An alternate reality game for facility resilience (ARGFR)

Jing Pan*, Xing Su, Zheng Zhou

International Conference on Sustainable Design, Engineering and Construction

Abstract

Disasters are immense and shocking disturbances that necessitate the collective efforts of the entire community, not just who serve as emergency management officials, to respond and recover. For better preparation, sharing of resources, engaging the public can make a substantial contribution to these improved community outcomes of disaster resilience through sharing information, identifying problems, and crafting possible solutions collectively. This research develops a framework of a serious game, which is typically used for non-entertainment educational purposes, to harness crowd wisdom and to engage them in facility resilience management.

This research first examines traditional methods used in emergency response training, as well as computer simulation-based emergency drills. It next reviews the use of gaming in emergency response training, from board games to computer games utilizing simulation technologies. It is found that alternate reality games, which are driven by transmedia storytelling and intensely devoted to establishing interactions across real and fictional worlds, suit the need of emergency response training best, yet is still lacking.

The alternate reality game is designed to provide appropriate challenges that are realistic, and to enhance essential aspects of the player’s experience. In the framework, the reality is integrated with virtual game design, and take places offline between play sessions with knowledgeable persons checking the appropriateness of the interface.

The alternate reality game is expected to engage facility occupants and to address the need of facility resilience management. Facility management team and emergency management officials are able to gather real-time information about a facility and its occupants. The idea of alternate reality game also has the potential to be applied in other aspects of facility management to achieve a shift from centralized knowledge to a collaborative model that is more adaptive to dynamic situations of a facility.

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of organizing committee of the International Conference on Sustainable Design, Engineering and Construction 2015

* Corresponding author. Tel.: +1-618-307-4411
E-mail address: jingpan_cm@126.com
1. Introduction

Engaging the public can make a substantial contribution to improved community outcomes through the sharing of information, identifying problems, and crafting possible solutions collectively [1]. National Response Framework points out that “... individuals, families, and households play an important role in emergency preparedness and response” [2]. The 9/11 Commission Report also notes that “individual citizens need to take responsibility for maximizing the probability that they will survive, should disaster strike” (National Commission on Terrorist Attacks upon the United States [3]. How to engage the public is therefore one of the major challenges in building disaster resilience [4,5]. In addition to traditional forms of engagement with the public, including curricular drills at school [6], professional classroom lectures, and hands-on practical training [7,8], games are increasingly used in emergency response training to provide opportunities to better engage the trainees [9], and alternate reality games are adopted in such trainings to enhance active learning and collaboration [10].

This paper presents an Alternate Reality Game for developing Facility Resilience (ARGFR). It first reviews traditional methods used in emergency response training, including computer simulation-based training programs. It next reviews the use of gaming in emergency response training, from board games to computer games utilizing simulation technologies. It is found that alternate reality games, which are driven by transmedia storytelling and intensely devoted to establishing interactions across real and fictional worlds, suit the need of emergency response training best, yet is still lacking. A theoretical framework of the ARGFR is then presented, including the technical route and the anticipated educational outcomes.

2. Background

2.1. Facility resilience

A resilient facility leads to a resilient community. Facility resilience goes one step further in disaster management – building up the capacity to disasters and uncertainties through experience – Not simply respond to disasters, but intentionally develop capacity to absorb effects of disasters [11]. This capacity of a facility and its occupants includes adapted/evolved facilities [12,13], actively engaged community resident groups [14], and stronger bonding among occupant groups [15].

Crisis results from unprepared residents and inadequate capacity of a facility to adapt to hazards [16,17]. During a crisis, the response and recovery team relies largely on intuition and is experience-based [18]. Many public buildings have paper-based design documents, which can be digitalized with professional efforts [19]. Some facility managers do not have access to such documents, and if these documents are ever needed, the facility management team has to describe or draft drawings for the need of emergency response and mitigation [20].

Facilities, or the built environment, are where most of human activities take place. Facility resilience therefore plays a significant role in building the capacity of community resilience [21]. However, little research is retrievable addressing the emergency management on a facility level.

Therefore, an integrated tool aiming at facility resilience building is needed to improve the capability of adapt to disasters in a community. Such tool will be able to engage facility residents; educate them to achieve value and action changing; address the need of facility resilience building; provide real-time data on key assets and spaces; and enhance pre-disaster relationship building among facility residents. Such tool has evolved from the most traditional classroom type workshops to games, including both none-computer based, and computer-based. These tools and
how the evolution of emergency management training methods are reviewed in the following sections starting with the traditional emergency management training.

