path Visualization

Our visualization process began with a CSV text-based spreadsheet, which was constructed based on the simulated movement of agents over a period of time. Through Grasshopper script and Autodesk Maya software, points were created to present the spatial location of agents, and form a continuous path in real time. This approach visualized the bottom-up interaction of individual agents to respond to other agents within the system. First, the X, Y, Z values of each point were woven into a timeline. Once the respective movement is reconstructed, the paths connect those points formed overplayed curves. The color map representing the agent density is used to study the possible evacuation route, safety issues, and pathfinding. We used various charts to visualize the agent interacts with other agents from neighboring groups based on their proximity, attraction, and collision. The virtual environment is formed by a series of static collision objects, including interior walls and none-destructive furniture. As a reactive agent, every agent along a path is analyzed in its relationship to other agents within the system. We optimized the movement paths by the computer simulation based on the proximity and interaction of agents. (Figure 3)

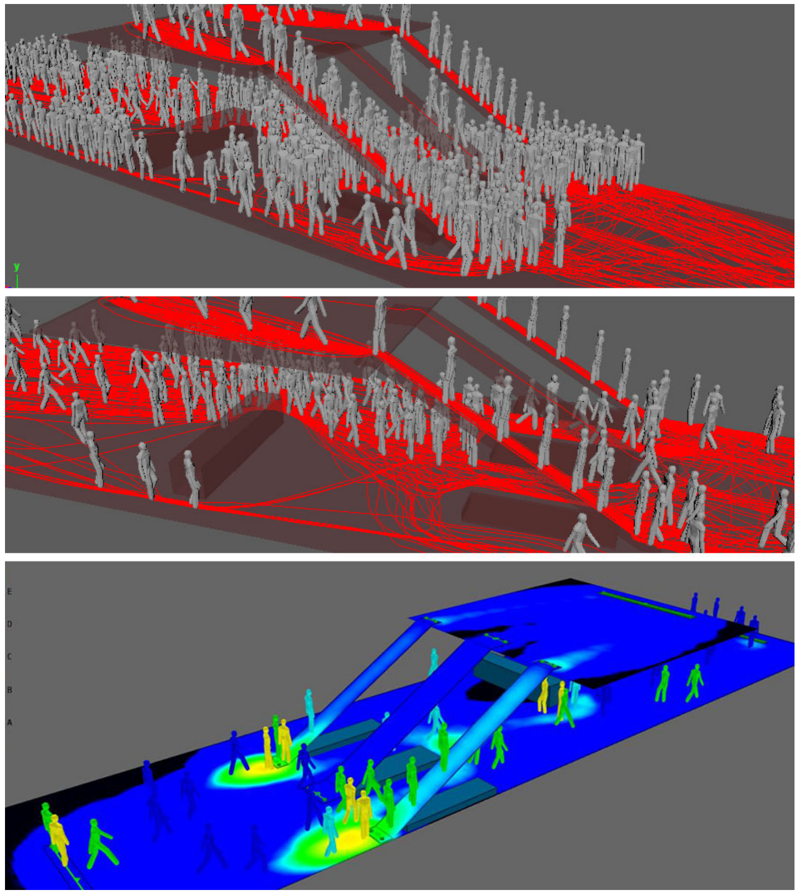

Figure 3. Path Visualization with curve and heat map. By Ming Tang.

With ABS, the autonomous “action” of each agent lies within modifying its movement based on the repulsion or attraction to neighboring agents in addition to the environment itself. Over a period, a crowd behavior is automatically formed as the agents stop and remain equilibrium.

PROJECTS

Pengche Square, Xuzhou, China

Pengchen Square is a proposed urban design project in Xuzhou, China. Designed by Beijing Jiaotong University, the goal is to create a mix-use urban cluster, which includes residential, commercial, cultural and public spaces. The existing subway system is integrated with the new proposed program to form a new urban center. Researchers from the University of Cincinnati and Beijing Jiaotong University collected the existing and projected pedestrian flow and generated several scenarios for crowd simulation. A complex crowd movement pattern emerged based on the micro-scale interactions among agents. Multiple paths and crowd movement automatically adopted a set of rules based on both bottom-up movements, as well as the top-down planning methods. The self-organizing pattern of the movement emerged based on the connection between circulation space and the proximity to the existing subway entrances. The spatial organization of public space, as while as a proposed pathways for pedestrian flow, were simulated and evaluated by ABS. (Figure 4).

