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The Web-based Framework of X-Band Polarimetric Radar System

Nooradilla Abu Hasan, Masa Goto, Kuniaki Miyamoto

Abstract*: The application of X-Band Polarimetric radar (X-Band MP radar) is very effective in disaster risk management which can help professional, researchers, private and government agencies to take actions for rainfall-related disaster preparedness and prevention activities. This needs dissemination of rainfall radar data and information for developing the methods, models and applications. With the emerging Internet technologies, many web-based systems are used as a fundamental platform for gathering, processing and delivering the data or information in many fields. This paper is aimed to recognize the requirements of a web-based framework for rainfall estimation system by using X-Band MP radar. Through the systematic approach, three requirements for the proposed architecture are identified, which are the source of rainfall data, the technology involved in the system development and the features of web-based system. Those requirements are represent the whole concept of X-Band MP radar system for Malaysia. Based on the outcome of this study, a web-based system framework is proposed and the prototype of the proposed system will be developed.

***Index Terms*: rainfall monitoring, system integration, web-based, X-Band MP.**

I. INTRODUCTION

In disaster risk management, monitoring of rainfall intensity and its spatial distribution is crucial as it is the basis for managing the rain-related risk or disaster. In the effective monitoring system for the rainfall estimation, the rainfall data have been collected by technologies such as weather radars and rain gauges, which have contributed to development of mathematical models, tools and warning applications for disaster preparedness and prevention. With the recent rapid advancement of internet and information technologies, the rainfall data in the various formats such as in jpeg, geotiff and kml, and disaster information such as time, intensity, location and geographical data on drainage area can be shared without limit.

The most conventional way to collect the rainfall data is by rain gauges, which can capture the actual rainfall events on the ground level. However, because rain gauge is a spot measurement, it can provide limited information on spatial rainfall variability [1, 2, 16]. On the other hand, weather radar provides the possibility to predict or estimate the precipitation in advance by monitoring movements of rain cloud before it reaches the area of interest, because it can provide spatial information of high resolution both in time and area. The weather radar is capable of taking snapshots of the radar reflectivity above the ground at high frequency [9, 13].

In these days, C-, S- and X-Bands radar waves are commonly used by weather radars. Table 1 summarizes the basic specifications of radar bands used by weather radars. As shown in Table 1, each radar band has different observation radius and spatial resolution depending on the wave length and frequency. For urban or local areal weather monitoring, X-Band radar is the better option due to its higher resolution in spite of its rather shorter observation range compared with the C- and S-Bands radars.

Table 1: The three weather radar bands and their specifications [7, 8, 12].

	X-Band	C-Band	S-Band
Wave Length	3-4 cm	5-6 cm	10-11 cm
Frequency	8-12 GHz	4-8 GHz	2- 4 GHz
Range (Radius)	30-80 km	200- 480 km	200- 480 km
Spatial Resolution	250 m mesh	1 km mesh	1 km mesh

Because of recent meteorological research and development, a few countries such as Japan have been using X-Band Polarimetric (MP) radars for rainfall estimation and disaster risk management. X-Band Polarimetric radar is a combination of X-Band radar with multiparametric or dual polarisation technology that provides the valuable data such as the diameter and shape distributions of rain drops for meteorological and hydrological studies, as well as practical applications [5, 17], especially, for short range areas. The application of this type of radars for rainfall estimation is vital, since the information obtained (such as the amount of rainfall) is useful for the governmental and private agencies to help each other in order to prepare for any circumstances of rainfall related disaster [1, 4].

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***** Correspondence Author
Nooradilla Abu Hasan*, Disaster Preparedness and Prevention Center, Malaysia Japan International Institute of Technology, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia.
Masa Goto, Disaster Preparedness and Prevention Center, Malaysia Japan International Institute of Technology, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia.
Professor Emiratus Kuniaki Miyamoto, University of Tsukuba, Tsukuba, Japan.

