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Tracking and Prediction of Dengue Outbreak Using Cloud-Based Services and Artificial Neural Network

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Abstract

Dengue is considered as one of the diseases which needs serious attention, especially in the less developed areas of the world. In order to allow sufficient time in taking necessary decisions and actions to safeguard the situation for local authorities, an accurate analysis of dengue epidemic seasons is crucial in preventing and counteracting its effect. To address the issue, this paper proposes a web-based dengue tracking system (DTS) that utilizes environmental factors in predicting the future behavior of dengue cases. The study aimed to track down and analyze the dengue cases that take place in the city of Iloilo, Philippines. The researchers used Artificial Neural Network for prediction based on the amount of rainfall, relative humidity, mean temperature, and monthly recorded cases. The system can serve a valuable purpose for the health sectors as it guides them to take action on recorded cases in areas which are prone to dengue. Through this, early detection and warning of dengue case growth can be monitored and preventive measures can be implemented immediately, thereby reducing the possibility of an outbreak.

Keywords*: Decision Support System, Dengue Monitoring, Outbreak Prediction, Heat maps, Artificial Neural Network*

1. Introduction

The spread of dengue especially in urban and semi-urban areas and has become a major international public health concern in the recent years. Dengue fever (DF) is a viral vector-borne disease that is common in the tropics and subtropics and is primarily spread by the female Aedes Aegypti mosquito. In tropical and subtropical regions of eastern and South-eastern Asia, DF and dengue hemorrhagic fever (DHF) outbreaks occur frequently. Various approaches have been attempted to control the spread of the virus, which includes the reduction in the population of Aedes aegypti in the field [1]. Other methods such as Fumigation have been used to reduce mosquitoes, and the use of temephos was also utilized to reduce the larvae if not totally eradicated. To cure patients, treatment in hospitals is usually given in the form of supportive care, which includes bed rest, antipyretics, and analgesics [2].

DHF is a potentially lethal complication, with an estimated 500 000 people requiring hospitalization each year, a very large proportion of whom are children. About 2.5% of those affected die. The incidence of DF has grown dramatically around the world in recent decades, with some 2.5 billion people now at risk of the disease [3]. Mathematical models have proved to be useful tools in the understanding of dengue transmission [4–6]. So far the dynamics of the dengue transmission are still an interesting issue in epidemiological modeling.

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A weather-based dengue early warning system [7] could benefit local area surveillance and control outbreaks in several ways. First, an early warning system enhances efforts of dengue control to reduce the size of an outbreak which in turn decreases disease transmission, averts possible mortality, and lowers healthcare burden and operating costs incurred during an outbreak. Second, the use of publicly available weather variables removes the necessity for financial investment in weather-based predictive methods and further allows vector control units to focus their operations on high risk period; thus, maximizing limited vector control resources. Third, reports and study have suggested that local authorities require a maximum 3 months to curb a localized dengue outbreak [8].

In recent years, the National Environment Agency of Singapore has been using rising ambient temperature as an indicator of increase in dengue cases. Previous study has shown that elevated weekly mean temperature and cumulative rainfall influence the risks of dengue cases in Singapore at lag times up to 20 weeks with higher relative risks of dengue cases at time lag of 3–4 months [9]. Dengue was serologically confirmed in Sri Lanka in 1962, the first outbreak was reported in 1965, and dengue epidemics in Sri Lanka have occurred almost every other year since 2002 [10].At present, the causes and influencing factors of dengue epidemics are unknown in Sri Lanka. Previous studies demonstrate statistically significant associations between infectious diseases and meteorological variations such as rainfall and temperature. The effects of climate change on the endemics of infectious diseases such as cholera, malaria, and plague have been recognized [11]. Dengue is described as hyperendemic in Thailand, and remains a major public health problem and represents the foremost cause of hospitalization, mainly in children, with the highest incidence in 9-14 year olds. However, there is considerable heterogeneity in dengue incidence within the country. Fortunately, due to appropriate case management the mortality rate is low [12].

