DESIGNING A VISUAL MAPPING SOLUTION FOR REAL-TIME REPORTING AND MONITORING OF DENGUE INCIDENTS IN METRO MANILA

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Abstract: The Dengue Fever is a worldwide-known disease caused by the dengue virus which is transmitted by a female *Aedes* mosquito. The disease caused outbreaks in different parts of the world but mainly in tropical and subtropical climates. This disease spread as the carriers multiply. Mosquitoes breed in places like stagnant water and old tires which is common in urban areas. The 1981 Cuba Outbreak is world's biggest known epidemic in which 116,000 has been hospitalized because of dengue. 10,000 people are hospitalized per day in that outbreak; this is how fast the disease can spread. Currently, there is no anti-viral medicine for the disease but it can be cured with the help of anti-pyretic. There is a severe case of dengue fever called dengue hemorrhagic fever (DHF). In this case, more supportive treatments are required like fluid replacement in order to prevent shock in patients which can lead to death. Dengue is also prevalent here in the Philippines because it is also has a tropical climate. In the year 2010, 173,032 dengue cases have been reported.

Since government officials and hospitals can only do so much, participation from major stakeholders is needed. Aedes Watch is an online system designed and carefully planned to raise awareness and provides education about dengue to the public. The project test bed had focused on two hospitals in Quezon City. The main feature of the system is the Dengue Map which provides a map of an area filled with markers in which a dengue case has been reported. The system collaborates with the hospitals to provide an accurate data. Every time there is a patient with dengue admitted to a hospital, the medical technicians of the participating hospital will input data into the system; most importantly the dengue virus type, the assumed place where the infected bite occurred, and the assumed bitten date. After inputting these data, a marker will automatically be plotted into the map based from the given information. Aside from that, the system provides reports and chart to help in decision making, facts and tips about dengue to educate the people, and a forecasting module which makes use of the SARIMA model. The system also provides real-time updates through twitter and also automated text messaging to the doctors and government officials once an area reached an alarming number of dengue cases. The system provides a tool that provides real-time updates about dengue. With proper control and monitoring, dengue outbreaks can be prevented with the help of this tool. The system proves that mapping is an excellent analytical tool. The map provides a visualization of data that can easily in interpreted by decision makers to help them in analyzing the dengue situation. The system helps in handling dengue better here in our country. With the tracking of dengue incidents, incoming possible outbreaks can now be detected and mitigated. Since the data in the system are real-time and accurate, major stakeholders can monitor the dengue situation and react quickly and execute their dengue drives. It also raises the awareness of the public about their surroundings. With that, hopefully the public will collaborate as well to fight dengue here in our country.

Keywords: visual mapping, dengue monitoring, Aedes Watch, dengue outbreaks, early warning system, emergency response

1. INTRODUCTION

The Dengue fever is a disease transmitted by a female Aedes mosquito. The disease caused outbreaks in different parts of the world but mainly in tropical and subtropical climates. This disease spread as the carriers multiply. The Mosquito carriers breed in places like stagnant water and old tires which is common in urban areas. Falling into the said categories, the Philippines is one of the countries that experiences dengue outbreaks that results to an alarming number of dengue incidents. The number of Dengue victims is also quite high because of the high population density in Manila. Currently, there is no real-time data provided when it comes to dengue cases. There is the Philippine Integrated Disease Surveillance and Response (PIDSR) but it only releases the data of the dengue cases annually. There is also no forecasting tool available for the dengue cases. This is important because in a disease as severe as dengue, prevention is very important.

Aedes Watch is an online dengue mapping and monitoring systems that allows its users to see a visual representation of dengue cases through an interactive "Dengue Map". Everytime a dengue case is added into the system, it automatically plots a marker into the area that a dengue case is reported. The plotted marker can be clicked to reveal detailed information about the reported case. The map also provides clustering and color coding of reported cases in order provide a better representation for analysis of the current situation. Aside from the Dengue Map, the system also provides reports and graphs about the dengue cases as well as a forecasting tool that uses the SARIMA model. The SARIMA model makes use of the past reported dengue cases in order to provide a predicted number of dengue cases that can happen. The system aims to help major stakeholders in their decision making with the real-time information and enhanced presentation of data provided by the Dengue Map. The map and dengue data can also be viewed by the public for transparency so that they will be aware about the dengue situation. Since the dengue data is now real-time and viewable through the Dengue Map, outbreaks can now be avoided or mitigated with the help of local government or the Department of Health. All of this adds up to the one big goal of lessening the cases and casualties of the dengue virus. The system is used in Quezon city and Marikina city for now since they have the most reported dengue cases but it is planned to be deployed in entire Philippines in the future.