However, not many researchers have discussed the desired structure of the monitoring and data management systems, especially, based upon X-Band Polarimetric radars. Moreover, there is no integrated rainfall monitoring systems in operation based on the X-Band Polarimetric radar data as pointed out by Nishio and Mori [11]. The web-based system is a convenient platform to collect, store, analyse and disseminate rainfall information and data for various purposes that can involve multiple levels of users. For instance, in Bopi, et al. [3] study they have used rain gauges as their main tool to collect rainfall data for developing the rainfall rate monitoring system. Their study area was in Kelantan, Malaysia where massive flood event had occurred in December 2014. A web-based system named "Kelantan Rainfall Rate Monitoring System" has been developed for the registered users (in the desktop application) and for public information (website application). The intention of their web-based system is to share the rainfall data collected from the hydrological station in Kelantan and manipulate the data to be used for preventing the future disaster and calculating the damages due to flood or landslide events. However, operation of the system depends on the reliability of rainfall data (by rain gauges) from Department of Irrigation and Drainage [6] Malaysia website. They have developed their own Relational Database Management System (RDBMS) to extract the rainfall data from the DID website. User interface for desktop and web applications were also developed in the project.

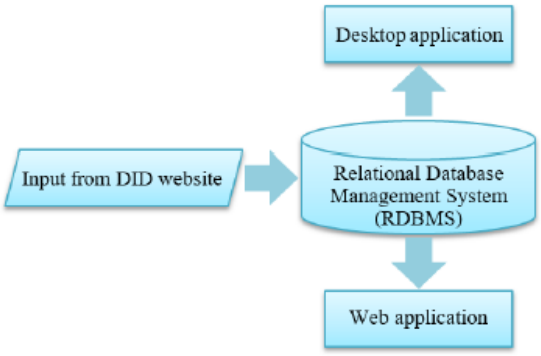

Figure 1: The framework of Kelantan Rainfall Rate Monitoring System [Extracted from 3]

As the newer and more advanced technologies than rain gauges, weather radars, especially, X-Band Polarimetric radars are effective tools for collecting the rainfall data, which can be further, processed and analysed for disaster prevention or mitigation purposes. An example is the study by Nishio and Mori [11], in which they have developed web-based monitoring system for cumulative rainfall data by using X-Band Polarimetric radar. Their new framework for the system allows the X-Band Polarimetric radar rainfall data from Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan to be used with the open source GIS system. The function of the system is to automatically convert rainfall data from MLIT X-Band Polarimetric radar network in binary format into text format, and store the converted data in the database as shown in Figure 2. In addition to the rainfall data, the spatial information is automatically added to the Keyhole Mark-up Language (KML) file which is compatible with Google Earth data format. The rainfall data (after conversion) can be overlaid on Google Maps, as shown in Figure 3, for further action by responsible persons or agencies [10, 11].

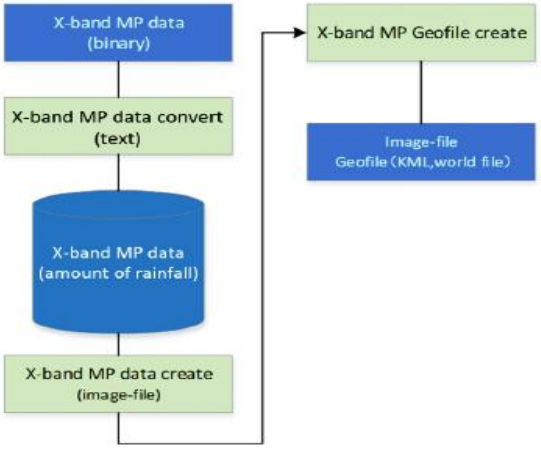

Figure 2 : The flow of X-Band Polarimetric radar rainfall data conversion [Extracted from 11].

