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CLOUD-BASED DEEP IMMERSIVE GAME FOR HUMAN EGRESS DATA COLLECTION: A FRAMEWORK

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SUMMARY: *Human behavior is one of the most important yet hard to capture factors in emergency evacuation simulation. It is difficult and most of the time virtually impossible in reality, to conduct an evacuation test to study human behavior in buildings during emergency situations. Various research efforts have determined that serious games integrated with rich building information can provide an effective and efficient alternative of real emergency situation. However, as different people may react very differently, real human behaviors in emergency scenarios need to be determined for a vast number of human beings in emergency scenarios to test and validate these games. Consequently, the development of a library that contains validated human egress behaviors is the key to the simulation of evacuation in an emergency environment and developing an accurate emergency evacuation analysis. This study develops the framework to build a human behavior library through a BIM based cloud gaming environment, which grants players accessibility to games via thin clients. As a result, such games have the possibility to solicit and collect human egress behavior data from a larger pool of human beings. The repository of the human library is based on the framework of Agent Based Modeling (ABM) where human behavioral data is encapsulated as methods of agents. To overcome the limitations related to individual human factors, the hypothesis is that human behavior can be explored in an immersive serious game and that the decisions made by the humans in the game scenario are identical to the decisions made during the same situation in the real world.*

KEYWORDS: *Human Behavior, Serious Game, Emergency Evacuation, BIM, Cloud Gaming*

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1. INTRODUCTION

1.1 Background

The frequency of terrorist attack and collective human disasters appears to be increasing (Elliott and Smith 1993; Helbing et al. 2000a). Efficient emergency simulation approaches can help building managers develop effective rescue and evacuation plans when an emergency or disaster happens (Wang et al. 2011; Zhang et al. 2012). Among emergency simulation approaches, consideration of human behavior factors in evacuation simulation is a big challenge for safety engineers (Rüppel and Schatz 2011). Most present evacuation simulation models are based on Agent Based Modeling (ABM) approaches (Rüppel and Schatz 2011). ABM is capable of capturing complex behaviors at the microscopic level and reproducing the "mass behaviors" in a bottom-up manner (Du and El-Gafy 2012). Despite the great success of existing ABM simulation studies, many of the behavioral models are incompletely represented, inconsistently developed or difficult to access, susceptible to omissions and several other limitations (Gwynne 2011).

On the other hand, conversion of a 3D model to a VR model and keeping the VR model up to date is time and money consuming. Augmented and virtual reality for a realistic visualization of the emergency environment has been investigated to solve these problems (Rüppel and Schatz 2011). The idea of using computer game technology to build a virtual world was proposed by Trenholme and Smith (2008) to optimize resources in the complex process of building realistic virtual environments (2008). Smith and Trenhomme (2009) proposed the rapid prototyping of an emergency fire virtual environment by using computer game technology (Smith and Trenholme 2009). One problem encountered when using augmented and virtual reality for developing an emergency virtual environment is that the game players always know it is a virtual world and not a real world, and as a results, their behavior and reaction to the emergency scenario may be different than in real emergency events.

1.2 Problem Statement and Research Questions

The problem in egress evacuation simulation is the human behavior simulation, from a data processing point of view, large amounts of real human reaction data in the simulated emergency situation is ideal and useful for developing the emergency simulation model. However, in reality, it is difficult or impossible to conduct an evacuation test to study human behavior in the simulated building condition during the prescribed emergency situations. Therefore, the research questions that need to be answered are:

> *How to build an egress behavior library that stores real-world human egress behavior collected from a broad pool of people?*

We propose as the solution for our research questions: a building information modelling (BIM)-based Immersive Evacuation Cloud Gaming" (BIM-IECG) environment, which provides entertaining immersive emergency gaming environments to solicit the behavior decisions made by the players. Could computing technology is used to collect and store the data contemporaneously with the players playing the game.

2. LITERATURE REVIEW

This section summarizes previously conducted related research on cloud computing and cloud gaming and existing research related to gaming and emergency evacuations that was used as a basis of our proposed methodology to solve the problem of human behavior factors in emergency evacuation simulations. The use of information derived from the building information model to enhance the emergency evacuation simulation is also summarized/

2.1 Cloud Computing and Cloud Gaming

2.1.1 Cloud Computing

Cloud computing refers to "both the applications that are delivered as services over the internet and systems software in the datacenters that provide those services"(Armbrust et al. 2009). The National Institute of Standards and Technology (NIST) defines cloud computing as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell and Grance 2011). Before 2010, confusion about what cloud computing exactly is, and when it is useful prevailed in the industry, which led Oracle's CEO Larry Ellison to express his frustration as follows: "The interesting thing about cloud computing is that we've redefined cloud computing to include everything that we already do…. I don't understand what we would do differently in the light of cloud computing other than change the wording of some of our ads." The Reliable, Adaptive and Distributed systems (RAD) lab at UC-Berkeley produced a technical report in order to reduce the confusion by clarifying terms related to cloud computing. In their definition, the services is referred to as Software as a Service (SaaS) while some other vendors used other terms such as IaaS (Infrastructure as a Service) and PaaS (Platform as a Service) to describe their products. The datacenter hardware is referred to as a *Cloud* (Armbrust et al. 2010). Later on, NIST (2011) identified the three service models that are currently employed by cloud computing. Matching the cloud architecture layers, the three service layers were explained by Ojala (2011)'s as follows:

- Infrastructure as a Service (IaaS) provides "computation and storage capacity"
- Platform as a Service (PaaS) provides "software development tools and an application execution environment"
- Software as a Service (SaaS) provides "applications on top of PaaS, IaaS, or a private datacenter"

Depending on the accessibility of a cloud service, four methods to deploy the cloud infrastructure have been defined including *Private Cloud*, *Community Cloud*, *Public Cloud* and *Hybrid Cloud* (Subashini and Kavitha 2011). Private cloud only allows a single organization access while public cloud can be provisioned for open use by the general public. The choice of a cloud deployment method depends on the concerns of the users such as missions, security policies and compliance considerations (Marinescu 2013). Despite deployment differences, a cloud infrastructure may be owned, managed, and operated by the organizations themselves, third-party service providers, or some combination of these two.

