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Development of a Rainfall Rate Monitoring System for Malaysia

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Abstract

Floods are one of the major disasters occurring all over the world, including Malaysia. It can lead to destruction of facilities, infrastructures as well as properties. Minimizing the risk of hazards and loss can be achieved by implementing several measures. Motivated from one of the biggest flood disasters ever occurred in the country, this monitoring system is developed as a means to reduce the risk of loss and damages. Monitoring rainfall rate may assist the community as it can provide early flood forecasting even though it cannot fully prevent the flood. Besides, it can give additional information on the probability of landslide occurrences. This paper presents the development of useful and reliable rainfall rate monitoring system for online hydrological stations in Kelantan. The whole processes in the development of this first prototype are conducted and performed using open-source software and tools such as Visual Basic and Quantum GIS (QGIS).

Keywords: Flood, Rain Gauge, Rainfall Rate, Real-Time Monitoring

1. Introduction

Floods are one of the common natural disasters that occur all around the globe. Natural floods disaster is said to be associated with continuous downpour of heavy rains for a period of time. Malaysia, which is located at the tropical region receives average annual rainfall of 2500 mm for the Peninsula area while Sabah and Sarawak receive 3500 mm[1]. This rainfall rate differs at different states due to several reasons such as winds, clouds and surface topography. The research area, Kelantan receives average annual rainfall of 2700 mm[2]. The most common period of heavy rains in this area which is located at the east coast of the country is during the North East Monsoon. This monsoon usually takes place around November to March each year. Figure 1 shows the map of Kelantan, Malaysia.

In December 2014, Kelantan has been hit by one of the worst flood disasters that ever happened in that state. Over 150,000 victims from 36,128 families had been evacuated from their settlements and about 309 relief centres were provided. Out of 11 districts, eight districts were affected by the floods especially Kota Bharu, which had the highest number of victims evacuated, namely 44, 061, followed by Tumpat, Pasir Mas, Kuala Krai, Gua Musang, Machang, Tanah Merah and Pasir Puteh[4]. During the massive flood, electricity was cut off for safety reasons at some places and victims lost connections to the outside world as communications links were also not available. Most of the places in Kelantan were paralyzed and even after the flood ends, a lot of efforts and resources are required for the state and its people to recover from the trauma. Figure 2 shows a flooded school in Tanah Merah that became a shelter for the victims during the flood.

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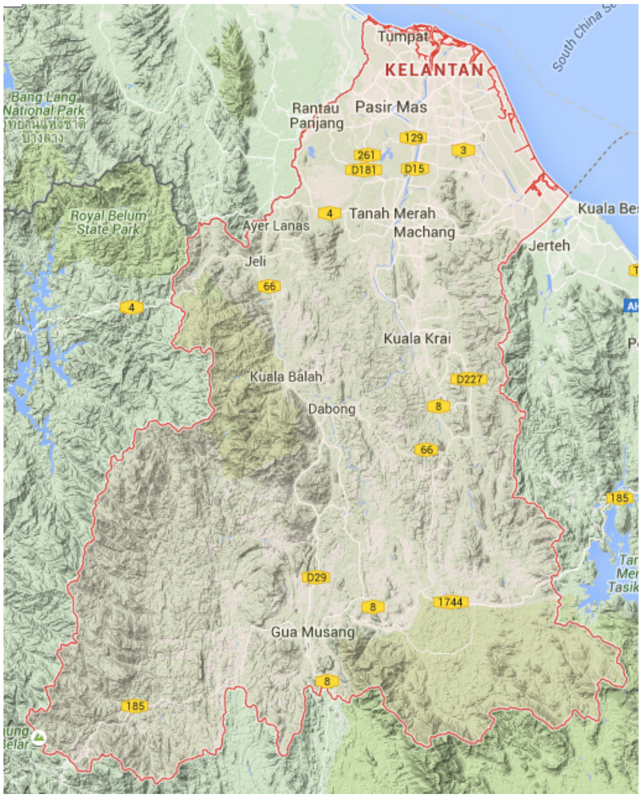


Figure 1. Map of Kelantan[3].

Figure 2. Flooded Sekolah Kebangsaan Kampung Kerilla in Tanah Merah, Kelantan during 2014 flood which became a shelter for nearby victims[5].