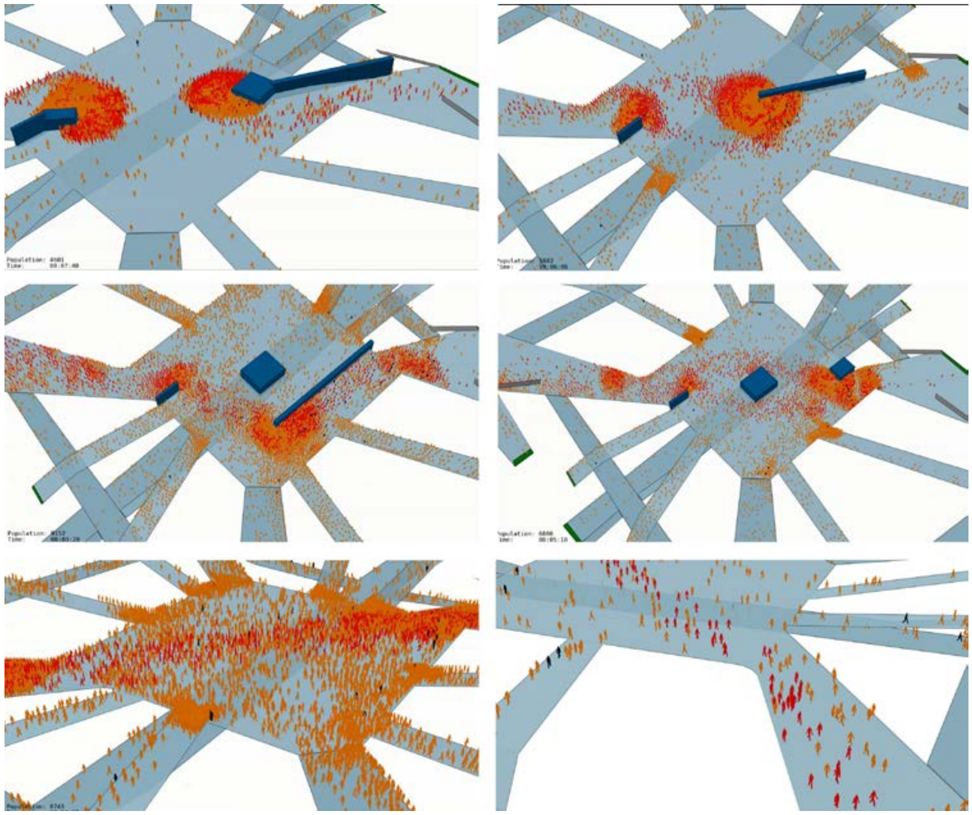

Figure 4. Adaptive urban model, Xuzhou, China. Multiple design iterations were simulated with projected pedestrian flow.

Sihui train station, Beijing, China

The research on the Sihui train station is focused on its connection to the public space and potential space for parking and retail. We collected daily passenger commute data through ticket system and compared with the onsite observation. We also estimated the future passenger increase after the new urban development in Beijing-Tianjin-Hebei Metropolitan Region. Through the multi-agent simulation, we evaluate the crowd flow, total travel time, density, and public accessibility in different scenarios such as peak hours and predicted future flow in the next few years. Based on the result of ABS, we analyzed whether various parking strategies can improve pedestrian flow efficiency and passenger experience, as well as shortening transfer time, and reducing congestion. We use the result of ABS to suggest the possible areas for retail development without affecting the pedestrian movement. (Figure 5)

When designing a public space outside a subway station, designers usually give priority to the characteristics of passenger peak flow. However, besides this basic function, designers should also consider public space to facilitate other urban functions. For example, user's three levels of needs, physiological, psychological and emotional should be considered in the planning stage. In many Chinese cities, the scale of public space outside the subway station is large and appears empty. As a consequence, the walking distance is long, and the environment quality is poor. Other problems include lacking spatial identity, lacking public gathering places, and lacking service facilities.

Conventionally, the public space is organized based on its purpose. It should serve for pedestrian flow, vehicular traffic, as well as spontaneous and social activities. However, in the planning process, it is often possible that planners cannot clearly define the needs of different functions. Sometimes environment usage deviates from designer's original plan (Luo Lingling, 1998). This is known as the concept of "adapted use". For example, in the Sihui station, there is unplanned car parking lots on both sides of the public space, which should be defined as the adapted use. We borrowed the concept of "adapted use" and "bucketed space" to discuss the human behavior based on time and space. By ABS, we analyzed different pedestrian behavior under various conditions. First, we revealed the needs in different periods of time based on humane design. Second, we analyzed how to meet the different pedestrian behavior in time and space distribution. Third, we explored several ways to improve the efficiency and comprehensive use of the public space.

