Flood Action VR: A Virtual Reality Framework for Disaster Awareness and Emergency Response Training

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Abstract - Natural disasters constitute unexpected and severe threats with devastating effects on communities worldwide. Recent studies emphasize the importance of public awareness and training of first responders in disaster preparedness and response activities. This paper presents a virtual reality framework that creates a realistic 3D gaming environment with real-time and historical weather and disaster conditions. Main goal of the project is to increase public awareness about disasters by using gamification techniques, and train and evaluate emergency responders by simulating real-life scenarios. The system is supported by voice recognition to interact with the virtual world, and analyze user's actions and voice to detect emotional and psychological state.

Keywords: virtual reality, disaster awareness, serious gaming, natural language processing, emergency response

1 INTRODUCTION

Number and devastating impacts of natural disasters have grown significantly worldwide. Total cost of Hurricane Harvey is estimated in the range of $198 billion, surpassing the estimates for Hurricane Katrina’s damages [1]. Recent studies emphasize the importance of Hurricane Katrina’s damages [1]. Recent studies emphasize the importance of public awareness and training of first responders in disaster preparedness and response activities [2]. However, the strategy of increasing awareness of disaster risks in communities is not a complete solution. The likelihood and potential consequences of rare extreme events are likely to be underestimated by public [3].

Recent developments in web technologies allowed analysis, visualization, and communication of large-scale geo-spatial disaster and weather data and information in online systems [4]. Novel devices in virtual reality (VR), and advanced techniques in artificial intelligence (AI), and graphical processor units (GPU) makes it possible for state-of-the-art simulations of real-world physics and scenarios in affordable devices [5]. Benefiting from these developments, a virtual world can be created for public and professionals to immerse themselves into an environment to experience a disaster or extreme weather event. Using VR to simulate different scenarios provides a realistic and safe workspace that allows repetition and precise measurements while removing limitations and challenges of real-world training.

Several studies present how virtual reality and gaming approaches can prove useful in disaster domain. In [6], a serious game that depends on a mobile application and QR codes placed on game elements is presented to allow participants to experience the challenges faced by emergency responders. A VR system for fire emergency evacuation is developed in [7] for simulation, drilling, and training purposes. In [8], authors argue how VR can facilitate to study human behavior in fire under controlled conditions. VROnSite is a single-user virtual reality first responder training platform that supports untethered mobile devices [9]. While navigating in the VR scene, users are offered to use either navigational input or an omnidirectional treadmill.

In this paper, we present Flood Action VR, a multi-player and voice-enabled virtual reality gaming framework, with extensive data resources. Application supports different untethered and tethered virtual reality devices. Design goals of the framework is to serve as an engaging game to increase public awareness on disasters, an educational environment for K-12 and college students, a training platform for emergency responders, and a decision support tool for decision makers and scientists.

Main contribution of this paper is the development of a virtual reality framework that dynamically creates an immersive gaming environment for flood simulation by utilizing real-world environmental (i.e. hydrological, geographical, and meteorological) data. Moreover, the ability to interact with the system using natural language and multi-player support of the game allow the utilization of the framework as a training and behavioral analysis tool for first responders and public.

2 FLOOD ACTION VR

Flood Action VR is a virtual reality framework that utilizes real-time and historical weather, disaster, and geographic data to construct a 3D gaming environment for awareness and training about disaster preparedness and response. Architecture of the game (Figure 1) includes weather and geographic data layer, VR game framework, interaction channels, and targeted devices. Data in the framework is retrieved from various sources including the United States Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), The Weather Channel (TWC), and ArcGIS City Engine. The framework allows users to interact with the environment using natural language by supporting speech recognition.

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2.1 Data Resources

Flood Action VR is empowered by various real-time and static data resources that are incorporated in different stages of the application. Elevation and terrain pattern is critical in the simulation of floods to calculate inundation level and water flow direction for specific locations. Digital elevation model (DEM) data is used to recreate the surface of the terrain. Resolution of the DEM data (e.g., 10m, 90m, 500m) is adjusted based on the location and the computational power of the client device. Texture for the reconstructed terrain is retrieved from satellite images and mapped to the 3D models. ArcGIS provides geolocation, elevation, and shape files for buildings, trees, roads, bridges, and traffic lights that are used for 3D construction. Weather and disaster data are integrated in the application to realistically create the environmental circumstances for disaster scenarios. Retrieved real-time and historical weather data consist of precipitation duration and intensity, humidity, wind speed and direction, temperature, and visibility along with the observation location and time. Historical flood events are defined by extent, depth, return period, watershed characteristics, and water level data.

2.2 3D Environment Construction

Retrieved real-time or historical weather conditions are used in various aspects of the 3D environment. Visibility in the scene is adjusted by integrating a virtual fog. Depending on the weather data, cloudiness, and precipitation (i.e., rain or snow) is simulated considering its intensity (i.e., drizzle, light, moderate, heavy, and downpour). A directional wind is integrated in the whole scene using the wind speed and direction. Wind direction is reported in azimuth degrees clockwise from north to show its origination direction. High quality tree models that are animated by the effect of the wind are created and placed in roadsides and parks. Finally, realistic water object that waves in the opposite direction of wind are created and placed in roadsides and parks. Quality tree models that are animated by the effect of the wind are created and placed in roadsides and parks. "C" shape files for buildings, trees, roads, bridges, and traffic lights that are used for 3D construction.