One of the reasons which are believed to be the cause for the last catastrophe to take place was the 'new moon' phenomenon, which occurred right after the unusual heavy rains[6]. The phenomena of 'new moon' and 'full moon', or called perigean spring tide occur when the moon is new or full and closest to the earth[7]. The short distance between the moon and Earth caused a stronger gravity force from the moon onto the sea water, resulting in exceptional high tide. This high tide phenomenon prevented the previous extreme rainwater that came from the headwaters through the rivers from flowing into the river mouth, caused the water to drown the land area. Figure 3 illustrates the 'new moon' phenomenon.

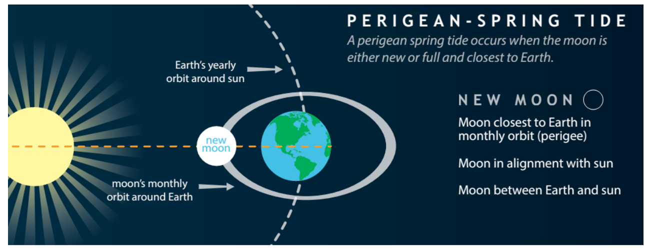


Figure 3. 'New Moon' phenomenon[7].

Various studies and researches have been carried out in developing real-time monitoring systems, especially flood monitoring[8,9]. In Pakistan, flood monitoring and damage assessment using remote technique sensing was developed[10]. In[11] states that remote sensing for rainfall monitoring gives better spatial estimates compared to the conventional method which is based on limited network and observations. An architectural model for flood monitoring using wireless sensor network system was designed in India[12]. This system exploits information such as flood flow, flood level and precipitation level and sends them to authorized parties.

Monitoring rainfall rate at river basins is essential as early flood prediction can be carried out and any important decisions can be achieved. Not only for floods forecasting, rainfall data can also be useful in indicating potential landslides. Generally, rainfall rate is defined as a parameter of measuring the rainfall intensity, which is the amount of rain falls to the ground per unit area per unit of time. Rains are categorized into several categories according to the amount of rainfall rate in unit of mm/h. Rains are considered as light rains when the rates are 1-10 mm/h. when the rate measured is ranged from 11-30 mm/h, the rain is categorized as moderate rain. Heavy and extreme rains take place when the rainfall rate reaches the ranges of 31-60 mm/h and more than 60 mm/h, respectively[13].

Time management is important in diminishing the effect of disasters. Insufficient data display in the current system may cause the public having a hard time in collecting the information during emergency situations.

An accurate and interactive real time monitoring system is needed to monitor rainfall rate from hydrological telemetry stations in Kelantan. This research focuses on 24 online stations as listed in Table 1.

Table 1. List of rainfall stations and their related information

No.	Station	District	River	River Basin
1	Air Bol	Jeli	Sg. Pergau	Sg. Pergau
2	Air Mulih	Pasir Mas	Sg. Kelantan	Sg. Kelantan
3	Bachok	Bachok	Sg. Kemasin	Sg. Kelantan
4	Batu 13 Jeli	Jeli	Sg. Pergau	Sg. Pergau
5	Dabong	Kuala Krai	Sg. Galas	Sg. Kelantan
6	Empan-gan Bukit Kwong	Pasir Mas		Sg. Golok
7	Gua Musang	Gua Musang	Sg. Galas	Sg. Kelantan
8	Gunung Gagau 1	Gua Musang	Sg. Gagau	Sg. Kelantan
9	Gunung Gagau 2	Gua Musang	Sg. Gagau	Sg, Kelantan
10	Jenob	Tanah Merah	Sg. Golok	Sg. Golok
11	Jeti Kastam	Kota Bharu	Sg. Kelantan	Sg. Kelantan
12	Kg. Aring	Gua Musang	Sg. Aring	Sg. Kelantan
13	Kg. Jeli	Jeli	Sg. Pergau	Sg. Kelantan
14	Kg. Laloh	Kuala Krai	Sg. Lebir	Sg. Kelantan
15	Kuala Jambu	Tumpat	Sg. Golok	Sg. Golok
16	Kuala Koh	Kuala Krai	Sg. Lebir	Sg. Kelantan
17	Kuala Krai	Kuala Krai	Sg. Kelantan	Sg. Kelantan
18	Kusial	Tanah Merah	Sg. Kelantan	Sg. Kelantan
19	Limau Kasturi	Gua Musang	Sg. Galas	Sg. Kelantan
20	Logging	Gua Musang		Sg. Kelantan
21	Pasir Puteh	Pasir Puteh	Sg. Semerak	Sg. Semerak
22	Rantau Panjang	Pasir Mas	Sg. Golok	Sg. Golok
23	Tualang	Kuala Krai	Sg. Lebir	Sg. Kelantan
24	Tumpat	Tumpat	Sg. Kelantan	Sg. Kelantan

The organization of the paper is as follows; Section 1 describes a brief introduction of this research, Section 2 gives a brief description of measurement set-up and collection of data. Section 3 and Section 4 consists of research methodology and preliminary results, respectively. Finally, Section 5 concludes the paper.