2.1.2 Cloud Gaming

Cloud gaming, or gaming on demand, is a type of online gaming, which allows direct and on-demand streaming of games onto computers, consoles and mobile devices. Similar to video on demand through the use of a thin client, the actual game is stored on game company's server and is streamed directly to terminals accessing the server through the client (Shea et al. 2013). Cloud gaming provides the interactive gaming application remotely in the cloud and streams the game scenes as a video sequence to the game player, which provides game players who have less powerful computational power on their devices the possibility to play the game through a thin client. Cloud gaming relieves game players from the need to constantly upgrade their computer hardware and helps them avoid the hassle of compatibility issues in playing the game (Chen et al. 2011).

Cloud gaming has generated a great deal of interest among gaming entrepreneurs, researchers and the general public. There are several startup companies that claim to offer cloud gaming services including Onlive, StreamMyGame, Gaikai, G-Cluster, OTOY and T5-labs. Among them, some of these services can only be accessed via thin clients on a PC while others are accessible via a TV (Chen et al. 2011). Onlive and Gaikai are two of the gaming industry pioneers of cloud gaming, both of them have experienced success with multimillion user bases (Shea et al. 2013). Onlive (2014) launched the Onlive Game Service in June 2010. Gaikai (2014) launched their live service across the Internet on February 2011, which they claimed to be the world first open gaming cloud. The industrial giant in digital entertainment, Sony, purchased Gaikai for $380 million (Sakr 2012). Since then, cloud gaming began to move into the gaming industry's mainstream (Shea et al. 2013). One of the benefits of cloud gaming is the ability to massively expand the user base to end users with less powerful devices such as smart-phones or tablets. Due to the limited computational power, these devices can only support thin clients. Using thin clients means that the computer program depends heavily on the server to achieve the computational roles. Recently, the NVDIA Grid cloud gaming service launched in beta to their customers in December, 2013. Like Onlive and Gaikai, Grid lets players play games hosted on NVIDIA's cloud servers but not local computers (Lee 2013).

However, cloud gaming is still in its infancy, there remain noteworthy challenges in both theory and practice. Shea et al. (2013) conducted a systematic analysis of the state-of-the-art for cloud gaming platforms for the cloud gaming design and gaming performance. For additional information about cloud gaming issues and challenges such as latency, please refer to (Shea et al. 2013).

2.2 BIM and the Virtual Reality Game Environment for Emergency Evacuation

It is difficult and most of the time virtually impossible in reality, to conduct an evacuation test to study human behavior in a building during emergency situations (e.g. a burning building). Therefore a serious game engine integrated with rich building information can provide an effective and efficient alternative. The proposed new serious gaming approach, based on Building Information Modeling (BIM), integrated with rich building information can simulate different emergency situations. It can also provide a 3D visualization and an interactive way for exploration of the effect of building conditions on human behavior during the evacuation process.

Emergency evacuation models are input intensive. They require a great amount of information about the building spaces where the occupants stay and routes which occupants can use to escape from the buildings (Watts 1987). With the development of BIM, the physical information about the buildings and possible evacuation paths become easier for researchers to simulate and modify. Ruppel and Schatz (2011) introduced the concept for a BIM-based Serious Human Rescue game. The work combined BIM and serious gaming technology into the building safety application. To overcome the limitation regarding human factors, Ruppel and Schatz (2011) hypothesized that human behavior can be explored with serious computer game. They believed that their work can bridge technology between the real and virtual world in the game(Tizani and Mawdesley 2011).

In addition, augmented and virtual reality has been adopted for a realistic visualization of the building environment. Woksepp and Olofsson (2008) studied the credibility and applicability of virtual reality models in design and construction. In their study, the 3D objects with their attributes such as volume and material are converted into the VR model manually. Their study found that the differences in the object definition and representation between CAD and VR system limit a direct visualization of the 3D models with VR systems. This is the result of an interoperability bottleneck when passing data between CAD and VR platforms(Rüppel and Schatz 2011). Trenholme and Smith (2008) published the idea of using gaming technology to build virtual worlds to solve the problem of time and expenses during conversion from 3D to VR models. One important result from their use study is that participants perceived the simulated environment as realistic. This result is used by Ruppel and Schatz (2011) as the basis of their hypothesis in consideration of human factors.

2.3 Human Factors in Emergency Evacuation

Considering human factors is perceived as a big challenge for fire safety engineers in the fire protection design process (Rüppel and Schatz 2011). Human thoughts and actions are hard to predict but tremendously important to be taken into consideration in emergency evacuation simulations. The following is a summary of the related research efforts on integrating human factor in emergency evacuation scenarios.

2.3.1 Socio-psychology and Physics Models

Helbing et al. (2000b) studied crowd stampedes and summarized nine characteristic features of escape panic based on socio-psychological literature, media reports, previous video materials, empirical studies and engineering handbooks. They simulated the crowd dynamics of pedestrians by using a "generalized force model. Factors affecting the pedestrians' behavior are considered as socio-psychological and physical forces and they were used to build the pedestrian behavior simulation model that forms the quantitative theories of predicting crowd dynamics (Helbing et al. 2000a).

Besides Helbing's social force model, individual pedestrian/evacuee's movement has also been studied using several other microscopic models such as the cellular automation model (Burstedde et al. 2001; Kirchner and Schadschneider 2002; Varas et al. 2007) and the random walk model (Tajima et al. 2001). Tajima investigated pedestrian channel flow at a bottleneck and a T-shaped channel with the biased random walk model(Tajima and Nagatani 2002). In addition to the microscopic model discussed above, emergency evacuation problems can be analyzed by macroscopic models, which are used to produce lower bounds for evacuation times without consideration of individual behavior during the emergency scenario (Zhang et al. 2012). One macroscopic study is the network flow model presented by Kim et al. (2008) by using mathematical graphs.

