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ADDRESSING FLOODING PROBLEMS IN MANILA THROUGH SYSTEMIZED REMOTE MONITORING AND MANIPULATION OF FLOOD PUMPING STATIONS, AND MAPPING SOLUTIONS

Jesse A. Mangulabnan[1], Ann Katherine B. Lee[2], Ma. Amelia S. Orcena[3], and Ma.Victoria G. Pineda[4]
[1234]De La Salle University-Manila

Abstract: Metro Manila is prone to incidents of flooding. As an immediate solution, water pumping stations were built to monitor and to ease the flow of flood waters around the city. But with the insufficient funding and outdated equipments, performance of these pumping stations has been greatly affected resulting to poor monitoring and mitigation of flood water. Based from the interviews conducted by the team, some pertinent problems identified were the clogging of waterways due to increasing amount of garbage, the uncoordinated urban planning, and the lack of early warning related to flooding situations. In order to address these problems, HERMES: Flood Monitoring and Early Warning System is developed with the objective of providing early warning, flood alerts, detecting clogged waterways, and keeping track of the water pumping station performance.

Rapid prototyping methodology was used in developing the system following four phases: requirements planning, user design, construction, and cutover. HERMES is a web-based early warning system that follows the machine to machine concept. It allows the reading of data and activation of machines without human intervention. Users of the system can receive updates and communicate with the system through the SMS feature of the system. Users of the system were given the chance to test the system and key results shown that the idea of the system following the machine to machine concept is feasible following that the waterways and drainage around Metro Manila, as well as the water pumping station be improved and cleaned together with the cooperation from the citizens. With the initial and key results the study has found, it is important to note that people nowadays are more informed and proactive in times of disasters. But no matter how sophisticated the technology being used, to be responsible, disciplined and cooperative is still the best way to prepare and act during disasters.

Key Words: Early Warning, Mapping, Pumping Station, Flooding, Machine to Machine

1. INTRODUCTION

All over the world there are different natural disasters that are occurring every day. It was noted that from 1994 to 2003, almost 2.5 billion people were affected by natural disasters alone worldwide which increased for about 60% over the past decade. In a statistics provided by United Nations International Strategy for Disaster Reduction (UN/ISDR) from 1975-2005 there are at least 10 most common natural disasters that occur all over the world. These are

Flood, Windstorm, Epidemic, Earthquake, Drought, Landslide, Extreme Temperature, Wildfire, Volcano Eruption and Insect Infestation. But amongst the ten disasters, flooding is the most common all over the world wherein it got an average of 30.7 % (Shirey, 2011) and has calculated that of the 5,210 disasters recorded in the world between 1991 and 2005, 2,029 (approximately 40 percent) have occurred in the Asia-Pacific region.

The Philippines is vulnerable to almost all types of natural hazards since it is located within the Circum-Pacific belt of fires and along typhoon path. It is exposed to natural threats like earthquakes, volcanic eruptions, typhoons and their resultant effects such as tsunami, landslides, floods, and flash floods. In average, the Philippines would at least experience 20 typhoons every year, destroying livelihood, agricultural harvests and taking lives. Here in Metro Manila, flooding has been a common natural occurrence, due to the rapid urbanization of the city. Different government offices and agencies have proposed solutions as to how to minimize the damaging effects of flooding. Flood mitigating facilities such as pumping stations were built to control the flood waters, but due to the limited resources and lack of proper cooperation from citizens and enormous amount of garbage clogging the important flood waterways these efforts are more often wasted.

In line with this underlying problem, a project in partnership with the Metro Manila Development Authority (MMDA) was developed. This project is aimed to help in preventing the damaging effects of flooding in Metro Manila. Using information technology, the HERMES Flood Monitoring and Early Warning System is developed. This system follows the machine to machine concept where in the equipment will communicate with one another requiring minimal or no human intervention. The system reads data from remotely deployed sensors and processes them by sending warnings to residents through SMS or activating pumping stations all with minimal or no human intervention. HERMES provides users with graphical reports on the different flooding situations around the city and monitors the status and performance of the MMDA pumping stations.

These reports utilize Google Maps, wherein areas vulnerable are plotted as well as the status of flood levels around Metro Manila. Warning alerts are also disseminated to concerned citizens through the push-and-pull SMS technology. The system is designed to be used with minimum human intervention particularly in operating the pumping stations. HERMES focuses on the Libertad Pumping Station and the areas it covers, but can handle all the pumping stations of the MMDA all over Metro Manila.