2. Measurement Set-Up and Data Collection

2.1 Measurement Set-Up

According to[14], Malaysian Department of Irrigation and Drainage (DID) uses rain gauges to measure rainfall. Rainfall collected at a certain location would represent the rainfall over the area around the rain gauge. Before implementing the usage of automatic recording rain gauge, the rainfall is measured using non-recording rain gauges. Figure 4 shows the standard rain gauge.

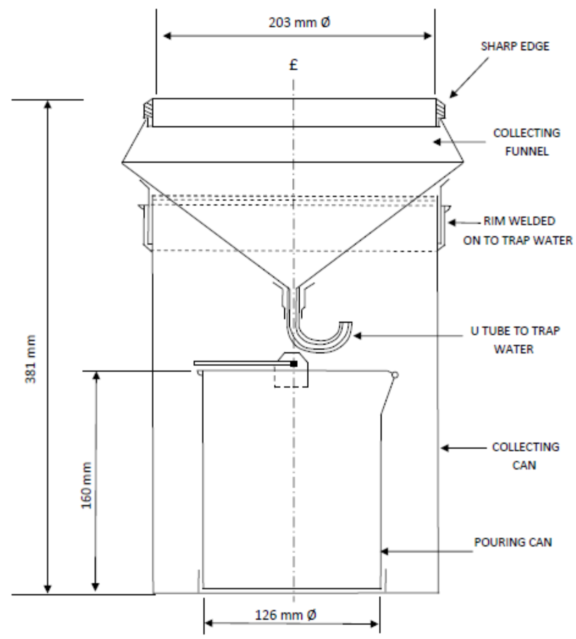


Figure 4. Standard 203 mm diameter rain gauge[14].

Non-recording rain gauges are divided into two types; 203 mm diameter rain gauge, which is referred as manual gauge and 127 mm diameter rain gauge, in which it is often used as check gauge. Readings of manual gauge are taken daily or weekly, while as for check gauge, which has the capacity to collect 4000 mm rainfall, the readings are taken monthly. 203 mm and 127 mm are referred to the diameter of receiver cap which is located on top of the rain gauge, as shown in the Figure. The receiver cap is used to catch and funnel the rain into a can. The sharp edge of the funnel is to ensure the funnel receive the rain precisely in the diameter of 203 mm or 127 mm. The amount of rainfall is collected by pouring the rainwater into a standard measuring cylinder, as shown in Figure 5.

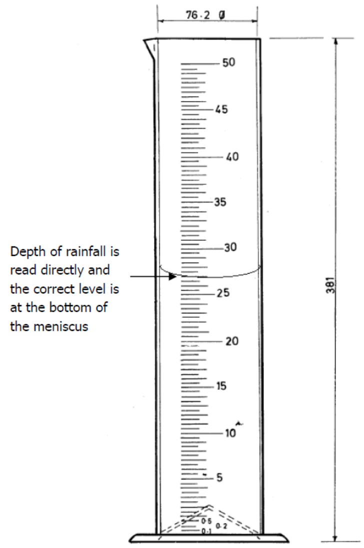


Figure 5. Standard measuring cylinder for the use with 203 mm rain gauge[14].

DID of Malaysia gradually replaces the manual rain gauges at the rainfall stations with recording rain gauge as it can provide detailed information such as the intensity of the rain over short periods of time. Figure 6 shows the tipping bucket, a type of recording rain gauge which is used at most of DID's rainfall stations.

Figure 6. Tipping bucket[14].

DID implements the use of 0.2 mm and 0.5 mm tipping bucket, which consists of a bucket system that catches rainfall. When the rainfall collected in the bucket surpasses its maximum value, the bucket will tip due to the weight of rainwater. The time is recorded whenever the bucket tips. Thus, the intensity of rainfall is calculated by finding the tipping rate and total amount of rain in a series of recordings. However, this type of recorder tends to record less rainfall due to loss during the tipping action and the evaporation of rainfall in the tipping bucket. To solve this problem, DID installs a check gauge in many of its stations to adjust the tipping bucket rainfall data.