In the Philippines, dengue cases can occur and increase anytime, which is the reason for different organizations to implement various programs which will aid in the prevention of dengue cases. However, many of those organizations still encounter difficulties in monitoring the dengue cases especially in remote areas where its occurrences can be very rampant due to lack of information dissemination and support. With the aid of technology, everything can be a boundless portal as well as major concerns can be solved and managed effectively. Sufficient information and proper guidance is really important so that awareness among people can be strengthened as well as unity to promote dengue-free community.

The main goal of this research is to develop a web-based dengue tracking system (DTS) that determines the correlation of the input factors in predicting the future behavior of the dengue cases using Artificial Neural Network. The system shows area mapping to classify plot points to determine case patterns as well as to predict the future behavior of the dengue cases using the different factors. The system will serve as an IS module for the health sectors that will inform them to take action if an increase in number of victims will be recorded to that certain place which are prone to dengue. This system can also generate an area analysis which determines where the widespread of dengue commonly occurs based on number of counts on a given year. Furthermore, this study also aims to develop a graphical representation of dengue case patterns and area analysis using Google Map Application.

2. Related Works

Identifying the dengue epidemic periods early would be helpful in taking necessary actions to prevent the dengue outbreaks. Providing an accurate prediction on dengue epidemic seasons will allow sufficient time in taking necessary decisions and actions to safeguard the situation for local authorities.

In a study in [13], they fitted a Vector Error Correction Model (VECM) to describe the number of dengue patients using the climatic factors (temperature and humidity). Even though the total rainfall of Colombo district was also considered initially, it was taken out from the model due to the less correlation with the number of dengue outbreaks. After fitting the model the accuracy of the model was tested using residual tests. In this study, the authors proposed a model to predict the dengue disease outbreak using the vector correction method. The proposed model only based on the humidity and temperature and does not take rainfall measurements into account. It was also shown that the proposed model approximately provides reliable predictions based on the aforementioned factors. This analysis is only based on the Colombo district in Srilanka. The proposed numerical approach can be used to study the dengue disease outbreak in any other tropical areas. The approximate prediction provided by this model on dengue epidemic seasons could facilitate the local authorities to take the necessary steps to safeguard the situation for local communities.

The study in [14] demonstrates that weather variables could be important factors for the development of a simple, precise, and low cost functional dengue early warning. They developed the weather-based dengue forecasting model based on scientific evidence that temperature and rainfall has significant influence on vectors and dengue viruses. Dengue cases are influenced by complex interactions of ecology, environment, human, vectors, and virus factors. The forecast window of 16 weeks shown in this model offers ample time for local authorities to mitigate a potential outbreak effectively.

The work in [15] employed Fuzzy Association Rule Mining to devise a prediction method to extract relationships between clinical, meteorological, climatic, and socio-political data from Peru. These relationships are in the form of rules, in which the best set of rules is automatically chosen and forms a classifier. That classifier is then used to predict future dengue incidence as either HIGH (outbreak) or LOW (no outbreak), where these values are defined as being above and below the mean previous dengue incidence plus two standard deviations, respectively. In order to perform spatiotemporal predictions, all the variables need to fit the same spatiotemporal scale. The spatiotemporal scale used in this work was selected based on the distribution of the dengue data: the chosen temporal scale was one week and the chosen spatial distribution was one district.

To gain better understanding, the researchers in [16] examined the effects of meteorological factors on dengue incidence in three geographically distinct areas of Sri Lanka by time series analysis of weekly data. The weekly average maximum temperature and total rainfall and the total number of dengue cases from 2005 to 2011 (7 years) were used as time series data in this study. Subsequently, time series analyses were performed on the basis of ordinary least squares regression analysis followed by the vector autoregressive model (VAR).