2. METHODOLOGY

2.1. Rapid Application Development

The methodology that the team used for the development this project is Rapid Application Development Process or RAD. This is a team based technique that speeds up the information systems development. The goal of RAD is to produce a functioning information system by the end of the project. The team chose this methodology over the other methods because it is less costly and has a shorter the development time. This is favorable to both the users and to the analysts that is using it. Since this project will not be used for money purposes, it is working on a small budget and RAD is the ideal development process for their system. And because RAD is more on prototyping, the users can examine the working model as early as possible allowing them to give suggestions early on, and until the system is completed and they are satisfied.

2.1.1. Requirements Planning

Requirements' planning is the first phase in the RAD model. This involves gathering of data, understanding the business needs, and agreeing on project scope, constraints, and system requirements.

This first thing the team did was to agree on the topic. Currently, the team had a major concern in the dengue issue. In the Philippines dengue is very prevalent; everyone can be a victim of this disease. Thus, the number of dengue cases in the country is very high. Therefore, the team was very eager to do a solution for this problem. Furthermore, the team discussed the opportunity and potential of the study. Once the team had fully agreed on the topic dengue and everyone knew their roles in the project, then they did a team contract. The team contract has all the details on what the team members had agreed upon. Next step that the team did was to gather data from the internet. The team collated very vital information and terms about dengue. The team researched the cause and effect of dengue, etc. Moreover, the team researched about the dengue cases all around the world. The team realized that there were similarities and trends on the cases which were studied. Furthermore, the team called the Department of Health (DoH) for valid statistics about dengue in the Philippines.

Then, next step was to find a valid test bed that will be beneficial to the project. Based on the records from the internet, the highest number of cases in the Philippines is Quezon City area. Therefore the team chose a Quezon City Hospital. The next set of activities for us was the analysis on current trend of Dengue in the world and in the Philippines. Based on the cases and the research materials, the team identified the problem and some trends that were very important to the project. The requirements planning stage ended after getting an approval from the hospital to continue the development of the system after presenting to them on what the team thinks is the problem based from the information the team gathered.

2.1.2. User Design

In this phase, the team developed models and prototypes that represent all the system processes, outputs and inputs. The team translated the user needs and the proposed solution into working models that can solve the community's problems in dengue. The team met up with the hospital to come up with a model that they would use. It was a continuous and interactive process that allowed the hospital to understand modify and chose a working model that will meet their needs. The team discussed and documented the model.

Then, the team came up with a user interface with all the inputs and features that will be necessary in the project.

2.1.3. Construction Design

The construction design phase focused on the development and completion of the programs and application. In this stage, the users from hospital participated actively so they could continuously give their suggestions on what needs to be improved or changed while the different reports and screens are being developed. With the help of users, the team came up of the user interface of the system and different reports that meet the needs of their daily reporting and data gathering operations.

2.1.4. Cutover

In this phase the team conducted a user acceptance test to know if the system developed is ready to be tested with the actual process of the hospital and community. After knowing that the feedback was positive, the team started planning on the system and data conversions. The team plans to conduct a Pilot Operation cutover for the system of the hospital as it is the most viable system conversion method. For data conversion plan, the team analyzed which data is necessary to be imported and which can be considered as garbage data. After a few rounds of critical analysis of the data of the system, the team proceeded with data conversion with the use of My SQL's built in functionalities to import. The user testing phase also took place in the cutover place.

2.2. Development Tools & Technologies to be Used

2.2.1. Programming Language

The developers decided to use PHP in the system because of the advantages of the programming languages. PHP has many advantages over other platforms when it comes to creating Web applications. Thus, the most significant advantage is it's free. Next, there are many support groups, forums, and teams supporting PHP. Therefore, the number of information about PHP is very high. Furthermore, it is very dynamic. Therefore, the developer can integrate other software to the system like Crystal Reports, JavaScript, MySQL, etc. Also, if the system will add new functions to the system, the developers can easily integrate it to the system because the system uses MVC method. Model View Controller is a software architecture that separates the system into three parts which can independently be manipulated. Another good thing about PHP is loading time of the website. It provides better performance by taking advantage of fast compilation, native optimization, and caching services. In addition, PHP makes for easy deployment. There is no need to register components because the configuration information is built-in.

The system also used JavaScript in implementing the alert functions. The team used alert functions in all the adding methods. In addition, the developers also used JavaScript confirmation functions which confirms all the inputted data in add functions of the system. In addition, another good side of JavaScript is it is very easy to integrate to the PHP program.