2.2 Data Collection

Real-time monitoring requires live transmission of data from rainfall stations to a master server. Therefore, telemetry system, which is maintained by DID is practiced. Telemetry is an automated telecommunications process which sending or receiving data from the measuring instruments are made remotely. Figure 7 depicts the basis of telemetry system.

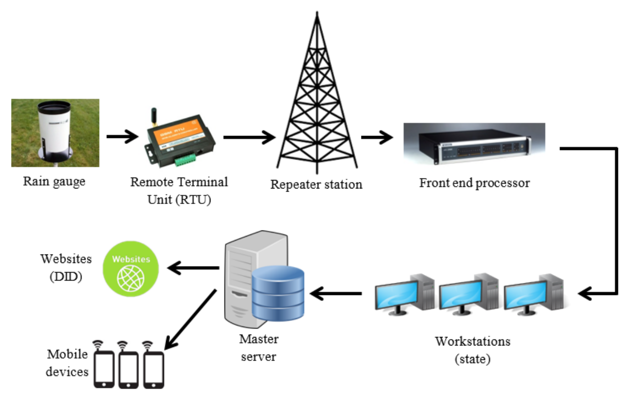


Figure 7. Data collection using telemetry station.

Data collected from the rain gauge is transmitted via a data cable to Remote Terminal Unit (RTU), which acts as a data logger and then, it sends the data to the front end processor through GSM technology. The data is received by workstations at respective states before it is transferred to the master server and stored in the database. Then, the data is displayed to the public through the Internet. Figure 8 shows the graph of sample data recorded by this system during the 2014 flood event at Air Mulih Station in Pasir Mas, Kelantan.

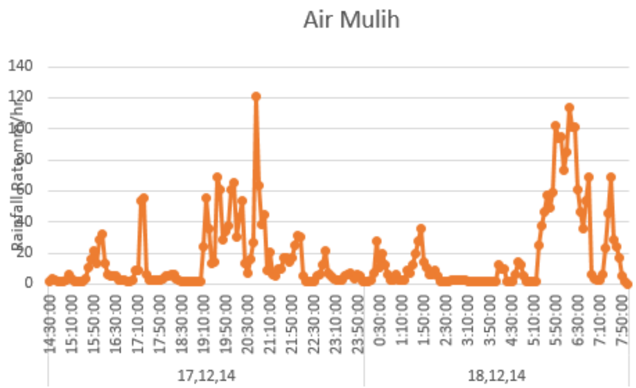


Figure 8. Sample of rainfall data for Air Mulih station during 2014 flood event.

3. Methodology

This research is conducted according to the activities in the flowchart as shown in Figure 9, which acts as the main guideline.

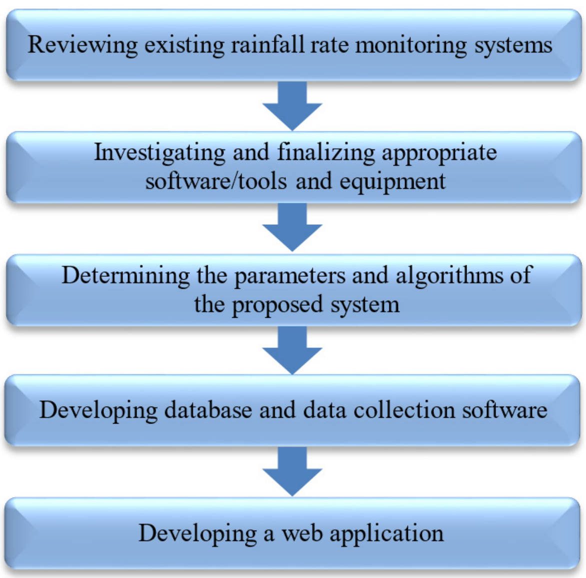


Figure 9. Research flowchart.

The workflow of the research is depicted in Figure 10. During the first phase, the preliminary phase, user needs and data requirement were evaluated. Database design also took place in this phase. The second phase, the development phase comprised of processes such as collecting data, developing the designed database as well as designing and developing the system. Subsequent phase was the evaluation phase, where the developed system was tested and evaluated. Any required enhancement and changes were performed in the phase. The previous phase may be repeated whenever it was found necessary and the same process in the third phase will be conducted before proceeding to the last phase. The implementation phase, which consisted of system implementation and maintenance, was carried out after the developed system was validated.