In [17], they sought to forecast the evolution of dengue epidemics in Singapore to provide early warning of outbreaks and to facilitate public health response to moderate an impending outbreak. They developed a set of statistical models using least absolute shrinkage and selection operator (LASSO) methods to forecast the weekly incidence of dengue notifications over a three-month time horizon. Statistical models built using machine learning methods such as LASSO is found to have the potential to improve forecasting techniques for recurrent infectious disease outbreaks such as dengue.

3. Web-Based Analysis for Dengue Tracking and Prediction

3.1. System Architecture

This section explains the overall structure of the system and how the major components interact. Figure 1 shows the main architectural design of the system. The system has two main users: the Admin and the User. The Admin can add, delete and update dengue cases as well as work on the over-all analysis of outbreaks like mapping and prediction. On the other hand, the User is only limited in adding, deleting and updating cases. Both levels are capable of viewing hot spots, case plots, case rates except for the case trends and prediction which can only be used by the Admin. In this system, the Users are the hospitals or health centers; the Admin would be the Department of Health. The user submits case information online, then the system filters it and distributes to its designated area for purposes such as plotting on the map, identifying the hotspot districts, and case analysis. The Admin oversees the analysis and filtering of data throughout the system.

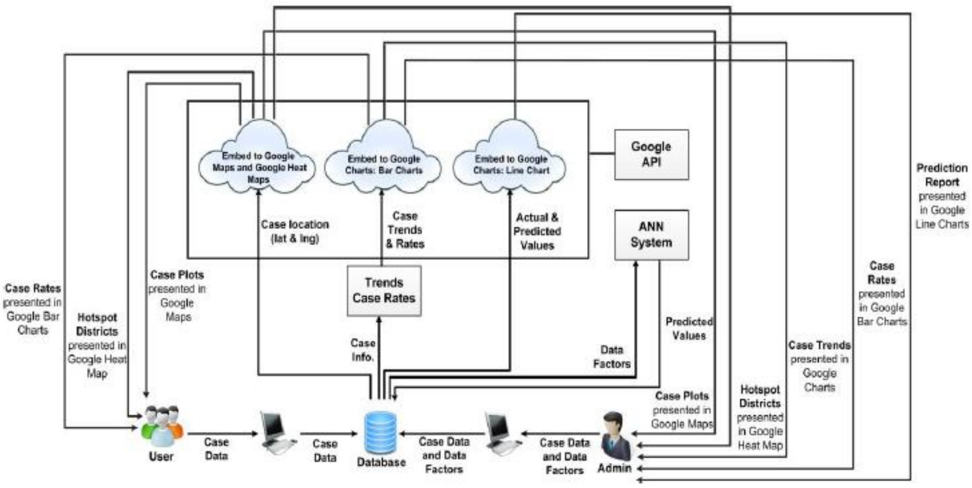

Figure 1. System Architecture of the Proposed System

The proposed system aims to track down the number of dengue victims and to predict the outbreak's future behavior so that the health organizations and sectors can take action to prevent it from getting worse. These will guide them on their campaigns and awareness so that the community prone to dengue outbreaks will be knowledgeable about it.

To realize the goals and ideas of the study, the researchers developed a web-based system which uses cloud computing. Various Google applications were utilized as a service provider and for the overall presentation of the system functions. Google Chart was for displaying the dengue case rates, trends and prediction. Google Map was utilized to plot the dengue cases. Google Heat Map was used for determining the hotspot districts on a given year. Figures 2-3 show the data flow diagrams of the system, which depicts the interaction of the components and the flow of relevant information between the users and the proposed system. The figures show how data are used and the processes they undergo to generate results.

