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Eddystone Beacons for Earthquake Survivors Identification

by

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Undergraduate honors thesis under the direction of

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Eddystone Beacons for Earthquake Survivors Identification

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Abstract. Natural disasters, such as earthquakes and floods, demonstrate the importance of organized, rapid, efficient rescue operations. In earthquakes, locating survivors trapped in the rubble of collapsed buildings is still an unresolved issue. If heavy equipment is brought in too early to dig, survivors may be crushed. However, the longer rescue crews hold off, the longer it will take them to reach any trapped survivors. Time is of the essence in these rescue operations in order to maximize the number of potential survivors. To address this dire issue, we implemented the use of Eddystone beacons in a manner that allows for a more expedited rescue operation. Upon creation of a companion application to the beacons, a series of experiments were run to determine the effectiveness and efficiency of the idea. As predicted, our results show that the rescuers with the app were much quicker than the rescuers without the app.

Keywords: Eddystone Beacons, Natural Disasters, Bluetooth Low Energy (BLE).

1 Introduction

There have been a total of 42 earthquakes with a magnitude of a 7.0 or higher since 2015 [USGS]. In those 42 earthquakes, over 11,000 people died. These quakes spanned the globe and affected much more than just those that died. For instance, the economies and societies in areas affected by these earthquakes were damaged significantly as many communities are still experiencing the long-term effects of massive destruction to their communities. Furthermore, the effects of earthquakes in one country often spread across borders into neighboring countries, but cross-border collaborations to respond may not always be in place. Despite the economic damage, the loss of life remains the greatest legacy of earthquakes. This is due to the difficulty of rescuing missing people that are trapped in rubble from collapsing structures. If heavy equipment is brought in too early to dig them out, survivors may be crushed. However, the longer the rescue crews hold off, the longer it will take them to reach any trapped survivors. Time is of the essence in these rescue operations in order to maximize the number of potential survivors. To expedite the time it takes to rescue these survivors, a new system is needed to increase efficiency and effectiveness. Specifically, a strategy that utilizes information in a manner that provides a method to visualize trapped people in real-time once the earthquake has destroyed the building is needed. We propose an Information Systems solution to possibly remediate this unresolved issue.

In order to fully examine a potential IS solution, a few key topics are examined: a proposed solution, implementation, validation, results and finally a closing discussion. The proposed solution will include a discussion of the technology and application created, while the implementation will cover how the solution will be executed. The next phase, validation, explains how the experiments are set up and why an experiment was preferred over mathematical modeling. Finally, the results will be examined and discussed.

2 Proposed Solution

2.1 Digital Data Streams

According to F. Pigni, digital data is a digital representation of an event. Our smartphones are able to gather real-time data pertaining to a variety of different parameters. All of these events are created, or streamed, digitally and therefore are available for processing in digital form as they occur. Thus, these digital data streams can capture up to six basic elements of an event. These events are derived from the 5W+H model, or when, where, who, what, how, and why. While some events might have multiple elements from the same category, some elements do not have to be evident in an event. In the case of this experiment, the three most important elements are: when (did the user check in), where (the user is located) and who (checked into the beacon).

When creating value, digital data streams (DDS) is about "recognizing and extracting the incremental value afforded by a DDS, as well as being able to prioritize execution of initiatives" [Pigni 10]. It also accounts for the loss of this value through delays in: "extracting needed data from an event of interest (*capture latency*); transforming data into usable information (*analysis latency*); and making a decision to act upon this new information (*decision latency*)" [Pigni 10]. But in terms of adding value, most would associate value with making a profit. With the application of an earthquake response system, value represents the loss of life. Thus, we must examine three main forms of latency. Capture latency represents the time it takes for rescuees to check into the beacon, analysis latency signifies the time it takes to see where, when and who checked into the beacon, and decision latency exemplifies the time it takes afterwards to dispatch a rescue team to the people in need. However, in order to extract maximum value from these events, response time latency needs to be minimized while a tactic (process-to-actuate or assimilate-to-analyze) needs to be employed. For our cases, the process-to-actuate methodology was analyzed, which creates value by initiating action based on real-time DDS processing. A search and rescue team monitoring the web application created can see whether anyone has checked into the app's database signifying that they are in need of rescue. Once people have checked in, the analysis team can dispatch a rescue team to save the individuals in need. This combines events that are currently streaming in a DDS (where, when and who) and the use of a database and real-time map to provide a solution to this time-sensitive problem. This example illustrates the immediacy of process-to-actuate.