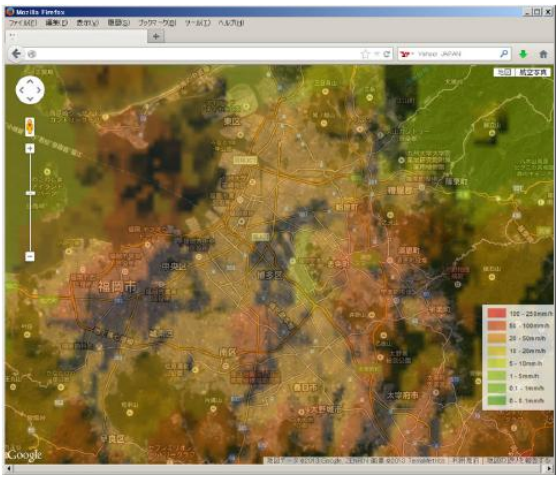

Figure 3: An example of rainfall data is overlaid on Google Maps for the Fukuoka prefecture, Japan [Extracted from 11].

This paper is aimed to establish and recommend the framework of the web-based system by using X-Band Polarimetric radar data which is most suitable to Malaysia. So far, there is no such system available in Malaysia as well as X-Band Polarimetric radar monitoring system for rainfall estimation study. The objective of this paper is a part of the research project objective which is to develop the rainfall monitoring system for rainfall estimation by using X-Band Polarimetric radar data for Malaysia

II. METHODOLOGY

The aim of this paper is to identify the requirements for establishing the framework of the web-based system by using X-Band Polarimetric radar data. In order to achieve the objective, the authors have applied the Systematic Literature Review principle. It was started with identification of the articles by using carefully selected keywords such as "X-Band MP", "X-Band Polarimetric", "monitoring system", and "rainfall estimation". With help from online UTM library, the Scopus database was searched.

The searching results yielded 25 key articles published between 2013 and 2018. Several articles regarding the introduction of X-Band Polarimetric radar and its implementation for disaster mitigation, which were published before 2013, were also taken as supporting data and information.

The second step was to analyse the articles by focusing on the specific issues such as 1) recognition of the source of rainfall data which focuses on X-Band Polarimetric radar as the main technology, 2) the technology of system development and its requirements, and 3) the features of the proposed or developed the web-based systems. For the third step, actual coding was carried out, where focused on to achieve the paper objectively. From the subjects extracted in the second step, details on the requirements of the framework for the proposed web-based system by using X-Band Polarimetric radar were identified. The last step was to analyse and write up the results. Each of result identified is explained in the following sections.

III. SYSTEM ARCHITECTURE

Since the X-Band Polarimetric radar is still new to Malaysia, it is necessary to understand the fundamental of data processing for X-Band Polarimetric radar data in order to develop the web-based system. The requirements for the proposed X-Band Polarimetric radar system and the proposed framework of the web-based system are presented in the following sections.

A. The sources of rainfall data

In this research, the X-Band Polarimetric radar is chosen as the key technology to collect the rainfall data. It is important to know how the rainfall data are collected and provided, because rainfall data from different technologies are described and presented in various formats. As for X-Band Polarimetric radar, it provides the precipitation rate data with 1-2 minutes response time. The binary data provided from radar need to be converted to text format for the actual processing and storage in the database (Figure 2). In addition, the stored data must be used in open source software such as Google Earth or Google Map with the geographical information added. Besides that, the 1-2 minutes of precipitation data can also be converted to the standard image formats such as jpeg, bmp or any of many other standard formats [10, 11].

A disaster even always needs to be analysed and evaluated with the location information. Therefore, the topographical data of the area where disaster event occurs are also needed. The additional data such as the Digital Elevation Model (DEM), digital surface model and any ward area map from local government are needed where can be integrated with the X-Band Polarimetric radar data.

B. The technology of system development

In developing the web-based system, it is important for the developer to understand all the relevant web technologies. For the communication among the web-based system components and the database, it is required the secure server-side application [14]. Firewall and network security features can help to prevent undesirable access to the server by intruders that may damage the data and the server system. AJAX (Asynchronous Java Script and XML) is commonly used in developing the system as it will quicken the data transfer between server and clients as well as decrease the process load at the server side [11, 14]. A programming language needs to be selected to write the scripts, especially, in creating and processing the mathematical models or tools. Open source languages such as PHP, Shell Script, Java and C, among others, are regarded desired for practical implementation.

