Augmented reality to guide pedestrian evacuation in earthquake events

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ABSTRACT

Augmented Reality is a promising technology to support safe pedestrian evacuation from buildings during earthquakes. The widespread availability of phone cameras makes this idea feasible. QR codes, for instance, can place virtual three-dimensional objects to guide people along a prescribed route. In this work, a prototypical system based on this premise was created in response to the 2020 sudden surge in seismic activity in Puerto Rico. The results point towards feasibility as well as to a series of areas that require improvement for a real-life implementation.

KEYWORDS

Augmented reality, pedestrian evacuation, earthquakes, emergencies.

RESUMEN

La realidad aumentada es una tecnología promisoria para habilitar la evacuación segura de personas durante un sismo. La amplia disponibilidad de teléfonos móviles con cámara refuerza la factibilidad de tal idea. Es posible, por ejemplo, utilizar códigos QR para configurar objetos virtuales tridimensionales que guíen a las personas hacia una ruta prescrita. Basados en esta premisa, este trabajo describe un sistema prototípico creado en respuesta al sorpresivo aumento de actividad sísmica experimentado en Puerto Rico en el 2020. Los resultados indican su factibilidad, así como una serie de mejorías que se deben atender ante una instauración en la vida real.

PALABRAS CLAVE

Realidad aumentada, rutas de evacuación, sismos, emergencias.

INTRODUCTION

Earthquakes are one of life's most sudden and impactful events in the modern world. In a society that has managed to comprehend and prevent most of nature’s challenges, the existence of events so disastrous and without warning is terrifying. These natural disasters have taken the lives of approximately 750 thousand people between 1998-2017 in the world, that is over half of all lives lost due to natural disasters.[1] The majority of these deaths are caused by structural collapses, which crush or trap victims. This tells us that an important course of action to save lives is to evacuate at-risk buildings as fast and safe as possible.

Staying in a building after an earthquake, even if no structural damage is observed, is dangerous as many earthquakes cause aftershocks that could make the building collapse. These aftershocks can start just minutes after the earthquake. For these reasons we want to evacuate people through the fastest and safest routes possible. There are cases where an escape route could be fast and efficient, but it is obstructed from view or hidden in a rarely transited hallway. The opposite might also be true, where a route is accessible and obvious but is nowhere near as fast and safe as it should be, leading to blockages and harm during an actual escape situation.

In Puerto Rico, between December 1 2019 and January 15 2021 there were more than 12,000 earthquakes.[2] This was roughly three times the annual average frequency measured between 2014 and 2018. The strongest ones reached magnitudes above 5.5 Mw. It was initially estimated that nearly 800 buildings were destroyed or severely damaged in association with the first months of occurrence of these events.[3] Due to this sudden surge of seismic activity, it became necessary to renew our attention to safety protocols, evacuation pathways, tsunami awareness, and prevention in the general population. In January 2020, our university had a three-week delay to return to classes to allow for inspection of buildings and revision of safety guidelines. Pedestrian evacuation was, indeed, a key concern. This problem has been described and studied thoroughly in the literature,[4] however, because of the usual chaos surrounding the situation,[5] pedestrian evacuation is still an area where multiple approaches can still contribute to its solution.[5,6] In this context, this work examines the use of augmented reality (AR) to guide people evacuation from a building in the occurrence of an earthquake. A prototypical solution with these characteristics developed for the Industrial Engineering building of the University of Puerto Rico at Mayaguez is described here. One important reason why AR became an option to be explored is the fact that any modification of the building in question is highly regulated due to its architectonic value. Noninvasiveness, simplicity, as well as effectiveness needed to be imbedded in any solution.

Selection of a plausible guiding system for evacuation

Navigation of building layouts can be difficult during and after an earthquake. Be it the complexity of the building or the rushed mindset, people tend to not follow designated emergency escape routes in an actual emergency.[5] Although it is a standard safety practice to have a map for emergency routes posted in buildings in the US and Puerto Rico, during an emergency, consulting it is not practical. On the other hand, physically placing additional signs is often balanced against the aesthetics, architectural and functional restrictions of a particular structure. A possible solution lies in the form of scannable QR codes that could project a series of arrows using augmented reality (figure 1) to follow a safe evacuation route. This solution would capitalize in the wide availability of camera-ready mobile phones and the recently gained experience of users who became acquainted with QR code scanning in restaurants during the Covid19 pandemic. Implementing this technology has the possibility of reducing confusion during an emergency. Furthermore, the number of arrows that could be placed is virtually limitless and potentially long-lasting.