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2.3 Gameplay

The game utilizes gamification techniques for engagement including social media competitions, high scores, badges, and disaster scenario challenges. There are certain precepts to make a game engaging and appealing to users from different backgrounds. Game should be straightforward to prevent users to have any difficulty on grasping the flow and the rules. Visuals and response time need to be compelling for users to feel natural. Game should offer seemingly-endless possibilities and present challenges to keep the users engaged each time they play. Motivating social interaction by allowing multiple players and creating a context that attract spectators during gameplay results in higher user satisfaction and game popularity [10].

Game consists of various tasks that need to be accomplished during extreme weather and disaster events. User can explore the environment by flying a rescue drone. Interaction is made via voice with natural language commands (Figure 2b) and using the default inputs of the client device via touchpad or controller. Voice input is used to analyze voice trends of the users along with their reactions to incidents in the game to detect emotional and psychological state. Game features both single and multiplayer options to allow team activities. Multiplayer option allows users to simultaneously play the game to achieve tasks while coordinating through real-time group voice chat. Although free-roaming is allowed for exploration of the virtual world, some of the tasks will require to be completed in a predefined time period. There are 2 main game modes of Flood Action VR: (1) indoor scenario (2) outdoor scenario.

2.3.1 Indoor Scenario

Indoor scenario option will simulate an immersive VR floor in a building where player will start the game by waking up from the bed and finding out that house is flooded due to the leaks in the structure, and water level is increasing as the time passes. Main character’s mission is to prioritize an indoor scenario (2) outdoor scenario. Accomplish several tasks in a time-limited round. These tasks include locating and rescuing the rest of the household, shutting down the electricity and gas, and finding a way to reach out to emergency responders, despite challenges and unforeseen incidents. The goal of this scenario is to increase public awareness of flooding by allowing users to experience the dangers of such unexpected and extreme events in their daily lives.

2.3.2 Outdoor Scenario

Outdoor scenario mode employs a realistic 3D world constructed using the extensive data resources such as digital elevation model, building footprints, and weather and disaster data. Player starts the game inside selected city and are given various tasks to accomplish during an extreme event (Figure 2a). Tasks include escaping the flood zone, assist or rescue survivor(s), delivering emergency supplies (Figure 2c-2d). Outdoor mode supports both single and multiple players to allow collaboration while working on the...
mission. In multiplayer mode, players communicate with each other through group voice chat to coordinate and develop strategies.

Time-constrained tasks require players to make prompt decisions under stress and provide a unique opportunity to study user behaviour. Players can choose from existing locations and scenarios or create a custom scene by setting various parameters. Any city in the world can be selected for disaster scene generation. Real-time or historic weather conditions is retrieved for the selected city upon setting of the date and time. Past flood events, if any, are listed for this location along with generated flood scenarios based on user’s selection.

### 2.4 Implementation

The application is implemented in C# using a cross-platform and virtual reality enabled game engine (Unity3D). Unity3D is utilized due to its rich 3D resources, support for advanced physics, and mobile deployment and publishing capabilities. 3D components for terrain and critical infrastructures are modeled and constructed in ESRI City Engine and exported in FBX file format which then is imported in Unity3D for use in scene generation. The Flood Action VR supports Android operating system for use with Samsung Gear VR virtual reality headset. Additionally, application can support compatible standalone virtual reality headsets (i.e. Oculus Go) without any modification as they are binary compatible and have the same controller inputs [11]. Other virtual reality headsets can be supported as well by updating the interaction methods adhering to the user interface of the targeted device.

### 3 DISCUSSION

The initial prototype of Flood Action VR was announced and presented at the 2017 Samsung Developer Conference (SDC) as part of The Weather Channel SDC Innovation Challenge (Figure 3). More than 200 individuals tested the prototype version of the application that features the outdoor mode with real-time weather data and generated flood scenario. Participants consist of a diverse set of people from various technical backgrounds, including students (K-12, undergraduate and graduate levels) developers, designers, professionals, entrepreneurs, and faculty from all around the world. Even though participants were not trained prior to testing the game and did not have a chance to play for long periods of time, they were able to successfully navigate in the game and complete tasks with little instruction due to the application’s intuitive gameplay. Participants provided positive impressions and feedback, and acknowledged the potential for the Flood Action VR in education and awareness for public and students, and training first responders for disaster response.

### 3.1 Education and Community Outreach

Due to its utilization of real-world data, Flood Action VR presents opportunities to be utilized as an educational tool for K-12 or college level students. Benefiting from the growing interest by students to technology and virtual reality, environmental sciences and social responsibilities can be taught more effectively. Furthermore, it can be used by agencies and organizations for community outreach to increase awareness on disasters and present new tools and data resources in an engaging way.
This paper presents Flood Action VR, a virtual reality framework to increase public awareness for extreme events and provide an immersive and interactive environment for training and education on disaster preparedness and response. Framework utilizes comprehensive real-time and historical weather and geographical datasets and employs gamification techniques to ensure an engaging and realistic experience. The framework provides extensive opportunities for accessibility, scalability, and adaptation to different use cases due to its global data support, utilization of dynamic geospatial datasets, immersive virtual reality models, capability to capture behavioral and psychological evaluation of the players, and potential to become a support tool for emergency responders and decision makers.

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REFERENCES
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