C. The features of the web-based system

To develop the web-based system, it is necessary to identify the user requirements and their abilities to conduct analyses or use the system. The users in the proposed web-based system are focused on disaster researchers, students, lecturers, private agencies and governmental officers that are mainly involved in disaster risk management activities. In common, the web-based system interface should have three components, which are able to interact with the users such as the public facing component, the member data viewing component and the administration component [15]. Therefore, user-friendly interface and easy access are the important features to be considered in developing such a system. Rich collection of web applications, which can easily be accessed by a typical web browser and can provide the users with smooth interaction with the data sources, are the necessity of a good web-based system [14].

IV. DISCUSSION AND CONCLUSION

From the requirements identified in the previous section, Figure 4 shows the engagement between 1) the sources of rainfall data (radar location), 2) the technology of system development (DPPC server) and 3) the features of the web-based system. The RadarID represents the location of physical radar which is including the observation area. File Transfer Protocol (FTP) is used to allow the communication and transferring the data between the RadarID and the database automatically.

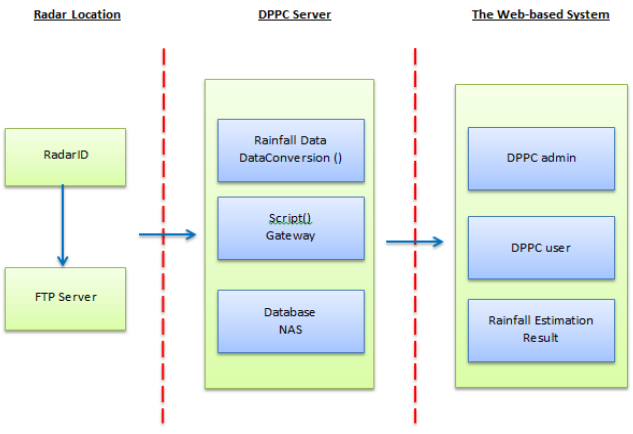

Figure 4: The proposed architecture of X-Band Polarimetric system radar for Malaysia.

The Disaster Preparedness and Prevention Centre (DPPC) server is the core of the X-Band Polarimetric radar system which stores and processes the rainfall data from the radar location.

In this server, all the data processing such as the rainfall data conversion from binary into text format, the package of scripting language for developing and processing the model, simulation and analyses are conducted in the server. Therefore, it is important for the server administrator to ensure the high-level network security is implemented. Since this server is to be placed in one of the public universities in Malaysia, this server system must be developed and installed according to the university network security policies. At the start, the DPPC server is accessible by using the private network and only registered users may access the data on the server. The web-based system, which the users can access and communicate, is under development. Three levels of users of the web-based system are being considered, which are the DPPC administer, the registered users and public users (without registration). For the registered users, they are allowed to download the X-Band rainfall data and the rainfall estimation results for their own purposes. For the public users, they can only view the results of rainfall estimation by using X-Band Polarimetric radar. As for the DPPC administer, who is the person responsible for monitoring the X-Band Polarimetric radar processed in real time with no errors, as well as managing the registered users and updating the web-based system when it is needed.

Based on the proposed architecture, the framework for web-based system core functions that provide the users to obtain the rainfall data from X-Band Polarimetric radar in real time is presented in Figure 5.

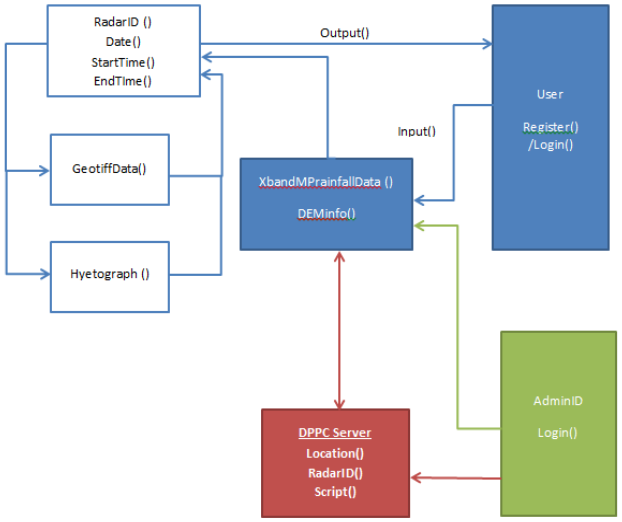

Figure 5: The framework for web-based system by using X-Band Polarimetric radar data.