2.2 Emergent Technologies

Adding value can also be increased through the inclusion of an emerging technology. According to V.K. Narayanan, emerging technologies is a term used to cover the description of novel technologies; the processes by which they begin to infuse themselves into the commercial market place and the nature of their impact over time. This experiment utilizes the power of Eddystone beacons. Eddystone is a format that BLE beacons use that allows for contextual awareness. This means that the devices can sense their physical environment and adapt their behavior accordingly. While the Eddystone beacons have the ability to operate under multiple broadcast signals- or frames- at once, this experiment only required the use of one of those frames, Eddystone-URL. According to M. Johnson, the three main frames are as follows:

- **Eddystone-URL (**Physical Web): This frame broadcasts URLs, allowing BLE devices to emit URL links to about location specific content.
- **Eddystone-UID:** Broadcasts specific unique identifiers which native applications listen for to trigger context-aware notifications and deliver proximity-aware user experiences.
- **Eddystone-TLM:** Broadcast telemetry information such as battery information, temperature, and many more.

The biggest differentiator of Eddystone-URL is the support of the Physical Web. The Physical Web is an open source solution created by Google to enable discovery of URLs based on nearby beacons with original purpose for it to be used as a solution to address the issue of inaccurate local search. Through the use of Physical Web with Eddystone, the accuracy and relevancy of local search and discovery activities is enhanced. According to M. Johnson, the Physical Web and Eddystone-URL also provide some other benefits and capabilities:

- **Easy to integrate:** URLs are ubiquitous and easy to manage.
- **URLs are easy to measure and optimize:** Leverage existing web analytics and optimization tools to measure performance.
- **Physical Web helps increase app downloads:** Create localized landing pages that promote your native app's capabilities and value.
- **It is Global:** URLs can be used anywhere.

When buying beacons, it is important to look at the hardware included as it will vary from brand to brand. This will impact the way they work, their stability and their longevity. Specifically, the type of battery (ion or AA battery), the types of sensors (NFC or RFID), and the casing of the hardware is in so that it can withstand the elements depending on its location. In 2018, there are plenty of beacons that meet the requirements of most projects with some of the more popular and reliable brands being Estimote, RadBeacon, Kontakt.io, and Bluvision (also known as Beeks). Through Google's IoT Research Award Tech Pilot, our team was granted Beeks beacons, which is what were used for this experiment.

2.3 System Design

According to G. Piccoli, information systems are formal, sociotechnical, organizational systems designed to collect, process, store, and distribute information. Information systems (IS), not to be confused with information technology (IT), has four fundamental components separated into two subsystems: technical and social. The technical subsystem, composed of technology and processes, is the portion of the information system that does not include human elements. The social subsystem, represents the human element of the IS.

IT. IT is defined as hardware, software, and telecommunication equipment. In the case of this experiment, the hardware is the Eddystone beacons, which are described above, and the web application created for this project. The web application has three main functional areas: the rescue team side, the admin team side, and the rescuee side. The rescue team portion is used for the process of saving the rescuees. When looking at the page from the top-down, you have the floor number, a map of the building layout, red pins to show activated beacons, a blue pin to show your current location, tabs to switch between floors and a button to return the home screen. The second portion holds the admin pages, which are used to add new beacons and view a database and map of all of the beacons. When adding new beacons, you are required to give each beacon a unique ID, alias, and location. The ID and alias are very similar but were differentiated for ease of use during coding, while the location is necessary for being able to determine the rescuees' location. The admin team's page to view the beacons is very similar to the rescue team's page. However, it also includes a table with all of the beacons in the database and it displays beacons that are both active and inactive as opposed to only the active ones on the rescue team site. Lastly, the rescuee portion allows for the users to check into beacon. This activates the beacon in our database and signifies to the rescue team that someone in that area needs to be rescued. The code for these three areas is attached in the appendix at the end of this report.