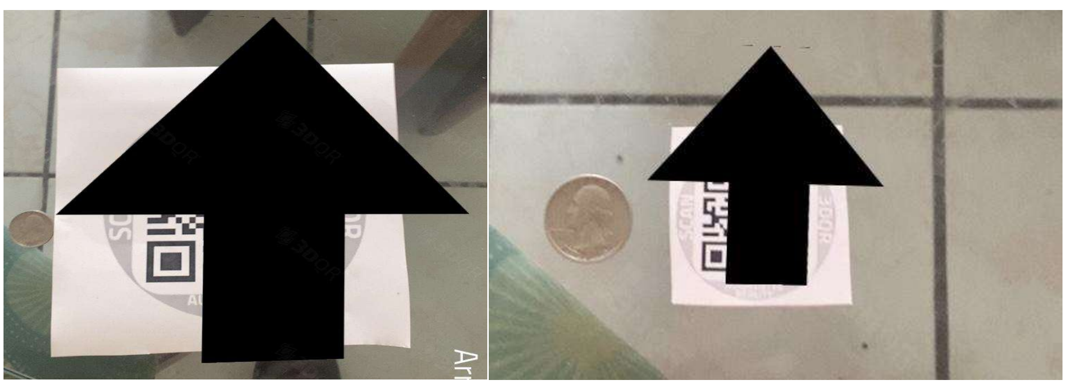

Fig. 1. The scanning of a QR code can generate an orientable arrow pointing in the desired direction of evacuation. The size of the arrow is proportional to the size of the printed QR code.

In order to solve the issue of quick navigation using AR, various alternatives were considered to ensure that people would evacuate safely and as fast as possible. The first alternative was that of utilizing wireless network's tracking capabilities. This seemed like a good idea due to most complex buildings having a pre-existing WIFI network, which would in turn imply low cost. The reason why this alternative was eventually discarded was due to the imprecise nature of WIFI tracking, which could be off by up to 5 meters. This presented a major problem in multilevel buildings as the system could place a person in the wrong floor resulting in erroneous directions. Another alternative considered was the utilization of Bluetooth beacons. These beacons were much more precise at determining the user's position, but their range was severely lacking compared to WIFI positioning. This poses a problem with larger buildings as increasingly more beacons and larger maintenance costs would become necessary. The last alternative considered was the utilization of markers. These markers would be placed at hallway intersections and would have asymmetrical designs so that the phone camera would be able to make clear distinctions based on the position of the user with respect to the marker. This alternative had a similar problem to Bluetooth beacons as each marker would have to be asymmetrical and distinct in design, leading to higher costs and, importantly, it defeated the purpose of making the process virtual. Finally, the method that was selected was that of QR codes together with an already established augmented reality scanner, in this particular case, 3DQR. The idea was to place printed codes at designated places where they could be easily scanned. This method was selected due to the availability of the software, since it could easily be downloaded for free, with low startup and maintenance costs. figure 2 shows one of the capabilities of this combination.