2.2. Traditional emergency management training

Emergency response is not common knowledge because of its characteristics of non-predictability [22]. Traditional emergency response trainings of the public include curricular drills at school [6], professional classroom lectures, and hands-on practical training [7,8]. The National Preparedness Guidelines collectively delineates 15 potential scenarios of both natural disasters and human-caused threats, followed by a Universal Task List that includes steps to facilitate efforts to respond to the major events represented by those scenarios [2,23]. The Federal Emergency Management Agency also offered a curriculum called “Be a Hero” to engage K-12 students. The lessons were either inquiry-based or project-based, depending on categories of four different age groups. The students were able to grasp the knowledge and skills that were needed to prepare for emergencies and disasters through a three-week course setting, as well as generate awareness of emergency preparedness among family, friends, and community by developing narratives, graphic novels, and campaigns [6]. From the perspective of professional practice, Brookhaven National Laboratory provided a three-day program for radiological emergency response training purposes, by utilizing a short-lived radionuclide to simulate an actual emergency radiation scenario [7]. To respond to a hazardous materials release, the Hazardous Materials Management and Emergency Response (HAMMER) Training Center provided a plan in 1994, which cost 35.4 million dollars, for classroom lectures and hands-on practical training in realistic situations for workers and emergency responders who are tasked with handling and clean-up of toxic substances [8]. However, traditional trainings fails to provide an engaging environment where learners can actively participate in decision making and action.

Effective learning requires active participation. Emergency is of dynamic nature as well. To solve the limitations of learning effectiveness caused by traditional learning paradigm, virtual trainings, or computer simulated trainings are developed, especially for first responders and emergency managers [24]. A number of researchers have studied emergency response strategies using computer simulation technologies to provide experience and to perform experiments [25] including systems dynamics, discrete-event simulation, stochastic modeling, and queuing networks [26,27]. Besides the above, agent-based simulation represents the state of the art and offers benefits for crowd presence and advantages such as phenomena capture, natural description, and flexibility. For example, Dimakis et al. [28] introduced an approach that mimicked the physical world by representing a building as a graph with a collection of Points of Interest, and real humans by using computer generated agents. Incorporated with a wireless sensory network, their simulator performed the fire evacuation of civilians under two different speeds of fire spreading, which were parameterized by mean fire-resistance. In a nutshell, the simulation tools imitated scenarios derived from real-life disaster events and presented them to human subjects with the intent to improve their capabilities for emergency response. Although the tools were mostly targeted at decision makers and first responders, few of them were aimed at engaging the general public, as well [29]. A more engaging paradigm is therefore needed to achieve community resilience.

2.3. Games for emergency management training

Games of many forms, including computer-based and non-computer-based, are designed to be visually pleasing, challenging, and entertaining, games provide an interactive platform to engage learners with target content. In this section, game-based learning projects that focus on how people teach, study, and evaluate spatial skills, which are directly related to how people move and navigate in physical spaces are reviewed.

With the help of game-based learning method, researchers introduced approaches that designed emergency response training practices in the form of either tabletop or computer-based serious games [30,31,32,33]. It is pointed out that serious games are increasingly used for training in emergency management with obvious
advantages including extensive control in complex situations, the ability to simulate the impossible, large surface validity [9], and all within a safe environment [31].

In 2005, a preschool-targeted disaster education game called “Bo-sai Duck” was created in Japan for training young children about natural disaster and daily threat prevention [34]. In the game, players were asked to take the first action, as quickly as possible, for the hazard appearing on a flashcard. The successor research Kikkawa [35] found that “Bo-sai Duck” was effective for teaching children about disasters. Following the study in Japan, researchers conducted another study introducing “Bo-sai Duck” to children in volcano regions of Indonesia and found that active involvement of the local community was necessary in order to overcome adaption difficulties of the game, in terms of environmental and cultural difference, institutional integration, and sustainability [36]. In another study, Japanese researcher [37] developed a tabletop game called Crossroad for Local Disaster Prevention. In this group-learning game, players read cards with a written scenario derived from interviews of earthquake survivors, and make a Yes/No decision on two conflicting alternatives. The study showed that motivating people to find viable response solutions based on their own knowledge was more effective than forcing a community to accept a universally correct and prescribed plan.

In addition to card games on the table or in the field, researchers designed and researched various state of the art digital serious games, aiming to help players gain a better understanding of disaster emergencies and learn how to respond through fun gameplay. A study in 2007 described a FPS serious game for simulating the scenario of radiological emergency, which Unreal engine and Heads-Up Display to render and display the 3D game scenes [38].