Next, the system requires storing of data. Therefore, the team used Microsoft SQL in the database. The one main benefits of using SQL Server is the use of stored procedures. Stored procedures are lines of code that are called by the application. Stored procedures are placed on the server, and they are pre-compiled for quicker response times. The use of stored procedures also centralizes codes, therefore troubleshooting garbage database requests can be observed by a database administrator. Next, the term scalability is used to describe the ability to grow when the business becomes bigger. Therefore, making the system bigger is possible for future implementations. This is possible because using SQL can easily handle new data integrations, for example adding new tables and relationships to the older database. In the system, it is inevitable that data grows bigger and bigger every time. Thus, SQL Server can handle millions of records and transactions. This is why SQL is an advantage for them. After that, security is a major issue for any site. SQL Server allows the administrator to grant access or deny access for users. The SQL Server has a specific section of the application where users are added to the permissions. SQL Server allows administrators to specify which tables and stored procedures users are able to access and query. This limits what records and user information can be queried, which protects the business's customer information. Next, SQL Server has an automatic backup option. The SQL Server automatically saves a copy of the database and the transaction logs on another hard drive or media like a CD-ROM or a DVD. Small applications like Access do not have this option, and backups are an integral part of disaster recovery. SQL Server also has procedures that allow the administrator to quickly restore a database when data is lost or corrupted, or the server has a hard drive crash.

2.2.2. Google Map

Google Map was the mapping tool which was used for the system. Its only software requirement is that the user uses the latest version of their respective browsers. The team also chose this mapping tool because it is an open source map which would allow room for customization. It is also an accurate map, which would lead to more accurate plotting of data for Aedes Watch. Google Maps also has multiple API's which would provide a lot of reading material on learning how to go about with it. Google Maps is also used so that future developers can understand because it can easily be used and its codes are not that sophisticated aside from having the multiple APIs already available. The Aedes Watch system does not require a purchase of Google Map's upgraded version since it would not be used for business. The upgraded (or paid) version of Google Maps provides enhanced features that are made for businesses. The team finds that the features that it offers is way too much compared to what the system really needs, a simple but accurate mapping tool (Google Maps API Licensing, 2012).

2.2.3. Ozeki Message Server

Ozeki Message Server allows software developers integrate an SMS gateway application that allows sending or receiving SMS messages to mobile devices through a computer. (ozeki.hu, n.d.) The team used a trial version of Ozeki's services for the prototype of the system.

2.3. SARIMA Model

Seasonal Autoregressive Integrated Moving Average (SARIMA) is a statistics model which can be used to create forecasts. It is derived from the Autoregressive Integrated Moving Average (ARMA) model. The forecasts that SARIMA makes are based on a time series of seasonal events (www.duke.edu, n.d). The SARIMA model allows handling cases which have random variations of a seasonal component from one cycle to another (Craigmile, 2011). SARIMA model has been used to forecast dengue cases in Sao Paolo, Brazil (Martinez et. al, 2011), Gaudelope, France (Gharbi et. al, 2011), Queensland, Australia (Hu et. al, 2009), and Dhaka, Bangladesh (Choudhury et. al, 2008). These four cases had shown that SARIMA model works with forecasting dengue as it is a seasonal disease. In Guadelope, France, the surveillance system has been improved based on the results of the forecast made (Gharbi et. al, 2011). However, Martinez et al (2011) point out that the forecast made by SARIMA models may not be as accurate if the period it forecasts is an endemic year where the amount of cases are significantly higher than that of a normal year.

2.3.1. Adaptation of the SARIMA Model

The SARIMA model that the team used was derived from the original model to fit the test bed of the study. The team contacted a practicing statistician since the SARIMA model falls under the higher levels of statistics which cannot be understand easily by information systems students. The model was used together with five years of data from the test bed. The seasonal factor of the model is based on the trend shown in the data on hand, the number of cases start to rise from June up to October. The equation used for forecasting is:

2.3.2. $$y_t = 0.0393 - (0.8962 * y_{t-1}) + (0.2166 * y_{t-4}) + (0.8964 * y_{t-12}) + (0.8034 * y_{t-13}) - (0.1942 * y_{t-16}) + a_t - (0.9948 * a_{t-2}) - (0.8425 * a_{t-12}) + (0.8381 * a_{t-14})$$

y_t is equal to the amount of cases for a month that will be forecasted and the subscript ‘t’ is equal to the month its self. y_{t-n} is the difference between the number of cases from n months minus the number of cases $n+1$ months prior to the month which would be forecasted. a_t is equal to the residual value of a month. As pointed out by the team’s resource person for the SARIMA model used in the system, the value of a_t is dependent on the modeling of the formula. The future values that go beyond the data used for modeling are equal to zero.