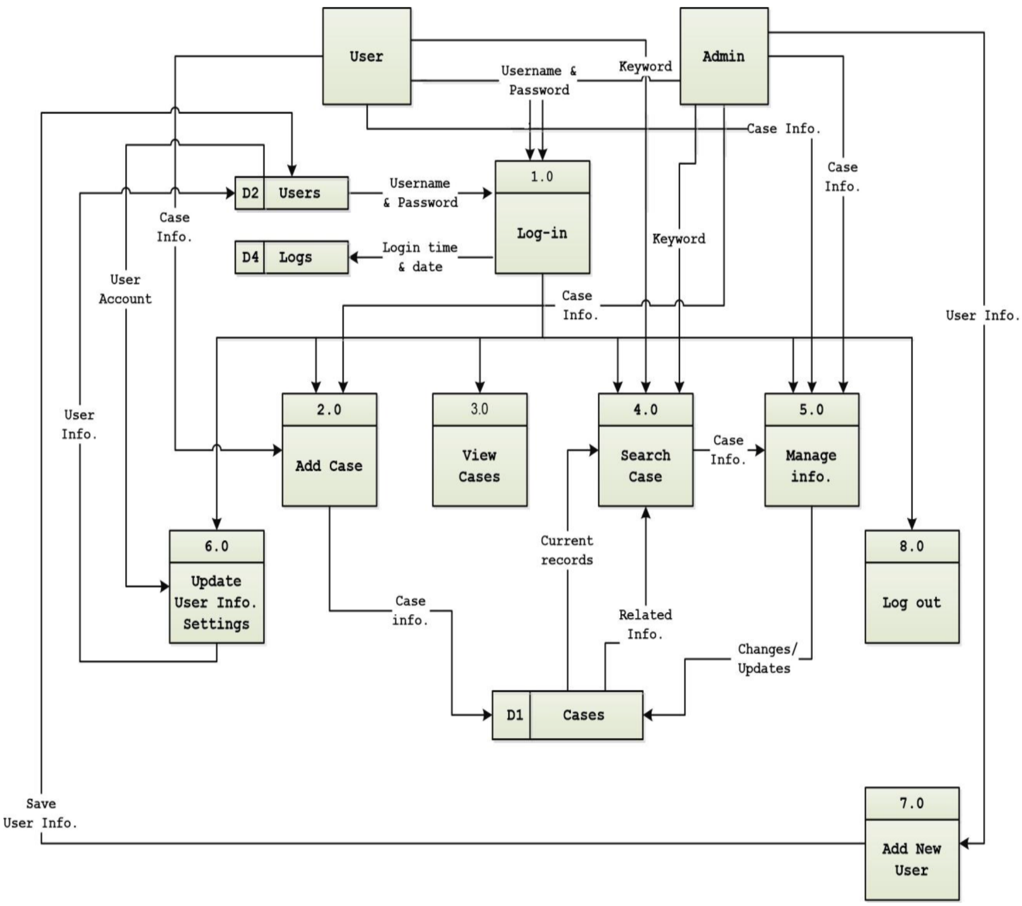

Figure 2. DFD of the Proposed System (Case Entry & User Information Management)