2.3.2 Immersion and Immersive Game

With the development of technology, immersion in gaming, previously a fantasy, has become a possible and important factor for computer game enjoyment. The term 'immersion' is frequently used in the gaming industry and it is referred to as one of the key aspects in games as it is the ability to draw people into the game and make games worthy of playing (Christou 2014; Huiberts 2010). However, the definitions of immersion are very few(Huiberts 2010) and there is little consensus in game studies literature (Calleja 2007). Overall, there are three aspects in the definition and description of game immersion(Huiberts 2010).

TABLE 1: Immersion Definition

Immersion Definition and Description	References
"feeling of being transported into the game world or surrounded by the game world"	(McMahan 2003); (Garneau 2001) (Dovey and Kennedy 2006) (Rollings and Morris 2003) (B Joseph Pine and Gilmore 2011)
"Absorption in the activity"	(Dansky and Kane 2006) (Dovey and Kennedy 2006) (Taylor 2002)
"Feelings of identification with the situation or a character of a game"	(Brown and Cairns 2004) (Rollings and Morris 2003) (Rollings and Adams 2003) (Taylor 2002)

All of the different descriptions of immersion in games have the same basic characteristics, the game has to have the ability to confuse the player between the game environment and reality. This characteristic is very important for soliciting real human behavior factors in emergency evacuation simulation. Smith and Ericson (2009) used immersive VR to teach children fire-safety skills. They concluded that the VR capabilities may create a new paradigm in learning because of the highly interactive, experiential, virtual-learning environment.

2.3.3 Agent-Based Emergency Evacuation Simulation

Van den Berg et al. (2008) proposed a new concept "Reciprocal Velocity Obstacle" to simulate real time multi-agent navigation. Their study assumed agents navigate without explicit communication with each other and simulation of hundreds of agents in densely occupied environments showed that real-time and scalable performance is achievable with static and moving obstacles.

Pan developed MASSEgress (Multi-Agent Simulation System for Egress analysis) which incorporates diverse human behavior such as competitive behavior, queuing behavior, herding behavior, leader-following behavior into evacuation simulation(Pan 2006). In Pan's simulation, the human being's attributes such as radius of whole body, average walking velocity, maximum running velocity were incorporated from the work of Eubanks et al. (1998) and Thompson et al. (2003). In order to determine the human factors, researchers used different approaches include interviews, questionnaires, experimentation and the analysis of past emergency situations records from media or public archives. The emphasis of these data-collecting work was to find out mobility parameters such as motion speed, required space of people at different ages and genders (Rüppel and Schatz 2011).Visual Agents in these studies act according to their pre-programmed behavior and decision making rules. These rules consider individual agent behavior, interactions among agents and group behaviors (Pan et al. 2007).

Rodriguez et al. (2012) investigated how the egress of pedestrians/agents was affected by their evacuation environment with consideration of complex egress scenario, which includes "pedestrians, vehicles, guidance agents and environment effect on agent flow" in order to have an informative and sensible building design decision. (Rodriguez et al. 2012). Ruppel and Schatz (2011) provided a comprehensive literature review in ABM evacuation simulation.

2.4 Game With a Purpose (GWAP)

GWAP (game with a purpose) has been successfully used for tasks that humans can easily solve but are hard to solve with computers (Von Ahn 2006; Walsh and Golbeck 2010). GWAP uses entertaining games, human brain reactions to the game can be captured and collected in order to solve large-scale computational problems. People who play the games have no interest in solving the problems but as they would like to be entertained by the game, they will play the game. At the same time, their activities in the game will be collected (Von Ahn and Dabbish 2008). The GWAP principle has been implemented in many problem solving cases. The most widely used case is the ESP game/the Google Image Labeler. Hundreds of thousands of players have contributed to tens of millions of labels for images(Von Ahn and Dabbish 2008). Other implementations include TagATune for gathering labels for songs and Peekaboom for identifying objects within images(Law and Von Ahn 2009; Von Ahn et al. 2006).

The Entertainment Software Association has reported more than 200 million hours spent by the computer and video game players in the US every single day. It provides us a good chance to access a big amount of people to collect their decision making data for the proposed emergency system simulation. The GWAP principle is implemented in this system for collecting human decision making data in emergency evacuation scenarios.

In summary, previous efforts in studying human factors during emergency evacuation scenarios were mainly based on ABM simulation. In ABM simulation, the definition of different agent behavior is the key step for a close to reality simulation. Previous researchers have used different approaches include interviews, questionnaires, etc. There is no human behavior data available for such research. With the development of technology, immersion in gaming, previously a fantasy, has become a possible and important factor for computer game enjoyment. Player's feelings and reactions in immersive games have been proven to be so real that the players would perceive those games as real life experiences. This make the collection of human reaction to the emergency environment a possibility.

3. CLOUD-BIM-GAMING FRAMEWORK

In order to develop the human egress library through an immersive online game, a three-step roadmap has been developed as shown in Fig 1. In order to solicit real human egress behavior and build the human egress library, an immersive online game will be first be designed and developed. We name our method "BIM-based Immersive Evacuation Cloud Gaming" (BIM-IECG).

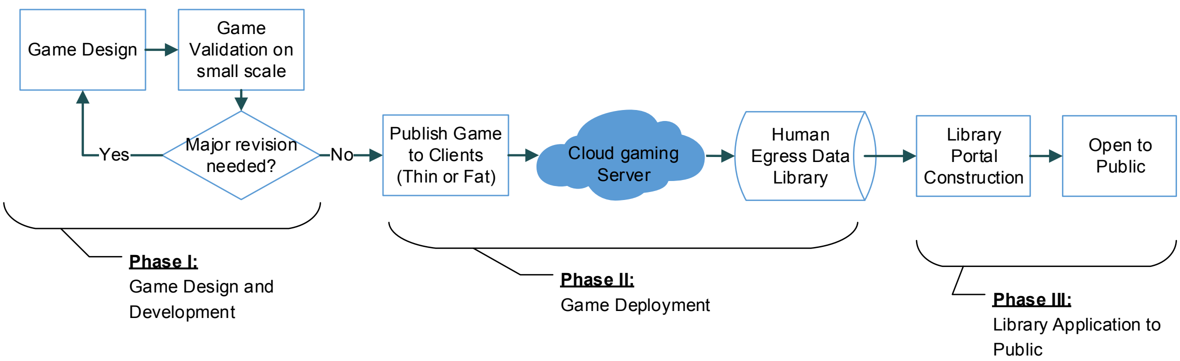

FIG. 1: Human Egress Data Library Research Roadmap

Phase I aims to build the game and game environment (Liu et al. 2014), different game scenarios are created by the BIM software platform which stores the building's spaces and evacuation paths information in its database. Phase II focuses on game deployment, after the validation of the behavior collected from the game in Phase I, the game will be published online as a cloud game, which does not require the end user to have powerful devices in order to access and play the game. While the players are playing the game, their behavior data are simultaneously collected and stored in the human egress data library. Phase III, is the last phase of this research, and involves the use of the human egress data library in future research and human behavioral studies. The successful development of this library will enhance research in the area of emergency simulation.