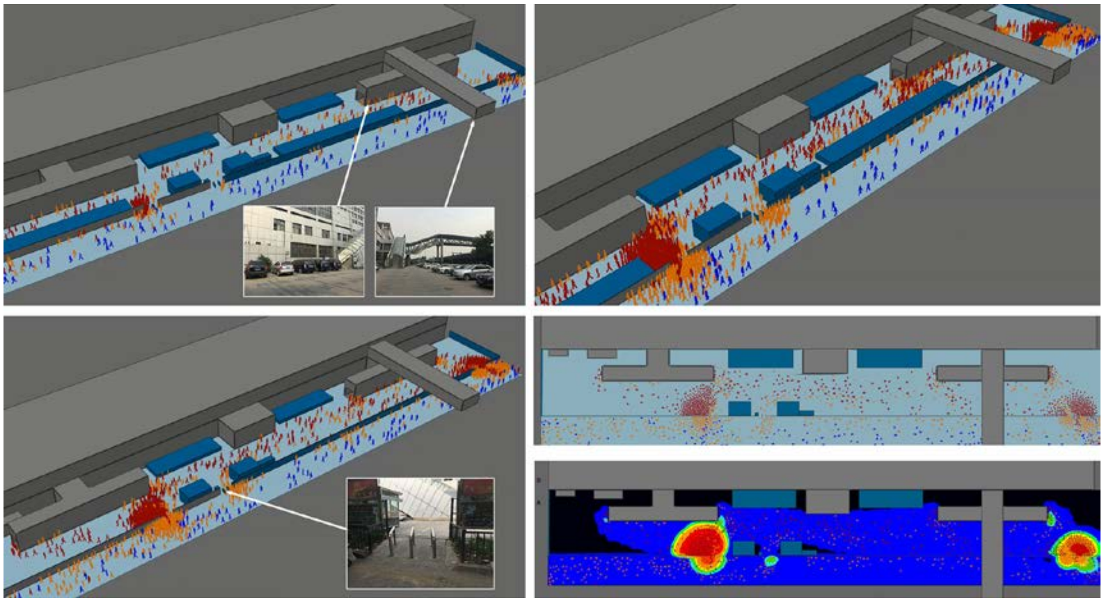

Figure 5. Top: Data collection from ticket system. Middle: Peak hours crowd simulation. 100 people/min; Bottom: Peak hours crowd simulation. 300 people/min. ABS shows that congestion areas of A / B exit square are mainly in three places located on the exit of the fence. Simulation results show that most blue and black area can be used for parking, business, leisure and other functions. These areas can be used to accommodate more diverse urban functions.

CONCLUSION

The research compared several crowd simulation systems and investigated how to integrate ABS into the design phase in two urban design projects. Different from the traditional top-down planning method, this crowd simulation method relies on the emergent properties and local interactions among agents. Within the process of ABS, design can be improved by observing the interaction between simulated crowd and the surrounding environment. Designers can observe agents' changing behaviors by proposing different spatial features. We believe the crowd simulation can produce measurable improvement in the design. , the ABS can predict certain "bottleneck" area with potential congestion issues near the train station entrance. Together with traditional humanistic evaluation and ABS, a new relationship of designer and design agent has been forged.

In the two urban design projects in China, we applied ABS for crowd analysis. The benefit is obvious for analyzing alternative design scenarios. The result of simulation was used to suggest the pedestrian paths, as well as comparing different spatial organization of building programs. However, this agent's behavior is not "realistic" enough for the emergency exit and fire evacuation analysis due to the lacking of complex social behaviors. Because the ABS is generated as a highly abstract in the micro level, designers should consider to combine ABS with other empirical methods, and building code to construct a realistic movement model for the panic and extreme conditions.

FUTURE RESEARCH

We are currently investigating crowd behavior using immersive virtual reality and augmented reality technology. The goal is to create an immersive virtual environment allowing a real person to react to various environmental conditions and behaviors of artificial agents and test various design theories in both micro and macro levels. We are adapting various process learned from previous ABS method. Oculus Rift and HoloLens devices will be used to study crowd behavior, and facilitate design decisions such as spatial organization. We are modeling various human-computer inference to test the influence of smoke, fire, signage, lighting, and architectural features for egress. In an ideal situation, these immersive experiences should be able to integrated ABS and serve as a feedback loop for crowd simulation.

ACKNOWLEDGMENTS

Thanks for the contribution and support from Haishan Xia, Qiang Sheng, Chuna Zhang, Zijia Wang at Beijing Jiaotong University. Laura Kennedy at the University of Cincinnati. More information on the research is available at http://ming3d.com/VR

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