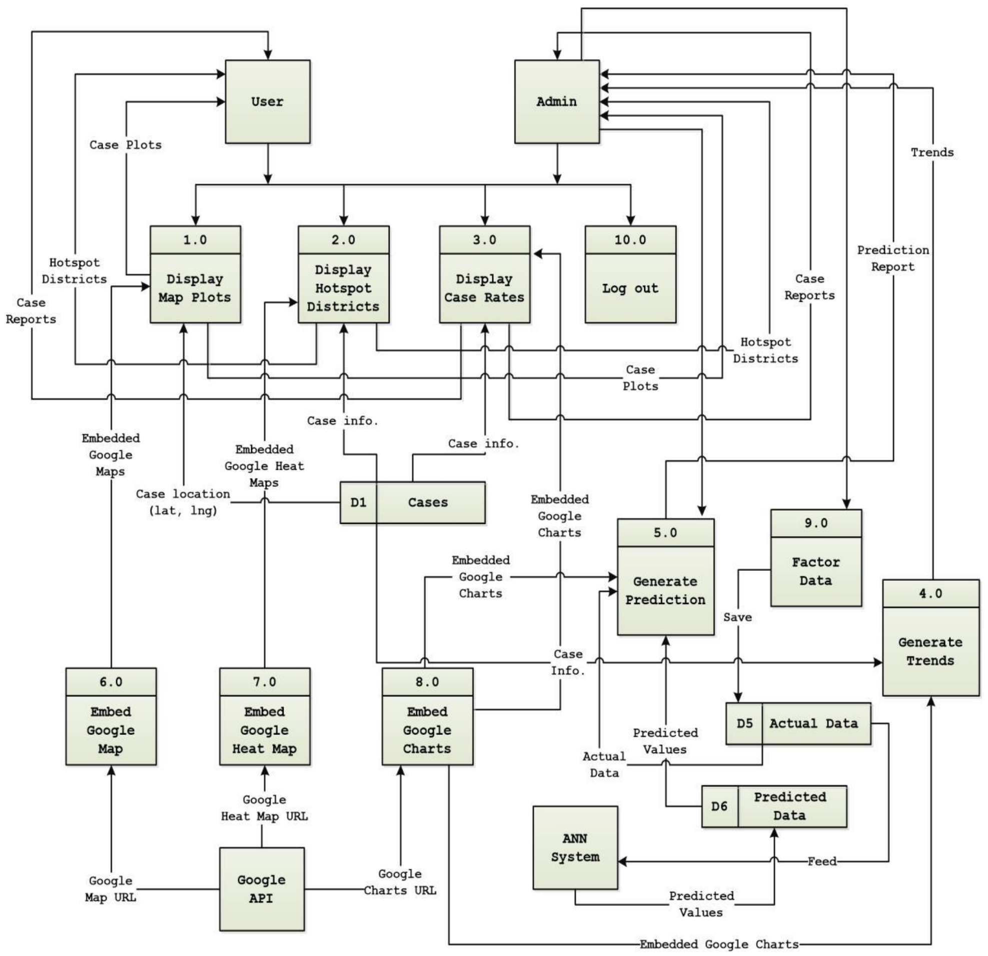

Figure 3. DFD of the Proposed System (Map Analysis, Case Rates, Generating Trends & Generating Prediction)

3.2. The ANN Model

As shown in Figure 4, the ANN model used in this study is the standard three-layer feed forward network. Since the one-step-ahead forecasting is considered, only one output node is employed. Through the input layer, the ANN model receives 5 inputs x(n) composed of the amount of rainfall, humidity rate, temperature rate, number of dengue cases and another number representing the dengue cases taken from the previous month. Each neuron comprises two units. The first unit sums up the products of weights coefficients and input signals; while the second one implements a nonlinear neuron activation function. The desired response vector is obtained at the output layer of the computation nodes. After the ANN processing is done, the output values will be integrated to the database and will be used to present the Trends and Prediction. This component generates an analysis report and comparison of the predicted data over the actual data through a graphical representation.

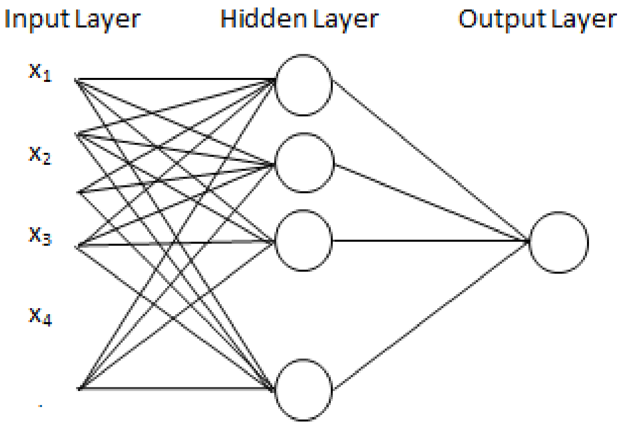

Figure 4. The ANN Model

4. Implementation

The proposed system is implemented using MySql as the backend, while CSS, PHP, Javascript and C# were used for developing the frontend of the system. The users of this system are the hospitals from Iloilo City and the administrator which is the City Health or the Department of Health. They must be equipped and knowledgeable in handling a computer so that they can use the system effectively.