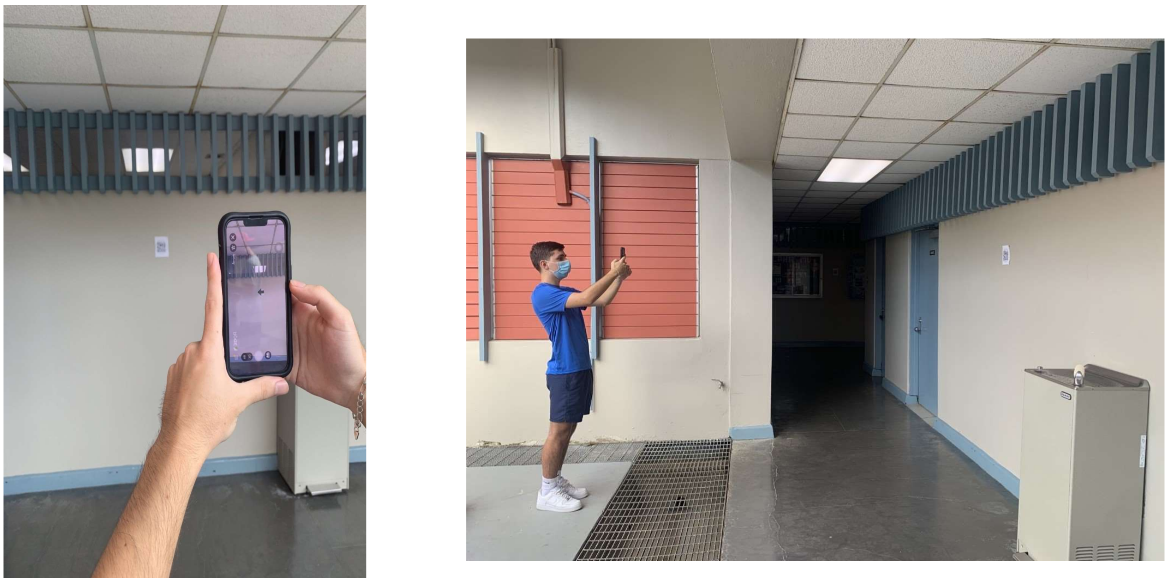

Fig. 2. A QR code of approximately 6 inches (15.2 cm) per side has a scannable range of about 7 feet (2.13 m)

MARSHALING THE PROTOTYPICAL AR SYSTEM

In the selection process described previously, the 3DQR app was favored over other applications because it can take advantage of file types varying from .jpgs to 3D models in .fbx (Autodesk Kaydara FilmBox Digital Content file). The creation of a QR code was next. When scanned using the 3DQR app on a mobile phone, an arrow pointing in the direction of the best evacuation route is displayed. The QR codes, and thus the arrows, are placed about 10 ft (3.05 m) apart. Once the phone scans the first arrow, it downloads the augmented reality object and projects it on the screen. For every subsequent code reading, the arrow will have already been downloaded on the phone and it should load faster or just re-orient the last arrow shown on screen. Compared to the option of reading an evacuation map in a single location during an emergency, the prototypical system is easier to grasp under those circumstances as illustrated in figure 3.

The app also supports direct links for websites or google docs. These links add versatility on the information that could be shared during and after an emergency. Links can be embedded in AR pictures as well. This opens many possibilities to have information available at different points in time if necessary.

Fig. 3. Following the 3DQR arrows (right) is simpler and less time consuming than traditional fire escape maps (left). Other printings can be used to denote dangerous paths if necessary.

Preliminary Evaluation

The proposed system was preliminarily tested in the building under discussion using ten subjects organized in two groups: the first five were instructed to individually evacuate the building without further instructions (control) and the other five were instructed to individually evacuate using the QR codes (treatment). It must be noted that all subjects were already familiar with the building, although not necessarily with an official evacuation route. Timewise, the group using the QR codes took a median of 13.88 more seconds to leave the building than the control group (One-sided Mann-Whitney Test for the Difference of Medians of Two Groups, p-value = 0.015). According to our observations, the slower times had to do with the initial download of the arrow as well as the attention paid by the users to the movement of the arrow in their screens. In a follow-up run, with a pre-loaded arrow in the phone, one subject timed almost two seconds below the control group´s previous median time. This tells us that with preparation and planning, it is possible for the proposed system to be more efficient. In an encouraging result, it is also reported that all subjects following the proposed system evacuated the building through the prescribed path, which was not the case for all the subjects in the control group.

CONCLUSIONS AND FUTURE WORK

This project is intended to be a proof of concept for the use of Augmented Reality to aid pedestrian evacuation during and after emergencies such as earthquakes. The prototypical system, based on QR codes, has the benefits of being low cost, low maintenance, and easily scalable. It is envisioned that with these characteristics, every building on campus could be furnished with a similar AR-based system. The step of downloading the right app can be made preemptively to facilitate the use of the proposed strategy.

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SCAN WITH 3DQR AUGMENTED REALITY

3DQR

https://3dqr.de/en/