2. METHODOLOGY

Development of the system followed the Rapid application development methodology or RAD. This software development methodology uses minimal pre-planning allowing the software to be rapidly developed and easier to be changed based on user’s feedback. The objective of Rapid Prototyping is to adapt the prototype to customer requirements as quickly and flexibly as possible (Borysowich, 2007).

During the system development, the existing processes of the MMDA Flood control and Sewerage Management Office was studied. Based on the information the team has gathered, it was found that there was no proper and effective way of distributing critical information to the public regarding the purpose and that status of the pumping stations during a flood event. With this, the system focused on the four essential processes of an early warning system which is Risk Knowledge, Monitoring and Predicting, Communication and Response.

Based on these four major processes, the system has five major modules namely Flood Level Condition Assessment, Identification of blocked waterways, Monitoring and Remote Manipulation of Flood Mitigation Facilities, Simulation of Flood Risk and Flood Analysis. Each module plays an important role on the overall functionality of the system. But amongst the five modules, the simulation of Flood risk module is the most important.

Under the simulation of flood risk module are the three major maps generated by the system. This module shows the flood risk calculations on the significant effects flood waters would do to people and the vulnerability of people and areas affected by the flood. Maps generated by the system based on these calculations are the following: Hazard Map, People Vulnerability Map and Area Vulnerability Map. Below is the discussion on the different formulas used for the said module.

For the system's Hazard mapping this equation was used to show the significant hazard or risk the floodwaters would be on people. This formula was derived from the DEFRA/Environment Agency based on their study about the Flood Risk to people.

$$HR = d \times (v + 0.5) + DF \qquad \textbf{(Eq. 1)}$$

where:

HR = (flood) hazard rating
d = depth of flooding (m)
v = velocity of floodwaters (m/sec)
DF = debris factor (= 0, 0.5, 1 depending on probability that debris will lead to a significantly greater hazard)

To get the velocity of flood waters in urban areas, this formula is used

$$V = Q/A \qquad \textbf{(Eq.2)}$$

where:

V= velocity (m/sec)
Q= flow rate (mm/hr)
A= flow area (sqm)

To get the flow rate, the authors have consulted with a mining and meteorological engineer, Engr. Jomar Saret on how to calculate the flow rate of waters

$$\textit{Flow rate} = \textit{rainfall rate} \times \textit{Area of brgy } (100-40)\% \qquad \textbf{(Eq.3)}$$

People vulnerability mapping focuses on showing the rate of people who are most vulnerable during a disaster. The following formula is used to calculate the number of people vulnerable in an area

$$PV\% = [(pwd + elderly + infants + pregnant)] / population * 100 \quad \text{(Eq. 4)}$$

where:

PV% = rating of people vulnerability expressed as percentage
pwd = number of people with disability
elderly = number of elderly people
infants = number of infants (0-12months)
pregnant = number of pregnant women
population = total population in the area

Area Vulnerability map shows the areas that are most likely vulnerable to risks. To calculate area vulnerability, 3 variables are considered; Nature of the area, speed of the flood and the warning scope. The formula used to get the area vulnerability is as follows

$$AV = speed + nature + (3 - ((P1 / TP1) * ((P2 / TP2) + (P3 / TP3)))) \quad \text{(Eq. 5)}$$

where:

speed = speed of onset score
nature = nature of area score
P1 = actual number of subscribers
TP1 = total population
P2 = % of warnings issued with the set time
TP2 = ideal % of warnings issued within the set time
P3 = actual people response
TP3 = ideal people response

The speed of onset score is a fixed value of 1, 2 or 3 depending on how fast the flood reaches its peak

Table 1. Speed of Onset Score

Time	Score
More than an Hour	1
An Hour	2
Less than an Hour	3

3. RESULTS AND DISCUSSION

The HERMES flood monitoring and early warning system was developed because of the need or opportunity the team saw on the way we get critical information during a disaster.

This IT solution is seen to help the way the MMDA handles their operation of the pumping station during a flooding event.

The main users of the system are the Local Government Unit (LGU), Flood Control Personnel, and the Pumping Station and Flood Gate Operations Department of the MMDA.