4. BIM-IEG FOR HUMAN LIBRARY IMPLEMENTATION DEMONSTRATION

Cloud gaming is a working concept based on prototypes that have been deployed in the gaming industry. This section provides a simple example of the human library data collection in a pilot cloud-based immersive online gaming environment.

4.1 Immersive Game Development Demonstration

Game players can choose different game scenarios before they start playing. For example, they can choose to play an emergency situation during shopping, as a result, the shopping mall scenario will be selected. In the pilot game, office, school, shopping mall and residential environment are the choices available to the user. Although the player can select the gaming scenario, they are not allowed to select the role they are playing, which means they can only play the game with their real identity. For example, if the player is a 20-year old female, she cannot choose to be a male or change her age. The process followed to create the game is shown Fig. 2.

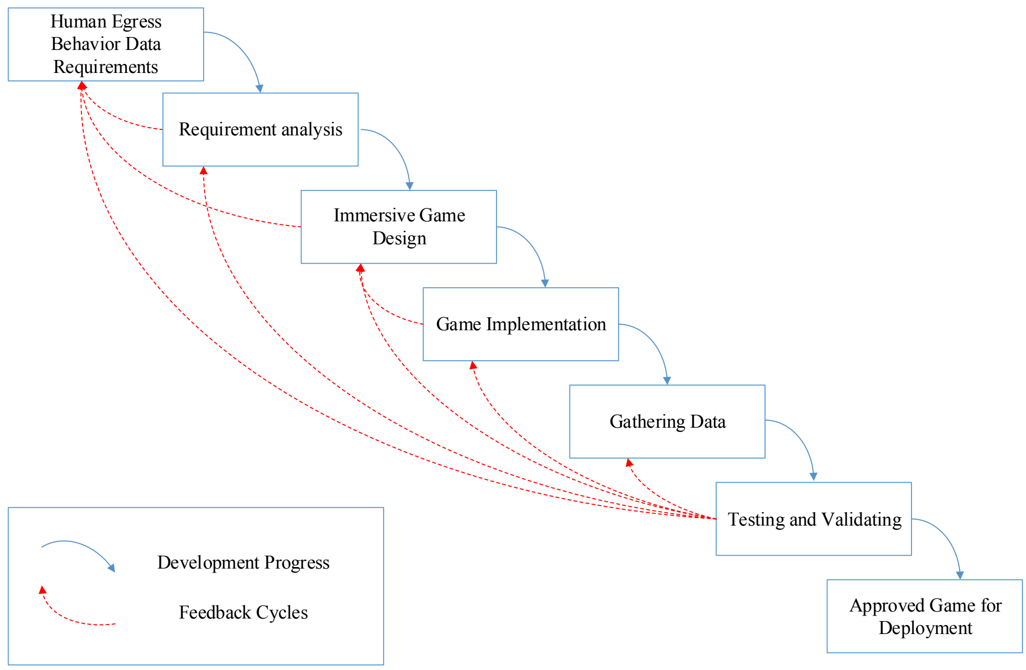

FIG. 2: Game Design Process

4.2 System Deployment

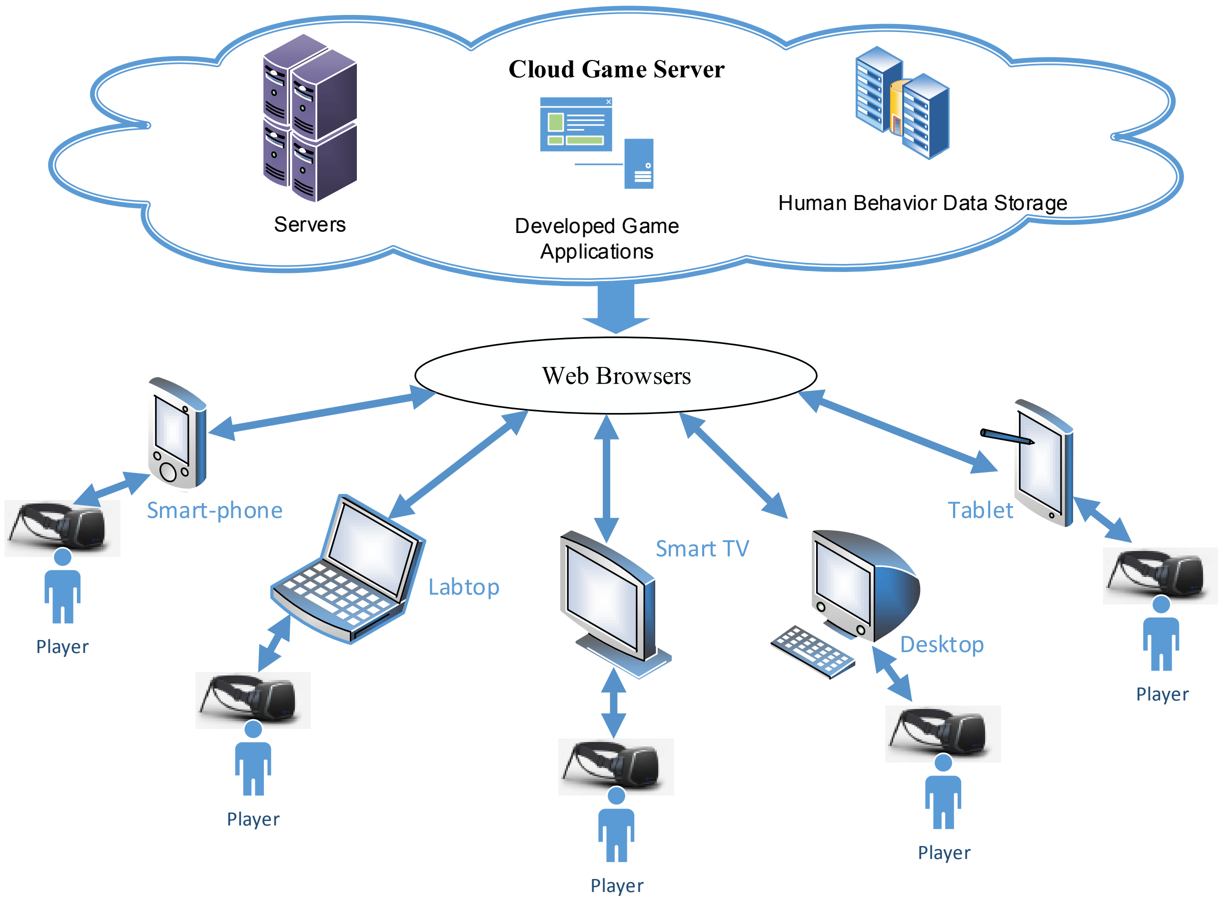

FIG. 3: Game Deployment

A user first logs into the system via a web browser portal server, which provides a list of available games to the user. The user can log into the system through any terminal device that they have available. The user is then asked to give their consent to allow data to be collected in an anonymous format. If no consent is granted, the system will inform the user that they will be logged out. Once the user consents to the data collection process, the user then selects a preferred game scenario and requests to play the game. Upon receipt of the request, the portal server finds an available game server, launches the selected game on the server, and returns the game server's URL to the user. Finally, the user connects to the game. As shown in Fig. 3, the users' behavior and attributes are collected by the web server, no matter what terminal devices they use (e.g. PDA, laptop, desktop tablet, or smartphone). In the case of immersive glasses, the user is provided a gaming environment similar to real world (Handrahan 2012). HMD (Head-mounted display) is required to play the game, which gives the player a higher sense of presence. Presence is a sense of "being there" in the virtual environment, a highly present player is more likely to behave in the virtual environment in a manner similar to their everyday reality behavior (Martin Usoh and Slater 1996; Riva and Waterworth 2014). The attributes collected from the players includes their age, gender, height and weight, this information would be collected from the data that players enter to create the character which represents themselves. The behavior information of interest includes "accelerate, avoid, decelerate, follow, run, and push" as shown in Fig 4 under operations. While the user is playing the game, their reaction to the emergency situation would be recorded and send to the cloud. For example, Player A sees an exit to the stair, he would run to the door and push the existing crowd at the door. His chain of activities will be stored in the character instance he created at the beginning of the game with the attributes that he entered. These collected data would be stored in the human egress database in the cloud. Different classes, that represent various pedestrians, inherit from the same abstract class, which for the purpose of this study is labeled EPedestrian. Currently, the attributes and operations are defined as shown in Fig.4.