The proposed system generates case plots, hotspot districts, trends and case rate that can help different health sectors in Iloilo City implementing awareness about dengue and to reduce overall case occurrence. The system has two (2) main users: (1) Admin and (2) User. The Admin can add, delete and update cases as well as on the over-all analysis like mapping, prediction and many more. On the other hand, the user is only limited in adding, deleting and updating cases. Both levels are capable of viewing hot spots, case plots, case rates except for the case trends and prediction which can only be used by the admin. Figures below show the different input required and outputs generated from the system.

As shown in Figure 5, the regular users are the hospitals in which, they are responsible for the management of the case data. Each hospital user has an account which was created by the admin. They input case information in the Case Entry form which requires them to input information about the victim. Some of its inputs are date, month and year of the case occurrence, district, location and more.

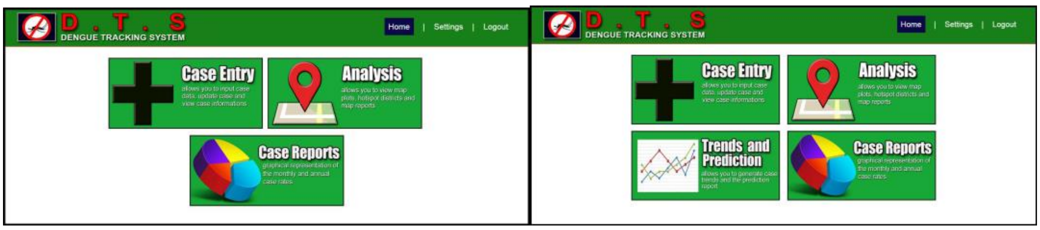

Figure 5. The Admin and User Home Page

The admin and user has separate system interfaces. Some of the functions in both of the user's pages are similar except for the Admin which holds the entire analysis of the system. In the User page, the system has three major components: the Case Entry, the Analysis and the Case Reports. While on the Admin page, the system has four major components: the Case Entry, the Analysis, Trends and Prediction, and the Case Reports.

The historical data that the researchers gathered from different organizations were consolidated so that it will be used for the prediction. As shown in Figure 6, prior to the prediction process the factors will be classified first into four categories: the monthly rainfall rate, monthly temperature rate, monthly relative humidity and the monthly number of cases. Then, the values of each category will be integrated into the system database and utilized for future predictions.

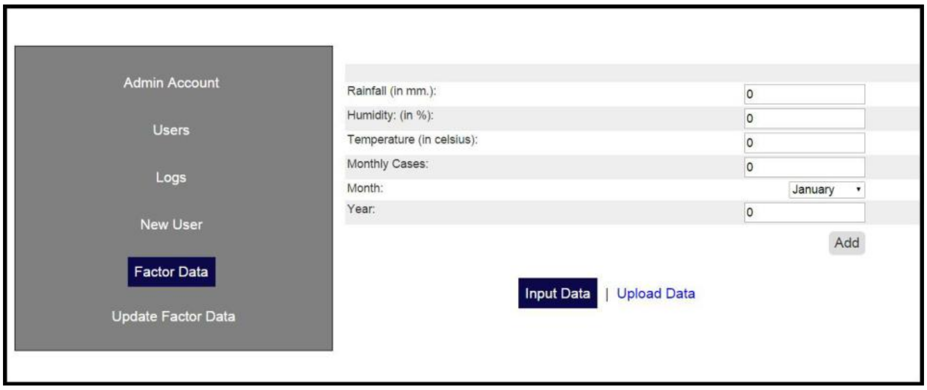

Figure 6. Parameter Entry Page for Dengue Cases

In Figure 7, the Case Entry is where the users of the system can input the occurrence of dengue case. Using an entry form, both the admin and user can input information of the current victims and their status. The users can also view all the cases recorded on the system. They can filter data by selecting their desired category, search for a specific keyword, as well as update and delete the cases.