2.4. Alternate reality game (ARG)

ARG is a new form of collaborative gaming in which players connect the online world with the real world, utilizing challenges and puzzles, and enhancing collaborative and individual efforts with various types of media [39]. So it has the ability to combine the features of both to complement the holdbacks of each other. They often use location-based technologies such as mobile devices with multiple sensors, physical objects, and social media, for the “game masters” to propel the story and keep the players engaged and challenged. Therefore ARG releases gamers from the computer screen or virtual environment with mice, keyboards, and gamepads, comparing to the traditional computer games [10].

![ARGFR Modules](image-url)
Whitton et al. [39] used “ViolaQuest” to improve students’ freshman orientation experience and familiarize them with an unfamiliar campus and surrounding community. Battles, Glenn, & Shedd [40] and Battles [41] presented the use of an alternate reality game in a library setting to teach college students knowledge acquisition methods such as search and research skills.

3. Theoretical framework of the ARGFR

The proposed ARGFR is a game system designed and implemented to engage and educate public of disaster mitigation and response to get them better prepared. Technically, it integrates VR and real time indoor tracking using location-based devices. The game architecture is shown in figure below. Four modules are included – user interface module, data exchanging module, and data storage module. The facility elements used in the ARGFR are identified and recorded in the facility information model, and are stored in the facility information server (FIS).

User interface (UI) module serves to interact with players. Besides human factors consideration of the UI, the UI module provides players control of game tasks, and basic information while playing the game. Firstly, a handler is provided on the UI to enabling access to the game task instruction. The instruction was originally sent to each player’s email box of registration, and can be recaptured from the handler by clicking on the button with text guidance. The game instruction can be recalled at any time during the game with the triggering event as a pop up window. Considering the nature of time stringency in many disaster response and recovery activities, 60% tasks of the ARGFR are designed to measure the time used by each gamer to complete them. Therefore the UI include a timer displayed at the bottom center. The timer can be triggered by gamer clicking the button with text “timer.”

Next important feature is the suspension trigger. It allows a gamer to stop playing the game or pausing the game at any point during the game. The button on the bottom right corner of the UI enables such in-game suspension by gamer execution.

NFC tag contains the ID specifically for the assigned location or asset. Once the NFC tag is read by the player’s device, it triggers the NFC interface with the following information as shown in Table 1.

Environment data on the NFC tag has the potential to provide indoor navigation aid in the future tasks of the ARGFR.

| Name  | ID                  | Specification                                     | Status                        | Process Data               | Environment Data                      |
|-------|---------------------|---------------------------------------------------|-------------------------------|---------------------------|---------------------------------------|
| Contents | Unique ID for the tagged object. | Manufacturerswarranties, manufacturing date, etc. | Work status of the tagged object. | Inspection, installation, maintenance history. | Space the item functions, occupancy of the space. |

During the game usability testing stage, all gamers join the game by invitation. Access to the game, in this way, are all authenticated by using invitation code mechanism. Therefore the access control module has not been activated for current stage. However, considering the future adoption of the ARGFR for facility resilience in higher education communities, the prototype of the ARGFR has planned for such access control module in consideration of information security, especially when the ARGFR interfaces with facility management system and emergency management systems.

Data retrieval module is where incoming data from players are received and processed, and outgoing feedbacks are retrieved and sent. The incoming information from the gamer are encoded as pure texts, they have to be matched with the NFC tag containing the specific texts. The NFC tag will then reveal the location information, which linked the incoming information from the gamer to the three dimensional location information of the facility as-built model. Necessary system information as well as the task instruction will be pushed back to the gamer from the location-
based data server back to the user. Based on the location, the specific tasks and associated facility elements are
located, and relevant properties will be automatically updated with incoming data pushed in by gamers.

Data storage module is where incoming data is integrated with the facility as-built information model. As the
central storage server, facility information are stored for the purpose of providing necessary information and
allowing dynamic monitoring of facility resilience level. Based on the tasks designed for the ARGFR, the
information included in the central server, facility information stored includes building service system process, key
assets process, space assignment, which are within the domain of facility management model (FMM). Also, facility
resilience management (FRM) relevant information are included in the central server, including the facility
evacuation plan, HAZMAT process, and business continuity plans of different departments within the facility. All
the FMM and FRM information are processed for the interoperability with the location-based mechanism of the
ARGFR server, using the specific coding scheme of ARGFRXML. Location information is retrieved from the data
storage module to map out the route a player has taken in complete certain evacuation-relevant tasks, or to update
service system or asset information based on the gamer’s input.