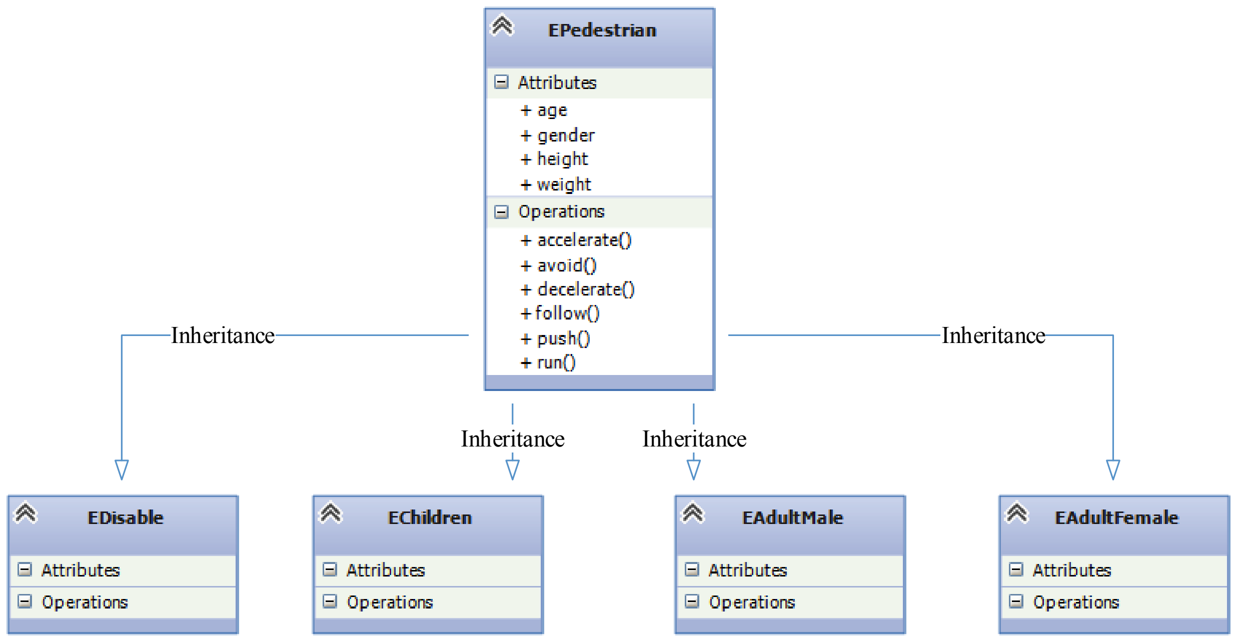

FIG. 4: Human Classes Demonstration

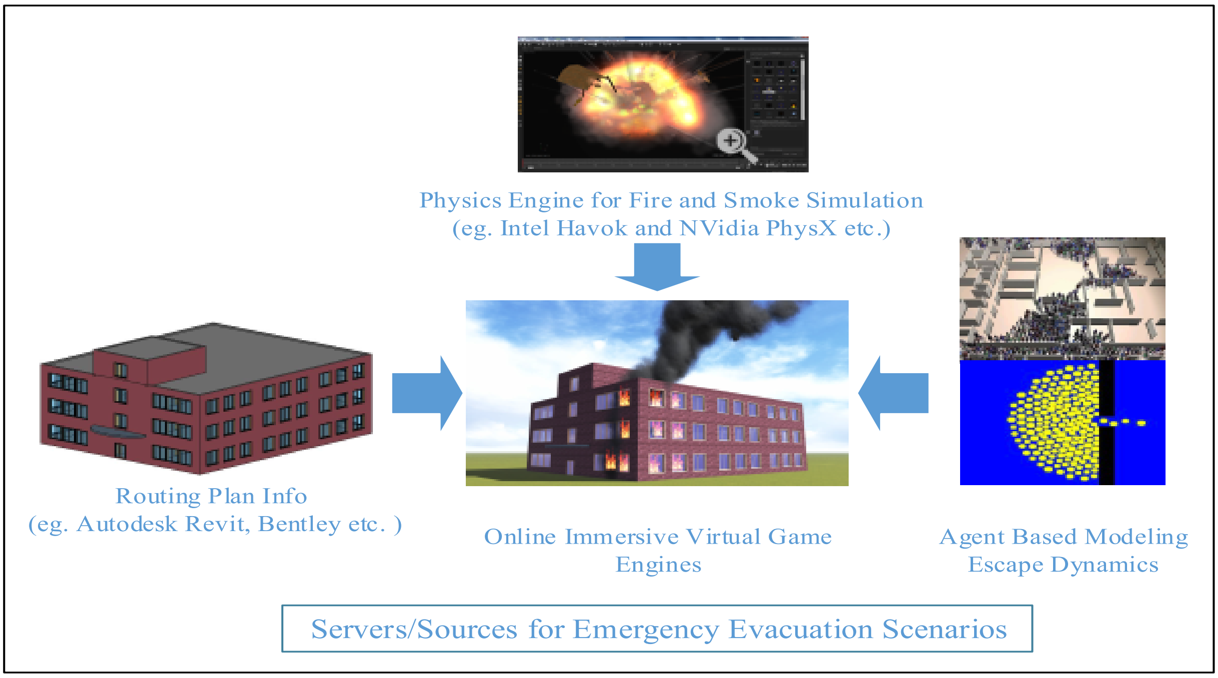

FIG. 5: Game Environment Demonstration

4.3 Game Environment Demonstration

Based on the characteristics of cloud gaming, mobile gaming through thin clients becomes possible, and a vast population can be exposed to the online game developed using their existing terminal devices. As shown in Fig. 5, BIM-based virtual reality (VR) and Agent Based Modeling (ABM) have so far been studied separately. An integrated approach that can solicit and collect real world human egress behavior contemporaneously is necessary for future emergency evacuation research studies. The framework of the integrated approach is as shown in Fig.1. To solve the emergency evacuation simulation with collective human behavior, a multidisciplinary effort is necessary. Building information models serve as sources of the game scenarios. The BIM model and the game engines provide different building environments with various building types and routing plans, and as a result different emergency scenarios for the game.

4.4 Library application and portal construction

Human agent behavior is collected for future simulation. Once the building model, agents and states are constructed, this information passes to the reasoning module, this module is responsible for modelling agent reasoning and generating the optimized strategies to achieve the objectives of different simulation purposes. The objectives can be the shortest evacuation time, the safest route, or the lowest fatality rate, keeping in mind that individual objectives and the system objectives may be different.

This approach has to be implemented and tested in different building environments, such as commercial office buildings, school projects with children pedestrians, shopping malls, and concert halls (in occupied scenario). The game can also be used for training purposes. For example, after playing the game multiple times, the total evacuation time and the fatality rate may change, a design change of the building environment or the managed evacuation routing plan may also change the evacuation time and fatality