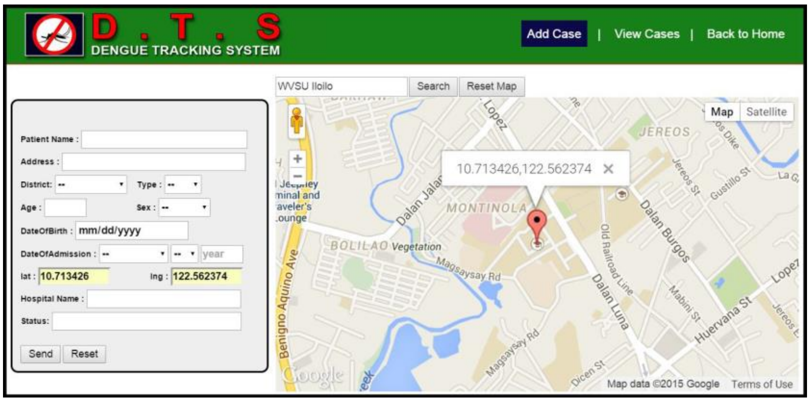

Figure 7. Add Dengue Case Page

The Analysis component has two major functions, namely Mapping and Heatmaps. In Figure 8, the map visualizes the location and contains the case plots that were recorded in the database. Using the latitude and longitude of these cases, the user can view the dengue cases on the map for easy graphical reference. The admin has the ability to filter plots on Google Maps by selecting different filtering options and perform a search based on those filters. Meanwhile, the user can search for a particular year and the map will display all the plots related to the searched year.

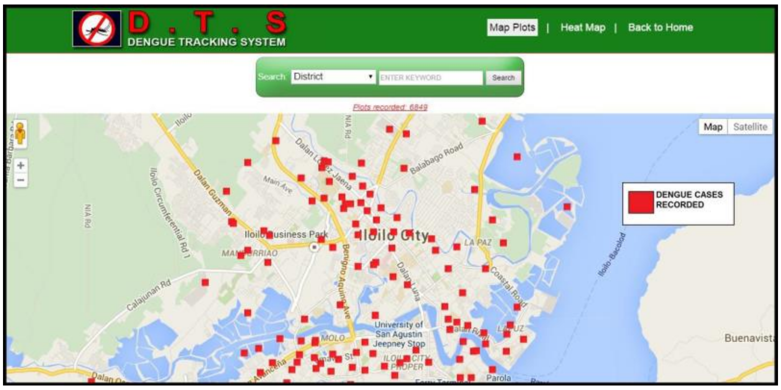

Figure 8. Dengue Case Mapping

Figure 9 shows an example of a heat map which depicts a dengue hotspot. Although the Admin has more control over this feature, the User also has permission to use this feature. The user can search a particular year, and then it will display the hotspot districts of that given year. The same as with the Admin but they have the ability to control the opacity, radius and gradient.