The system is divided into five major modules as discussed in the previous chapter. The first module which is the Flood level condition assessment is the module wherein the monitoring of flood level is crucial. Monitoring of the flood water level is done through the use of water level sensors placed around flood prone areas. Data coming from the water level sensors are transmitted to the system and is used to generate the sensor or flood level map. In this module, flood level categories set by the team are used, each stage are represented by a colored icon that can be seen in the map. Ankle level stage of flood waters is represented by the yellow color, Knee deep flood is orange, waist level is red and neck deep waters is represented with a black icon.

The second module of the system is the Identification of blocked waterways wherein it provides information of what particular areas are still flooded while surrounding areas are not. It helps the MMDA to identify blocked waterways usually caused by garbage clogging the waterways. This is determined with the use of the water level sensors. Data coming from the sensors are processed by the system and information is shown through the system's sensor maps. The line marker in the map turns red if the sensors detected that the water levels in a certain area are unequal.

An important feature of the system is the use of telemetry wherein the system can remotely manipulate the MMDA pumping stations and its mitigation facilities such as pumps and floodgates. This falls under the third module of the system which is the Monitoring and Remote Manipulation of Flood Mitigation Facilities. In this module, mitigation facilities are being manipulated based on the date received by the system from the water level sensors placed in the catchment basin area, outside the flood gates, on each working pumps, and on the engine of the flood gates. Using telemetry, the water level sensors transmit data to the system prompting the system to immediately open or close the pumps or the flood gates. The opening of the pumps and flood gates are determined based on the water level in the catchment basin. When the water rises to a certain level, pumps and flood gates are being opened based on how high the water is. At the same time, the system sends SMS warning to its subscribers informing them what level the water has already reached.

The system also aims to provide its users and the public of knowledge and awareness about the flooding situations. With this objective, the system's homepage provides dashboards available to its users and the public. This allow the citizens to easier understand and comprehend information with the use of graphical representation of data about the status of rain gauges, overview of the pumping station status, and the flood water level status.

Also, Hermes being an early warning system makes use of SMS to give out information to the public. People can subscribe to the system. Subscribers can receive reports and warning messages through SMS and be updated of the current status of the pumping station and the water level.

Reports are also used to summarize all the data the system has generated. These reports show the behavior and the different status of the pumping stations and water level sensors. Reports generated are mainly for the use of the MMDA.

4. CONCLUSIONS

The Philippines being an archipelago and located in the south pacific is vulnerable to almost all types of natural hazards. Therefore, there are lots of efforts from different organizations, government agencies and other concerned citizens to solve the problem of flooding. Metro Manila is one of the most flood prone areas because of the rapid urbanization in the city. As a solution pumping stations were built in order to minimize the devastating and destructing effects of flooding in the city. The project is part of an overall flood control and drainage scheme for Metro Manila and its suburbs.

HERMES flood monitoring and early warning system was developed focusing on the Libertad Pumping Station and the areas it covers. HERMES s objective is to develop a sustainable tool or a system that would minimize the destructing effect of flooding in Metro Manila. HERMES was made in order to monitor the performance of pumping stations, city flooding situation, and issuance of early warning with minimal human intervention as much as possible.

This study is still an ongoing process. With all the data the team has gathered throughout the study, the rapid development of technology nowadays has done a lot of good for everyone but on the onset of a disaster there is no perfect technological solution to prevent the damaging effects of a disaster such as flooding. During a disaster there would be risks and we have learned that a risk is a situation wherein it would mean exposing or involving oneself to danger. It is that uncertainty of not knowing what to expect. It is the instance wherein the outcome is not what we expect and the chance of losing something because of external or internal hazards. Aside from risks during a disaster, there is the vulnerability during these situations. Vulnerability is that concept that links something or someone to their environment; something that is susceptible or more than exposed to a hazard or disaster or who is mostly at loss during a situation.

With this concepts defined, we say that an early warning system is not just about relying the alert or message on time before disaster happens. There can never be an exact time on how early, early warning is. Early warning as we know is that advance notice we receive before an event but no matter how early a warning is, it is still up to those who have received the warning whether they would act on it or ignore the said warning

In order for all of this technological solutions or efforts to be effective during a disaster, proper and active cooperation from citizens is very much needed. Because no matter how sophisticated the technological solution may be, each individual from each community should be disciplined and know their duties and responsibilities. Discipline and cooperation is and would always be the most important key and solution to the problem

The system can eventually be expanded to handle evacuation and other kinds of emergencies such as fire using the machine to machine concept. It can also utilize RF ID to further aid in operations.

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