The proposed web-based system framework will be applied in Malaysia by using X-Band Polarimetric radar data from the selected local area. The next step is to develop the prototype of this web-based system.

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AUTHORS PROFILE

Nooradilla Abu Hasan is currently doing her PhD in Disaster Risk and Management area at Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia (UTM), Kuala Lumpur, Malaysia. She received her Master Degree in Information Technology Specialization in Information Technology Management from Universiti Teknologi Malaysia (UTM), Johor, Malaysia in 2016. Previously, she received her Bachelor Degree in Information Technology (E-Commerce) from Universiti Malaysia Sabah (UMS), Sabah, Malaysia in 2008. Experienced as a research assistant for one year while she was study in her Master Degree. Her research interests are in Information System, Business Intelligence system and Disaster Preparedness and Prevention Management and Application.

Professor Dr Masa Goto is a Japanese Professor at Malaysia-Jpan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia (UTM), Kuala Lumpur since 2013. He also is the director of Disaster Preparedness and Prevention Center (DPPC) at MJIIT, UTM, Kuala Lumpur. He received his PhD from Rice University, Houston,

Texas, the USA in Environmental Science and Engineering field in 1985. Previously, he received his Bachelor Degree of Engineering in Environmental and Sanitary Engineering in 1976 and continue his Master Degree in 1978 at Kyoto University, Kyoto, Japan with his research in Municipal Solid Waste and Sewage Sludge Management. He is a member of the International Water Association and its ICA Specialists Group [IWA, SG on ICA], the Japan Society of Civil Engineers [JSCE], the Society of Environmental Instrumentation, Control and Automation [EICA, Japan] , the Licenced Professional Engineer, Japan, in two disciplines (i) Engineering Management and (ii) Environmental Engineering - Waste Management and Registered Graduate Engineer, BOE of Malaysia. He specially appointed as Professor of Shibaura Institute of Technology since 2013 until now and experienced as Visiting Professor of Hokkaido University form 2013- 2014 to manage the Biomass Waste Management Chair. Before joining MJIIT in 2013, he experienced working in the private sector as a senior research engineer and an executive research engineer for several multi-year national projects funded by the Japanese government or its subsidiary. He also is the inventor or co-inventor of more than 15 industrial patents, registered or pending, on bio-gasification, BDF production, wastewater treatment process and others and involved in establishing several ISO and JIS standards on biodegradable plastics. To date, he has more than 35 publications as author or co-author since he working with UTM. His research expertise and interests are in Solid Waste Management, Anaerobic Digestion and Fermentation, Wastewater Management, Renewable Energy (BDF, Bio-alcohol, Bio-hydrogen, and Biogas) and Disaster Management.

Professor Emeritus Kuniaki Miyamoto is awarded as Professor Emeritus by the University of Tsukuba in 2018. Previously, he is an Associate Professor at the University of Tsukuba since 2000 and become a Professor in 2003. He has graduated his Bachelor Degree in Civil Engineering in 1979 and pursues his Master Degree in Civil Engineering, Graduate Course of Science and Engineering from Ritsumeikan University, Kyoto, Japan. Later, in 1984 he is graduated from Doctoral program in Civil Engineering, Graduate Course of Science and Engineering, from Ritsumeikan University also. He experienced working Researcher at Disaster Prevention Research Association Foundation of Kyoto University in1984 and as Senior Researcher at Sabo Technical Center Foundation in 1986. In 1994, he works as Associate Professor at Tottori University, Japan before joining the University of Tsukuba. His research expertise and interest are in Hydraulic Engineering, Forest Science, Natural Disaster and Prevention Sciences