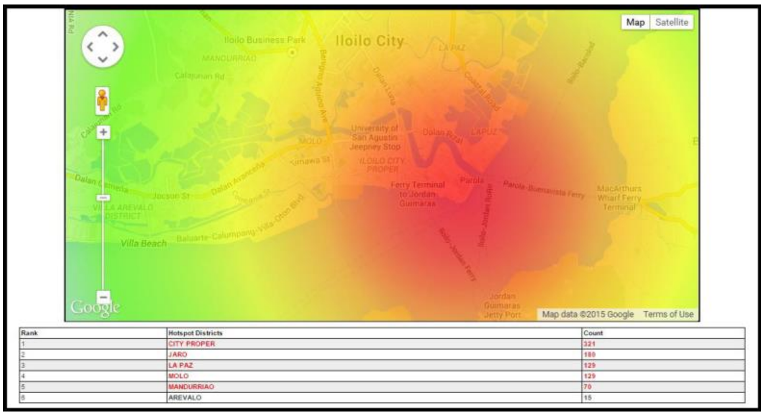

Figure 9. Dengue Hotspot Mapping

In Figure 10, another component of the system is the Case Reports, where all the case reports are consolidated and displayed in a chart. The Admin and User can search for a year and it will display all the monthly cases that were recorded on that specific year.

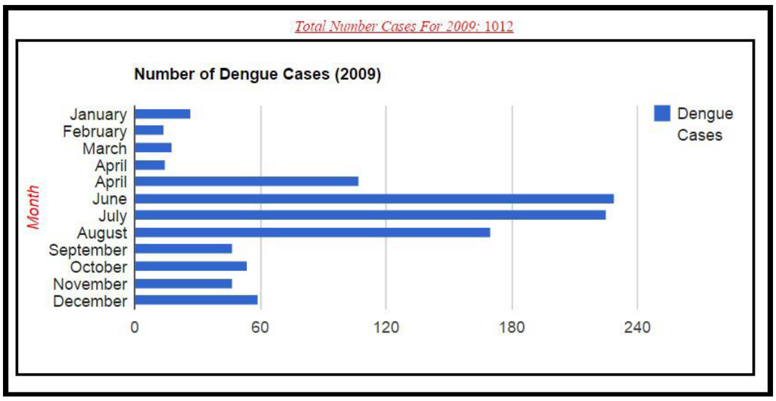

Figure 10. Generate Monthly Case Report

Figure 11 shows an example of how the ANN model was applied to predict dengue cases using historical data. As can be seen, the data trends indicate a close match between the actual and the predicted number of dengue cases.

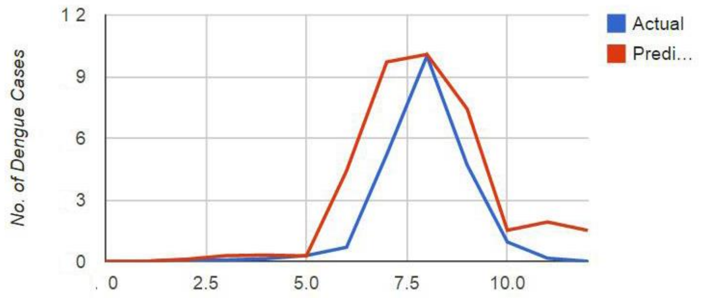

Figure 11. Dengue Case Prediction (X=Months / Y= No. of Cases)

5. Conclusion and Recommendations

The research aimed to develop a system which identifies case rate, trends and dengue case behavior. It uses trend analysis for generating trends and Artificial Neural Networks for dengue case prediction and embedded to Google applications for its overall presentation. The proposed system was developed to help the health sectors in identifying the hotspot places, trends, dengue prediction behavior, and case rate in Iloilo City. The Dengue Tracking System uses several tools for the analysis of given data such as Google Maps for the case plotting, Google Heat Maps for identifying the possible hotspot districts, Trend Analysis for generating trends and the Artificial Neural Networks System for predicting the behavior of dengue cases. CSS, Javascript, PHP and Visual C# were used for the entire development of the system.

It intended users found it very useful especially in terms of helping the health sectors in Iloilo City especially in implementing programs to lessen the number of dengue cases and promote awareness to the people. Firstly, to further improve the system, the researchers recommend integrating offline tools in generating outputs such as the map system and the charts since Google applications may not be available at all times. Secondly, the environment of the system should be improved such as putting instruction in each menu for understandability. Lastly, the prediction process of the ANN system could be improved and deployed to the Web in order for the users to focus on just one familiar environment. Moreover, another algorithm that could handle missing data should also be employed.

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