rate. Based on such simulation, better designs for emergency evacuation or better evacuation plans can be developed and implemented. In residential projects, the game environment can provide the residents familiarity with their emergency evacuation route and possible situations that they may encountered in that environment, which will help them obtain optimized results.

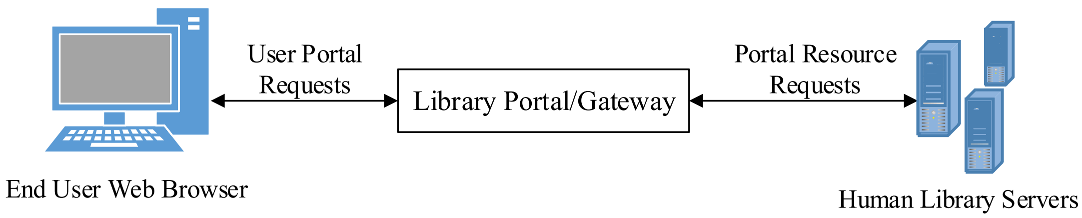

FIG 6. Library Portal Demonstration (Adapted from (Liu et al. 2014))

While the end users play the designed game, their behavior information with their attributes information will be collected and saved to the human library database server. After a massive population has played the game, the data collected will be analysed and categorized for use in future human egress behavior studies.

5. DISCUSSION

5.1 Research Contributions

Among emergency simulation approaches, consideration of human behavior factors in evacuation simulation is a big challenge for safety engineers. We proposed using immersive virtual reality games for the collection of behavioral data and making the game available through cloud computing technology which makes the game more accessible for a larger base of human players, especially those with thin clients. A more comprehensive human egress behavioral database construction will be beneficial for future emergency simulations. Compared to other databases that could be built in a laboratory environment, this database will contain "big data". This human egress behavior library (HEBL) will be the foundation for future emergency evacuation studies. The successful implementation of the HEBL system will lead to collection of human brain's decision making data in the emergency environment from a considerable large amount of people, which is currently considered as an impossibility in traditional emergency evacuation study. As the emergency environment is always dangerous for human beings, it is impossible to setup the emergency scenario in the real world and collect those human reactions. The immersive gaming technology makes it possible and affordable to collect this critical human data with a proper designed immersive entertaining game.