Process. Process is defined as the series of steps necessary to complete a business activity. For the search and rescue experiment, there are two main parts to the process: how the rescuees make themselves known and how the rescuers find the people in need with or without the application. In order for the rescuees to make themselves known in the event of an earthquake, they must follow a series of steps:

1) Before a natural disaster, each person in the target area must have a smart device with the app PhyWeb installed. PhyWeb is used to view the beacons on their phone through the physical web.

2) In the event of a disaster, the user will open PhyWeb and select each beacon that is visible on the application, which will open a page unique to each beacon. This allows for a user to check into multiple beacons that will create a more precise, potential rescue location.

3) Once rescued, the rescuees will then check out of each beacon that they checked into originally. This deactivates the beacon so the rescue team knows that there are not any other people in need in that area.

In order for the rescuers to find the people in need with or without the application, they must follow a separate series of steps. The team without the application will conduct a search and rescue operation in the typical manner. The team with the application will use a smart device, in our case an iPad, to monitor beacon activity. Once they notice an active beacon, rescuers will be dispatched to save the people in need.

People. The people component refers to the individuals or groups directly involved in the information system. For this experiment, people will fall into one of three aforementioned groups: rescuees, rescuers, and the admin team. Rescuees are the users in need of being saved from the disaster, rescuers are the ones saving people in need, and the admin team administratively monitors the web application to ensure that there are no technological or human errors during use.

Structure. Structure refers to the organizational design, reporting, and relationships within the information system. The structure component is important because user resistance and relationships are critical to IS success that go undetected before, and sometimes even after, IS failure becomes apparent. The main concerns that would arise during a search and rescue operation when pertaining to structure is the pressure rescuers feel from the family of the people that are below rubble that requires heavy equipment to rescue as opposed to that of the family of those above the rubble. In order to appease both families and manage their pressure, increased information visibility is necessary. This could be accomplished through the addition of the who aspect of the aforementioned 5W+H model. By including the knowledge of who is checking into each beacon, families should be more at ease when awaiting the news of their trapped loved ones. By managing these pressures, the rescue operations should be more efficient and effective and families will be less pervasive throughout the process.

3 Implementation

During implementation, instead of having one main issue regarding the rescue operations, there are a class of problems. This process would greatly benefit from improved information and the ability to locate survivors in the rubble. Having the ability to implement these qualities into an application would be the first steps in creating a proper solution to the class of problems. As a result, our lab developed the idea of using Eddystone beacons to expedite the duration of search and rescue operations during catastrophic events such as earthquakes. Through the power of the Physical Web, the ability to utilize BLE beacons to locate survivors was possible. By attaching a unique URL to each beacon, rescuees can check into beacons within their proximity, which updates our database to reflect that there is a person in need in a certain area. With this technology, it not only opens up a practical use for the innovative Eddystone Beacons but it also allows for an improved search and rescue operation that can be utilized worldwide. Natural disasters are a common occurrence in our world and executing a method that could potentially save lives is a process worth developing and considering. With the variety of beacons in the market currently, there are plenty of options depending on the climate of the location and structure of the building. The beacons should be placed inside of the building but if they cannot be installed there, more rugged beacons can be purchased to be used outside. It is also recommended to purchase beacons with a minimum battery life of at least one year to ensure that the beacons do not need to be replaced too frequently.

4 Validation

4.1 Overview of Experimental Setup

As with most experiments, the key to gathering accurate results depends on how similar the tests can replicate a real scenario. It is not possible to have completely realistic situations as feasibility issues will always prevent this outcoming from occurring. In regards to this experiment, garnering precise data would probably require the use of a simulated earthquake and a testing site with structural damages that could be attributed to the earthquake. Due to that, the experiment was designed with as much practical realism as possible. The specifics of the experimental setup are detailed in the next sections with the attention focused on the design of the experiment and why an experiment was better than analyzing mathematical models.