4. Discussions

To validate the game design, two rounds of game tests were planned. A Midwestern university campus building
was selected as a sample to validate the game design and usability. The facility as-built model was modified for
level of details and attributes to fit the needs of ARGFR with consideration of cost of calculation. The emergency
response plan of the building was retrieved and stored in the BIM model associated with each space and department
within the building. Also included in the BIM were space assignment schedules, building coordinators’ contact
information, and point of contact for each department/unit within the building, and external first responders for key
assets.

Student participants were recruited voluntarily through social media and traditional media such as posters. Goals
are set for each task. Each task has goals in two aspects – game mechanism effectiveness in engaging, and game
contents effectiveness in training. In one of the tasks where the players were assigned to check the server. Pattern of
human behaviour under pressure in disasters can be track, and the first responders can refer to such patterns to more
effective rescue and mitigation plans.

Also, a large scale game playing would be able to capture the crowd wisdom in checking key assets status within
facilities, and test run the planned evacuation routes and discovering potential hazards and risks using big data
retrieved from player inputs.

References

[1] F. H. Norris, S. P Stevens, B. Pfefferbaum, K. Wyche, R. L. Pfefferbaum, Community resilience as a metaphor, theory, set of capacities, and
strategy for disaster readiness. American Journal of Community Psychology, 41(2008), 127-150.
[2] U.S. Federal Emergency Management Agency, National response framework, (2014), http://www.fema.gov/media-
library/assets/documents/32230?id=7371.
[3] National Commission on Terrorist Attacks upon the United States, Final report of the national commission on terrorist attacks upon the
United States, (2004), http://www.9-11commission.gov/report/911Report.pdf.
[4] Y. Nakagawa, R. Shaw, Social capital: a missing link to disaster recovery, International Journal of Mass Emergencies and Disasters, 22(2004),
5-34.
[5] K. Yang, K. Callahan, Citizen involvement efforts and bureaucratic responsiveness: Participatory values, stakeholder pressures, and
administrative practicality. Public administration review, 67(2007), 249-264.
[6] U.S. Federal Emergency Management Agency, Youth emergency preparedness curriculum, (2013), https://www.fema.gov/media-
library/assets/documents/34411.
[7] R.D. Williams, R.D., Greenhouse, N.A. Short radiological emergency response training program. [radiological emergency response training
program outline], (1977), http://www.osti.gov/scitech/servlets/purl/7254605.
[8] M.E. Borgeson, Project plan, hazardous materials management and emergency response training center (1994).
[9] T. van Ruijven, Serious games as experiments for emergency management research: a review. Proceedings of the Eighth International ISCRAM Conference, (2011), 1-5.

[10] C. Magerkurth, A.D. Cheok, R.L. Mandryk, T. Nilsen, Pervasive games: Bringing computer entertainment back to the real world, Computers in Entertainment - Theoretical and Practical Computer Applications in Entertainment, 3(2005), 1-19.

[11] P.T. Jaeger, B. Shneiderman, K. Fleischmann, J. Preece, Y. Qu, P.F. Wu, Community response grids: E-government, social networks, and effective emergency management. Telecommunications Policy, 31(2007), 592-604.

[12] F. Berkes, F., H. Ross, Community resilience: Toward an integrated approach, Society & Natural Resources, 26(2013), 5-20.

[13] D. Bouraoui, G. Lizardalle, Centralized decision making, users' participation and satisfaction in post-disaster reconstruction: The case of Tunisia. International Journal of Disaster Resilience in the Built Environment, 4(2013), 145-167.

[14] K. Magis, Community resilience: an indicator of social sustainability. Society and Natural Resources, 23(2010), 401-416.

[15] S.L. Cutter, B.J. Boruff, W.L. Shirley, Social vulnerability to environmental hazards, Social science quarterly, 84(2003), 242-261.

[16] J.S. Mayunga, Understanding and applying the concept of community disaster resilience: a capital-based approach. Summer Academy for Social Vulnerability and Resilience Building, (2007), 1-16.

[17] D. McLoughlin, A framework for integrated emergency management. Public Administration Review, 45(2003), 165-172.

[18] J.Chia, Engaging communities before an emergency: Developing community capacity through social capital investment. Australian Journal of Emergency Management, 25(2010), 18-22.

[19] W. East, E., N. Nisbet, T. Liebich, Facility management handover model view. Journal of computing in civil engineering, 27(2013), 61-67.