5.2 Limitation and Future Studies

This study shows that it is feasible to implement an online immersive gaming environment for the collection of human behavior data. A prototype will be developed as the next step of this study. This framework does not evaluate the game quality and performance of the cloud-based online gaming environment and the server requirement for massive access to the gaming server. During the implementation phase, these issues should be considered in more details. In addition, the player's gaming experience in an immersive gaming environment, such as lack of comfort in an immersive game, ways to help end users adjust in uncomfortable game situation have not yet been explored. Finally, the cloud end-user latency problem (Choy et al. 2012; Claypool and Claypool 2010) should also be taken into consideration. Even though immersive gaming technology has been shown to have a good feeling of presence (Martin Usoh and Slater 1996), the game players feeling about this proposed game has not be tested yet. Before the massive distribution of the system, some pilot study players' feedback about the gaming environment will be necessary. The quality and authentication of the identity information provided by the user is hard to control. For example, the players may enter his data as a 20 year-old woman, while in fact he is a 50 year-old man. Even though this problem exist, we believe the immersive environment with a good presence feeling of the emergency scenes will at least make the players provide their decision making choices, which is the interest of current phase of this study. Physical information about the player is outside the current scope of this study, however, such data may be beneficial and will be investigated in future studies. Last but not least, in order to attract as many players as possible, an effective reward system should be developed as an incentive for players. This direction is should also be included in future phases of this study.

6. CONCLUSION

This paper discussed the possibility of the integration of BIM, immersive games, online games, and socio-psychology and physics models to solicit and collect real human behavior in different emergency scenarios. A framework was proposed to use current technology such as cloud gaming, immersive gaming, and BIM to solve the problem of the capturing of real human behavior in emergency situations. BIM is used in the game design phases to create different building environments and evacuation routes information. Cloud computing is proposed to solve the problem of accessibility by players and make it possible to have vast numbers of connected game devices for human behavior collection. An immersive game is proposed to confuse the player between game environment and reality so as to solicit their real behavior in the gaming environment. The human egress data collected from the game is expected to greatly benefit future emergency evacuation simulation studies.

7. REFERENCES

Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., and Stoica, I. (2010). "A view of cloud computing." *Communications of the ACM*, 53(4), 50-58.

Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R. H., Konwinski, A., Lee, G., Patterson, D. A., Rabkin, A., and Stoica, I. (2009). "Above the clouds: A Berkeley view of cloud computing (February 2009)."

Pine B. J., and Gilmore, J. H. (2011). *The experience economy*, Harvard Business Press.

Brown, E., and Cairns, P. "A grounded investigation of game immersion." *Proc., CHI'04 extended abstracts on Human factors in computing systems*, ACM, 1297-1300.

Burstedde, C., Klauck, K., Schadschneider, A., and Zittartz, J. (2001). "Simulation of pedestrian dynamics using a two-dimensional cellular automaton." *Physica A: Statistical Mechanics and its Applications*, 295(3), 507-525.

Calleja, G. (2007). "Digital games as designed experience: Reframing the concept of immersion." *Unpublished Doctoral Thesis, Victoria University of Wellington, Wellington*.

Chen, K.-T., Chang, Y.-C., Tseng, P.-H., Huang, C.-Y., and Lei, C.-L. "Measuring the latency of cloud gaming systems." *Proc., Proceedings of the 19th ACM international conference on Multimedia*, ACM, 1269-1272.

Choy, S., Wong, B., Simon, G., and Rosenberg, C. "The brewing storm in cloud gaming: A measurement study on cloud to end-user latency." *Proc., Network and Systems Support for Games (NetGames), 2012 11th Annual Workshop on*, IEEE, 1-6.

Christou, G. (2014). "The interplay between immersion and appeal in video games." *Computers in Human Behavior*, 32, 92-100.

Claypool, M., and Claypool, K. "Latency can kill: precision and deadline in online games." *Proc., Proceedings of the first annual ACM SIGMM conference on Multimedia systems*, ACM, 215-222.

Dansky, R., and Kane, B. (2006). "Book Excerpt and Review-Game Writing: Narrative Skills for Videogames." http://www.gamasutra.com/view/feature/1838/book_excerpt_and_review__game_.php. (December 29, 2013).

Dovey, J., and Kennedy, H. W. (2006). *Games cultures: Computer games as new media*, McGraw-Hill International.

Du, J., and El-Gafy, M. (2012). "Virtual Organizational Imitation for Construction Enterprises: Agent-Based Simulation Framework for Exploring Human and Organizational Implications in Construction Management." *Journal of Computing in Civil Engineering*, 26(3), 282-297.

Elliott, D., and Smith, D. (1993). "Football stadia disasters in the United Kingdom: learning from tragedy?" *Organization & Environment*, 7(3), 205-229.

Gaikai, http://www.gaikai.com

Garneau, P.-A. (2001). "Fourteen Forms of Fun." http://accad.osu.edu/~pgarrett/730/gamasutra/Gamasutra-Fourteen-Forms-of-Fun.html

Gamasutra, http://www.gamasutra.com/features/20011012/garneau_01.htm. (December 29, 2013).

Gwynne, S. (2011). "Employing Human Egress Data." *Pedestrian and Evacuation Dynamics*, Springer, 47-57.

Handrahan, M. (2012). "Oculus Rift and the Virtual Reality Revolution." http://www.gamesindustry.biz/articles/2012-12-18-oculus-rift-and-the-virtual-reality-revolution. (December 16, 2013).

Helbing, D., Farkas, I., and Vicsek, T. (2000a). "Simulating dynamical features of escape panic." *Nature*, 407(6803), 487-490.

Helbing, D., Farkas, I. J., and Vicsek, T. (2000b). "Freezing by heating in a driven mesoscopic system." *Physical review letters*, 84(6), 1240.

Huiberts, S. (2010). "Captivating sound the role of audio for immersion in computer games." PhD, University of Portsmouth.

Kim, S., Shekhar, S., and Min, M. (2008). "Contraflow transportation network reconfiguration for evacuation route planning." *Knowledge and Data Engineering, IEEE Transactions on*, 20(8), 1115-1129.