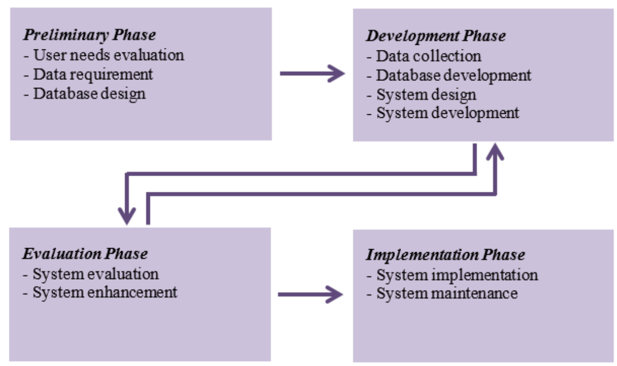


Figure 10. Research workflow.

Figure 11 shows the overall structure of the proposed system. The input of the system can be retrieved from a website maintained by DID and stored in a database. The database consists of 24 tables, where each table serves to store data from a station. Then, a desktop application was developed for the use of registered users to monitor the rainfall rate. Finally, a web application was built in order to convey the rainfall rate information to the public.

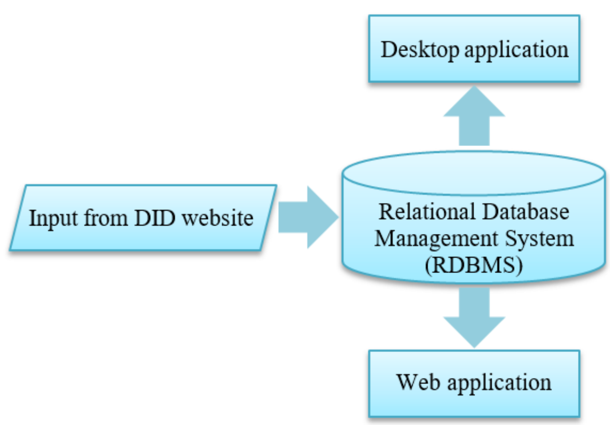


Figure 11. Overall structure of the proposed system.

Tools and software used in developing the proposed system are summarised in Table 2. Visual Basic programming language, which is available in Visual Studio Community 2015 was used in developing the desktop application. An open-source database, PostgreSQL, serves to store rainfall rate data in this system. PHP and JavaScript are the main scripting languages used in building the web application. Quantum GIS or QGIS is an open-source Geographic Information System (GIS) software and it assisted in generating the stations location on the map of Kelantan.

Table 2. Tools and software used for system development

Open-source GIS Software	QGIS 2.12 (Lyon)
Integrated Development Environment (IDE)	Visual Studio Community 2015
Programming Languages	Visual Basic
Scripting Language	- PHP - JavaScript
Open-source Database	PostgreSQL 9.3
Open-source Web Server	Apache
Text Editor	- Sublime Text 2 - Notepad++
Web Browser	Google Chrome
Equipment	Dell Inspiron 2350 (Intel Core i7)
OS Platform	Windows 10

4. Preliminary Results and Discussions

A desktop application solution called "Kelantan Rainfall Rate Monitoring System" has been developed. The desktop application is meant for legal registered users. To log into this system, a user must register beforehand by contacting the administrator. After the registration completes, the user can log in using provided username and password. There are two levels of user for this system. The first level is for the system's administrator, in which the administrator is the only user that has the privilege to add new users and remove existing users as well as edit some information about the registered users. Figure 12 shows a proposed login page of the desktop application.

After logging into the system, users will be redirected to a map showing 24 rainfall stations in Kelantan, as shown in Figure 13(a). By hovering the cursor over the coordinate points of each station, information about the station, such as its coordinates, district where it is located as well as related river and river basin will be popped-up (Figure 13(b)).