3. RESULTS AND DISCUSSION

With the alarming rate of dengue through the years, the team developed a system that maps and monitors dengue incidents along with a forecasting and an information section to educate and raise awareness of the public. There are 5 users: a super user/admin which will watch over the whole system, the head physician which is assigned per hospital, the medical technicians of the hospital, barangay officials, and the public.

First, the admin of the system will be the Department of Health (DoH). The DoH will observe the dengue situation in Quezon City and Marikina using the system; and in the future, the whole Philippines. The DoH is the perfect super user/admin for the job because they are the authority when it comes to the health of the public which gives them the resources to act about it. Second, the head physician will serve as the representative for a hospital that is participating in the Aedes Watch. He will also serve as the admin of the hospital whose role is to manage the other user accounts which are for the medical technicians. To gain access, the medical technicians will apply for a user account into the system and the head physician is that one that will approve the application. Only the Head Physician and the Medical Techs are the ones that can add dengue cases in the system. The team removed the ability of users to delete cases to preserve the integrity and accuracy of data. Third, Barangay Officials also has an account so that they can be informed and track the dengue situation of their barangay. And lastly, the public can see all of the system’s features other than the ones that are exclusive for the admin, physician, medical technicians, and barangay official.

The admin account for DoH has access to all the features of the system. It is done so that the DoH can monitor the whole dengue situation of the Philippines. The Head Physician account also has access to all the features of the system but some functions like the approval of users and the patient list is limited only to the hospital he/she is asigned to. Same thing applies to the barangay official accounts, the access is also limited to his/her designated barangay.

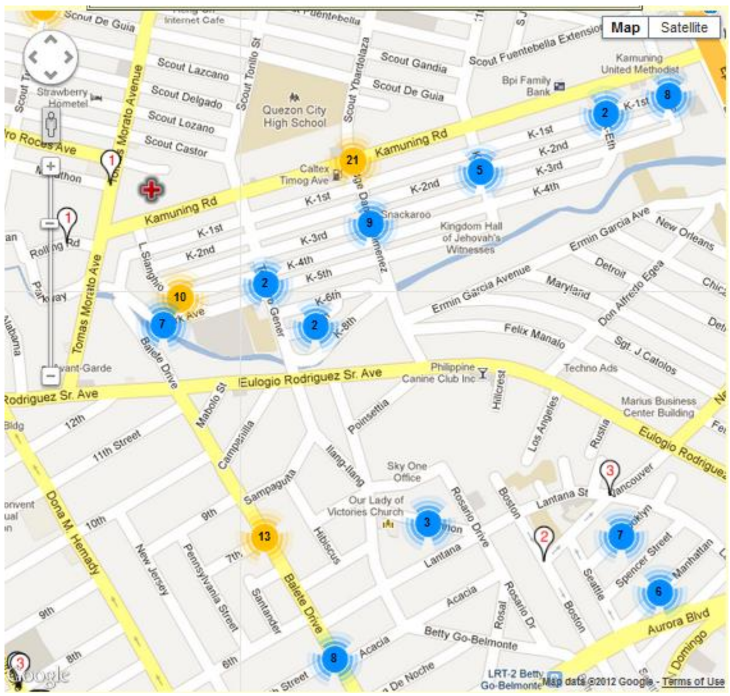

Figure 1: Sample Screenshot of the Dengue Map

With the help of the Dengue Map, reported dengue cases can now be visualized to help in decision making. Through this incoming outbreaks can now be identified and mitigated. There are also reports and charts provided to supplement the function of the Dengue Map. There is a module called "Aedes Read" which educates the public about dengue, its symptoms, and how to prevent it. Also, with the help of Ozeki Messaging, stakeholders will be alerted right away if there is an alarming number of cases have been reported. Twitter is also integrated into the system so that the public would be informed every time a dengue case has been reported. Lastly, with the help of the forecasting tool that uses the SARIMA model, it can help predict the dengue trends in the incoming year.

Table 1. Sample Dengue Forecast for 2012

	2011	2012 Prediction
January	7	15
February	0	1
March	1	11
April	0	2
May	0	13
June	2	2
July	10	17

August	42	40
September	57	64
October	29	23
November	12	18
December	4	0

4. CONCLUSION

At the end of developing the Aedes Watch Dengue Mapping and Monitoring System, the team believes that the system was able to address the various issues in that were found at the beginning of the team's study. The system was able to address the general issue that there is currently no real-time information on dengue being conveyed through any channel. The system is capable of providing real-time data, although it is only able to provide data based on the cases from the test bed hospitals. Delving deeper into the information available, it was pointed out that there was data available. However the data available did not show what dengue string was prevalent. The dengue strings in the cases inputted into Aedes Watch has a dengue string value together with it.