The experiments were conducted throughout the LSU campus Business Education Complex (BEC). Given the unique pattern of the BEC, the experiment design was utilized so that the survivors were not visible but had to be detected before decisions could be made by the rescue team. To simulate the earthquake scenario, search teams were provided with an exact plan of the BEC and beacon layout. Three survivors were requested to authenticate with the beacons in their proximity which commenced the search and rescue effort. The web application shows, in real-time, which beacons the survivors have authenticated. Search crews only used the beacon's map, the information about survivors' proximity to the beacons and their smartphone to locate the survivors. The results of this experiment were then compared to the other search crew's performance. This group will have to search without using their phone and the beacons, only using traditional search methods to locate survivors. It is believed that the resulting times of the group with access to their smartphones and beacons will be much faster than the group without those materials. The experiment will be conducted multiple times using many variations and iterations to test different situations which are expected to make the experiment a more lifelike re-creation. The variations used during this test trial were sound cues, dispersion of rescuees, visual clues and additional clues to aid the rescuers without the app.

Due to the variability of the experiments and technology, a mathematical model was not utilized when determining the effectiveness of the application. While simulating the experiment can offer several advantages, a good mathematical model can also "provide a common framework for understanding what might otherwise appear to be diverse and unrelated behavioral phenomena" (Mazur). In order to have an accurate model, the constants, or the inherent properties of the materials and equipment used in a given experiment, must be chosen carefully. For this experiment, determining a model to estimate rescue speed would have multiple parameters. Some of these parameters would be size of location, number of people trapped, amount of damage to structure, or number of rescuers searching. Using these variables, you should be able to simulate a search and rescue operation after a disaster. However, mathematical models do have limitations. One limitation of using a mathematical model is that you must assume there are no anomalies in the procedure. For instance, the application and Eddystone beacons can be complicated for first-time users but the model would assume that there are no deficiencies in the user's technological aptitude when conducting the experiment. This is why a true experiment and pilot test were conducted, as opposed to running a mathematical model.

5 Results

The results of the experiments were as expected; however, there were a few flaws that can be remediated for future experiments, as needed. Specifically, the variables in the SQL database can only be accessed one at a time and may cause issues if too many people try to check in at once. When this happens, the beacons do not get checked out properly and are left activated. In this event, the time that it took the rescuer to find all three of the rescuees were recorded with a time cap at eight minutes. However, the first test had a time cap of ten minutes to get the rescue teams accustomed to the experiment process. The number of rescuees found were also recorded if the rescuer did not find all three rescuees before the time expired. As indicated in the results, the rescuers with the app were much quicker and more efficient than the rescuers without the app.

Table 1. Rescue Team with Application

Trial *	Time Elapsed	# of People Found
1	4:42	3 of 3
2	2:34	3 of 3
3	1:50	3 of 3
4	2:40	3 of 3
5	3:13	3 of 3

Table 2. Rescue Team without Application

Trial *	Time Elapsed	# of People Found
1	10:00	2 of 3
2	5:36	3 of 3
3	8:00	0 of 3
4	8:00	2 of 3
5	4:42	3 of 3

**(Table 1 and 2).* Trial 1 was a baseline run of the experiment. Trial 2 involved giving the team, without the app, information on the last known whereabouts of the rescuees. Trial 3 involved clustering the rescuees in a single area. Trial 4 had the rescuees visible in plain sight. Trial 5 incorporated an audio file that played a loop “yelling help”. It was used to aid both parties by being able to hear the rescuees in need of assistance.

6 Discussion

After clearing up the errors and bugs listed above and running the experiment an additional time, the technology should be cleared to be run through more in-depth testing. From a technological perspective, further experiments should expose any other hidden bugs and mistakes. For instance, the use of variables when people check in could be enhanced. However, this could be resolved when adding in a unique ID for each person that checks in to the beacon though. Regardless, it is expected that the results will be similar to the two prior experiments. Along with this, there could be variations in the location of experiment and the severity of the environment to simulate a more realistic environment. Given the expansiveness of testing still required to become a fully-equipped, relevant technological innovation, more thorough examinations and extensive evaluations should be planned for the future. However, the results of any future tests should not differ drastically from the current results as the app is much more efficient than traditional searching methods.

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Appendix

File Repository: https://github.com/gconno3/postnode

Main files:
- Index.js
- About.html

Rescue Team files:
- Index.ejs
- Index2.ejs
- Index3.ejs

Admin Team files:
- indexAdmin.ejs
- adminfloor1.ejs
- adminfloor2.ejs
- adminfloor3.ejs
- setup.html

Rescuee files:

- beaconcheck.html
- beaconsaved.html
- thankyou.html