[20] O. Rozenfeld, R. Sacks, Y. Rosenfeld, ‘CHASTE’: construction hazard assessment with spatial and temporal exposure. Construction Management and Economics, 27(2009), 625-638.

[21] R. Haigh, D. Amaratunga, An integrative review of the built environment discipline's role in the development of society's resilience to disasters. International Journal of Disaster Resilience in the Built Environment, (2010), 11-24.

[22] S. Urano, P. Yu, J. Hoshino, Disaster experience game in a real world. Proceedings of Ninth International Conference on Advances in Computer Entertainment, (2012), 581-584.

[23] U.S. Department of Homeland Security, Universal task list, (2005), http://www.ncrhomelandsecurity.org/ncr/downloads/Universal%20Task%20List.pdf.

[24] F. Leite, B. Akinci, Formalized representation for supporting automated identification of critical assets in facilities during emergencies triggered by failures in building systems, Journal of Computing in Civil Engineering 26(2011), 519-529.

[25] T. Oren, F. Longo, Emergence, anticipation and multisimulation: Bases for conflict simulation. In Proceedings of EMMS 2008 - 20th European Modeling and Simulation Symposium, (2008), 546-555.

[26] L.G. Connelly, A.E. Bair, Discrete event simulation of emergency department activity: a platform for system-level operations research. Academic Emergency Medicine, 11(2004), 1177-1185.

[27] G.I. Hawe, G. Coates, D.A. Wilson, R.S. Crouch, Agent-based simulation for large-scale emergency response: a survey of usage and implementation. ACM Computing Surveys, 45(2012), 1-51.

[28] N. Dimakis, F. Avgoustino, E. Gelenbe. Distributed building evacuation simulator for smart emergency management. The Computer Journal (2010), 012.

[29] S. Jain, C. McLean, Simulation for emergency response: a framework for modeling and simulation for emergency response., proceedings of the 35th conference on Winter simulation: driving innovation. Winter Simulation Conference (2003).

[30] V. Clerveaux, B. Spence, ‘The communication of disaster information and knowledge to children using game technique: the disaster awareness game (DAGi). International Journal of Environmental Research, 3(2009), 209-222.

[31] Haferkamp, N., Kraemer, N.C., Linehan, C., & Schembrí, M. (2011). Training disaster communication by means of serious games in virtual environments. Entertainment Computing, 2(2), 81-88. doi: 10.1016/j.entcom.2010.12.009.

[32] G. Rebollo-Mendez, K. Avramides, S. de Freitas, K. Memarzia, Societal impact of a serious game on raising public awareness: the case of floodsim. Proceedings of the 2009 ACM SIGGRAPH Symposium on Video Games, (2009), 15-22.

[33] Z.O. Toups, A. Kerne, W.A. Hamilton, The team coordination game: Zero-fidelity simulation abstracted from fire emergency response practice. ACM Transaction of Computer-Human Interaction, 18(2011), 1-37.

[34] K. Hayashi, T. Kikkawa, K. Yamori, J. Tawa, Development and implementation of a card game "bo-sai duck": One case of the city of Kure Japan. Japanese Journal of Risk Analysis, 17(2008), 103-110.

[35] T. Kikkawa, Effectiveness of a simulation game as a disaster drill for young children. International Journal of Psychology, 43(2008), 680.

[36] R. Dwiyani, S.P. Saraswati, K. Yamori, N. Okada, N. Adaptation of a disaster education game from Japanese context into Indonesian volcanic prone area context: lessons learned, Asian Journal of Environment and Disaster Management, 4(2012), 37-56.

[37] K. Yamori, Using games in community disaster prevention exercises. Group Decision and Negotiation, 21(2012), 571-583.

[38] R.L. Sanders, G.S. Rhodes, A simulation learning approach to training first responders for radiological emergencies, Proceedings of the 2007 Summer Computer Simulation Conference, (2007), 1-3.

[39] N. Whitton, R. Jones, S. Wilson, P. Whitton, Alternate reality games as learning environments for student induction, Interactive Learning Environments, 22(2012), 243-252.

[40] J.J. Battles, Beyond the board: alternate reality games in libraries, In B. A. Kirsch (Ed.), Games in Libraries: Essays on Using Play to Connect and Instruct, McFarland & Company, Inc., Jefferson, NC, 2014, pp. 187-203.
[41] J. Battles, V. Glenn, L. Shedd, Rethinking the library game: Creating an alternate reality with social media, Journal of Web Librarianship, 5(2011), 114-131.