Also, the issue that the public lacks knowledge in detection of dengue, the system is ~~somewhat~~ able to address this in various ways. First, the Aedes Read module would allow a system user to learn the symptoms and ways to prevent dengue. Second, the system makes use of Twitter to inform even more people on the dengue cases, this would direct people to check out the website and may learn more on dengue.

The government officials, hospital physicians, and the local government unit are also updated thanks to the mobile update texting of the system. Although Ozeki, the software the team used, only allows 5 text messages containing the complete detail since it is just the trial version. It also charges the mobile phone attached to the server every time it sends out text messages. Without credits, Ozeki will not send out text messages. Despite these limitations, the system still proves that mobile update texting is still a good support function as long as it used in its full capabilities.

The Aedes Watch is a meaningful system that is able to provide a real-time aggregated version of the data available compared from the delayed consolidated data of the Department of Health (DOH). Another unique advantage of Aedes Watch is the availability of the Dengue Map. With the use of mapping technologies, the team was able to realize that mapping is an excellent analytical tool. With the map used in Aedes Watch, decision makers can gain data from it at a glance, discuss amongst each other what they can see plotted on it and at the same time interact with the map.

The team also found that there must be a religious practice of data recording. This is necessary for a lot of the parts of the system. If data is not religiously captured, then the information that would be provided in the various reports of the system would be inadequate and maybe less accurate. Furthermore, forecasting relies heavily on the data provided for each month. Insufficient data will cause the forecasting to provide a wrong forecast. By religiously recording the data, the system will be able to generate timely and accurate information that would support critical decision-making.

Aedes Watch is an excellent outbreak prevention information system very much fitted to the Filipino needs. However, the team still finds room for improvements for the system.

First, is for the mapping tool. Currently, the mapping tool used in the system is Google Maps. Sometimes it has an issue when it comes to the plotting of cases. This is because the current version of the Google Maps in the Philippines is outdated compared to other Google Map versions of other countries. There are some features that are not present in the Philippine Google Map. One is that it does not include the use of corners in their search which can provide some issues when it comes to accuracy. Another issue is that when it comes to provinces, the map is not that detailed anymore. The team thought of using a static map instead for the provinces in order to address this issue. When it comes to the map version, the team recommends upgrading the map to the business version. This is because the basic version only allows 2,500 requests per day while the business version provides 100,000 requests per day. This is a good investment especially if the system will be launched in the entire Philippines.

Second, a possible issue is that identifying the dengue string of the patient is not a standard procedure in all hospitals. Some hospitals run a different set of tests in order to figure out if the patient is positive of dengue. This is because not all hospitals can simply change to the process which includes the detection of what string the patient has contracted. Another possible reason for this, which the team recommends to look at, is if these hospitals cannot change their process to accommodate detection of dengue strings because it may require certain things such as machines to administer them. This can be addressed by making the data capturing of the dengue string optional but it is still better if the medical technicians can provide it for research purposes.

Third, since the current dengue forecast of the system is for the whole Philippines, it would be better if there is another option of forecasting which is done per city. This is a good additional function so that the forecasted numbers caters specifically to an individual city. This will result to accurate mobile update texting because the forecasted numbers that will trigger the function are coming from a specific city and not the whole number of the Philippines.

Fourth, the team thought that the inventory of blood in each hospital should also be considered into the system. Since it is one of the vital items needed especially when the patient's platelet count is low. Users will be able to see the blood inventory of each hospital and can request if they are in need. If there is not blood available, the admin or officials can deploy a blood drive to meet the demand. This can help save lives and answer the demand for blood especially if a dengue outbreak is already happening.

Fifth, the current version of Ozeki that the system is using is just a trial version. The trial version only sends out 5 texts with detail while the rest after that contains notice that the user is just using a trial version. For the text update of the system to be fully functional, a purchase of the *Ozeki Message Server 6 - Single connection edition*is advised. It cost USD 799 or something around PHP 35,000 when converted to Philippine Peso. This would allow the developers to fully integrate Ozeki into the system without any limitations.

Finally, another problem that the team was not able to address with regards to the system is if the hospital loses internet connection while recording a dengue case to the system. The mapping tool does not work when there is no internet. A case added when there is no internet is not plotted into the map but is inputted into the system's database. It would be best if the system be improved so that it would plot a case recorded during a time that the hospital is offline the moment that it goes online.

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