Kirchner, A., and Schadschneider, A. (2002). "Simulation of evacuation processes using a bionics-inspired cellular automaton model for pedestrian dynamics." *Physica A: Statistical Mechanics and its Applications*, 312(1–2), 260-276.

Law, E., and Von Ahn, L. "Input-agreement: a new mechanism for collecting data using human computation games." *Proc., Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 1197-1206.

Lee, N. (2013). "NVIDIA GRID Cloud Gaming Service Now In Open Beta For Shielf Owners In Northern California." http://www.engadget.com/2013/12/04/nvidia-grid-open-beta/. (December 28, 2013).

Liu, R., Du, J., and Issa, R. R. A. "Human Library for Emergency Evaluation in BIM-based Serious Game Environment." *Proc., ICCCBE and the CIB W078 conferences*.

Marinescu, D. C. (2013). *Cloud Computing: Theory and Practice*, Access Online via Elsevier.

Martin Usoh, C. A., and Slater, M. (1996). "Presence: Experiments in the Psychology of Virtual Environments."

McMahan, A. (2003). "Immersion, engagement and presence." *The video game theory reader*, 67-86.

Mell, P., and Grance, T. (2011). "The NIST definition of cloud computing (draft)." *NIST special publication*, 800(145), 7.

Onlive, http://www.onlive.com

Ojala, A., and Tyrvainen, P. (2011). "Developing Cloud Business Models: A Case Study on Cloud Gaming." *Software, IEEE*, 28(4), 42-47.

Pan, X. (2006). "Computational modeling of human and social behaviors for emergency egress analysis." Stanford University.

Pan, X., Han, C. S., Dauber, K., and Law, K. H. (2007). "A multi-agent based framework for the simulation of human and social behaviors during emergency evacuations." *Ai & Society*, 22(2), 113-132.

Riva, G., and Waterworth, J. (2014). "Being Present in a Virtual World." *The Oxford Handbook of Virtuality*, 205.

Rodriguez, S., Giese, A., Amato, N. M., Zarrinmehr, S., Al-Douri, F., and Clayton, M. J. (2012). "Environmental Effect on Egress Simulation." *Motion in Games*, Springer, 7-18.

Rollings, A., and Adams, E. (2003). *Andrew Rollings and Ernest Adams on game design*, New Riders.

Rollings, A., and Morris, D. (2003). "Game architecture and design: a new edition."

Rüppel, U., and Schatz, K. (2011). "Designing a BIM-based serious game for fire safety evacuation simulations." *Advanced Engineering Informatics*, 25(4), 600-611.

Sakr, S. (2012). "Sony Buys Gaikai cloud gaming service for $380 million." http://www.engadget.com/2012/07/02/sony-buys-gaikai/.

Shea, R., Jiangchuan, L., Ngai, E. C. H., and Yong, C. (2013). "Cloud gaming: architecture and performance." *Network, IEEE*, 27(4), 16-21.

Smith, S., and Ericson, E. (2009). "Using immersive game-based virtual reality to teach fire-safety skills to children." *Virtual reality*, 13(2), 87-99.

Smith, S. P., and Trenholme, D. (2009). "Rapid prototyping a virtual fire drill environment using computer game technology." *Fire Safety Journal*, 44(4), 559-569.

Subashini, S., and Kavitha, V. (2011). "A survey on security issues in service delivery models of cloud computing." *Journal of Network and Computer Applications*, 34(1), 1-11.

Tajima, Y., and Nagatani, T. (2002). "Clogging transition of pedestrian flow in T-shaped channel." *Physica A: Statistical Mechanics and its Applications*, 303(1–2), 239-250.

Tajima, Y., Takimoto, K., and Nagatani, T. (2001). "Scaling of pedestrian channel flow with a bottleneck." *Physica A: Statistical Mechanics and its Applications*, 294(1), 257-268.

Taylor, L. N. (2002). "Video games: Perspective, point-of-view, and immersion." University of Florida.

Tizani, W., and Mawdesley, M. J. (2011). "Advances and challenges in computing in civil and building engineering." *Advanced Engineering Informatics*, 25(4), 569-572.

Trenholme, D., and Smith, S. P. (2008). "Computer game engines for developing first-person virtual environments." *Virtual reality*, 12(3), 181-187.

Van den Berg, J., Lin, M., and Manocha, D. "Reciprocal velocity obstacles for real-time multi-agent navigation." *Proc., Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on*, IEEE, 1928-1935.

Varas, A., Cornejo, M. D., Mainemer, D., Toledo, B., Rogan, J., Muñoz, V., and Valdivia, J. A. (2007). "Cellular automaton model for evacuation process with obstacles." *Physica A: Statistical Mechanics and its Applications*, 382(2), 631-642.

Von Ahn, L. (2006). "Games with a purpose." *Computer*, 39(6), 92-94.

Von Ahn, L., and Dabbish, L. (2008). "Designing games with a purpose." *Communications of the ACM*, 51(8), 58-67.

Von Ahn, L., Liu, R., and Blum, M. "Peekaboom: a game for locating objects in images." *Proc., Proceedings of the SIGCHI conference on Human Factors in computing systems*, ACM, 55-64.

Walsh, G., and Golbeck, J. "Curator: a game with a purpose for collection recommendation." *Proc., Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 2079-2082.

Wang, Y., Zhang, L., Ma, J., Liu, L., You, D., and Zhang, L. (2011). "Combining building and behavior models for evacuation planning." *Computer Graphics and Applications, IEEE*, 31(3), 42-55.

Watts, J. J. M. (1987). "Computer models for evacuation analysis." *Fire Safety Journal*, 12(3), 237-245.

Woksepp, S., and Olofsson, T. (2008). "Credibility and applicability of virtual reality models in design and construction." *Advanced Engineering Informatics*, 22(4), 520-528.

Zhang, L., Wang, Y., Shi, H., and Zhang, L. (2012). "Modeling and analyzing 3D complex building interiors for effective evacuation simulations." *Fire Safety Journal*, 53, 1-12.