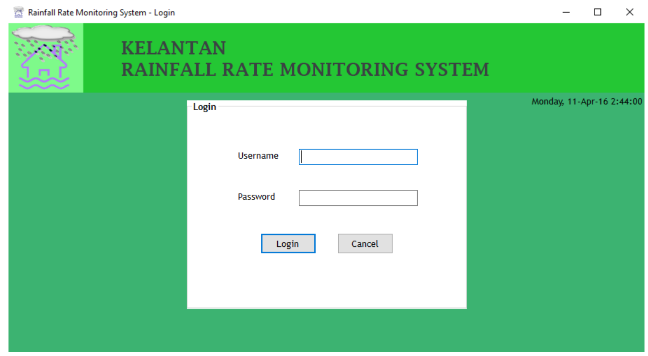
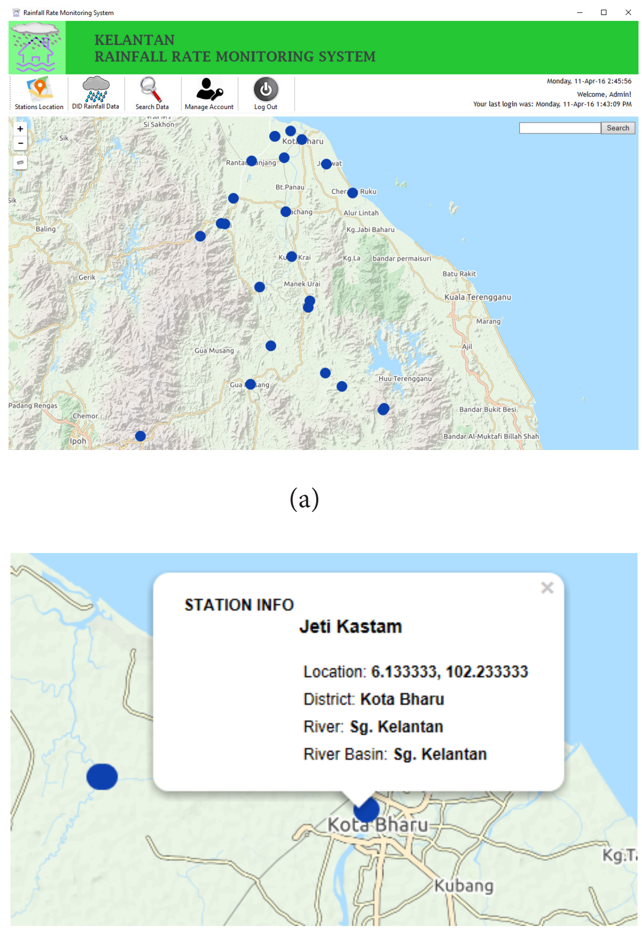


Figure 12. A proposed login page of the desktop application.



(a)

Figure 13. (a) Locations of hydrological rainfall stations on the map of Kelantan. (b) A pop-up showing station's information.

DID rainfall data can be retrieved from the website governed by DID. The information is shown to the users by clicking on the 'DID Rainfall Data' tab. Figure 14 shows the list of 24 rainfall stations along with their related information. The data is updated regularly within one hour interval. Rainfall rate is shown in the unit of millimeter per hour (mm/h) and it is collected accumulatively starting at midnight for each day.

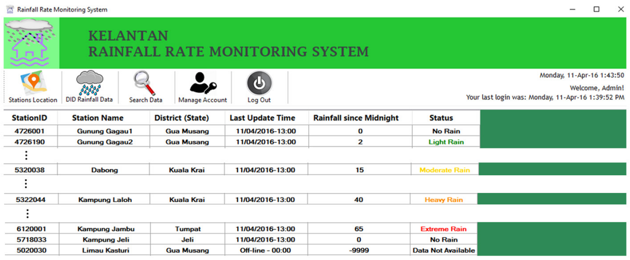


Figure 14. Display of rainfall data from rainfall stations in Kelantan.

The rainfall rate is monitored according to certain values as per determined by DID. The 'Status' column will show the rainfall status for the latest data updated. 'No Rain' status will be shown if the station does not receive rainfall since the midnight of the day. Status 'Light rain', 'Moderate Rain', and 'Heavy Rain' will be updated if the rainfall rate of the day is in the range of 1-10 mm/h, 11-30 mm/h, and 31-60 mm/h respectively. If the rainfall rate exceeds 60 mm/h, status 'Extreme Rain' will be shown.

The limitation of this system is that it totally depends on the availability of the data from DID website. This system cannot retrieve the required data once the system is not connected to the Internet or the website. However, the system displays more interactive and informative interface compared to the existing system.

5. Conclusion

The proposed prototype system of Kelantan Rainfall Rate Monitoring System is presented in this paper. Consisting of two solutions, which are web and desktop application, at this juncture, the paper focuses only on the desktop application. The development of the system utilizes minimal cost as possible by exploiting powerful open-source and free-licensed resources. The proposed system is open for any changes and improvement to adopt with new technologies available. The next progress of the system includes the development of web application and enrichment on the data display of the desktop application.

6. Acknowledgements

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