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The Progress Development of a Real-Time Monitoring System for Precipitable Water Vapor Measurements

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Abstract: This study reports the progress of development of a real-time monitoring system for Precipitable Water Vapor (PWV) at Universiti Kebangsaan Malaysia (UKM). The first stage of PWV system was developed under the LabVIEW platform and as of now, it is updated by adding the monitoring of Zenith Total Delay (ZTD) with a storage management. The ZTD parameter was estimated by using the Adaptive Neuro Fuzzy Inference System (ANFIS) Model that was generated by Matlab™. To estimate the ZTD value, the model input was taken from real-time data measured by the meteorological sensors (pressure, temperature and relative humidity) that was included in the system. The storage management system has been updated using a database management which capable to store the results of the monitoring data. A database was constructed using a MySQL that is open source database and integrated with the powerful of LabVIEW system. This system has been successfully implemented in our laboratory and proved easier to operate and provide a faster response under a windows platform. Furthermore, the real-time monitoring system data will be published in a website and their development was carried out. The data generated from this system will make easier to users around the world and provide benefits to forecasters and modelers to improve the accuracy of weather forecasts and predictions.

Key words: Monitoring system, ZTD, ANFIS, LabVIEW, database

INTRODUCTION

In the last decade, many scientists have been developed a tool to estimate water vapor content in the atmosphere. Since 1990s, Global Positioning System (GPS) is one of the tools that used to estimate water vapor profiles as well as Zenith Total Delay (ZTD) based on the ground-based GPS Meteorology (Bevis *et al*., 1992; Bar-Sever *et al*., 1998; Gendt., 1998; Suparta *et al*., 2008). GPS data may serve the estimation of water vapor content in atmosphere using their ZTD. The GPS technique work based on the signals electromagnetic that they are transmitted to a ground-based receiver at fixed location on the earth. During traveling, the signals have been delayed due to the characteristics of pressure, temperature and water vapor variability in the atmosphere. The total delay is measured and ZTD is obtained from the summation of the Zenith Hydrostatic Delay (ZHD) and the Zenith Wet Delay (ZWD). Since, the water vapor profiles provided by GPS is importance for mitigation of climate change, the accuracy and accessible are necessary.

However, sometimes the GPS receiver is not providing a full data 24 h period, especially in certain place which had extreme weather or area where no GPS receiver provided. Thus, it will influence the accuracy in the estimation of water vapor content in atmosphere. In that regard, we have previously developed a real-time monitoring PWV system using the Adaptive Neuro Fuzzy Inference System (ANFIS) and surface meteorological data as input (Suparta and Alhasa, 2013a). The system has been developed using a LabView platform. The system has been installed in the roof of research complex building at the Universiti Kebangsaan Malaysia (UKM) Bangi, Selangor, Malaysia. The PWV parameter is estimated using ANFIS Model that was generated by Matlab™ (Suparta and Alhasa, 2013b; Suparta and Alhasa, 2013c).

In line with the progress of development system, this study presents the updating of a real-time PWV monitoring system. The system was added with the ZTD monitoring and database for management storage. Similar to PWV estimation, the ZTD parameter is estimated using the ANFIS Model generated using Matlab™ (Suparta and Alhasa, 2013d). For database management, it is constructed using MySQL database where the software is open source provided by Oracle and integrated with LabView database connectivity.

Implementation of ZTD ANFIS Model: After the ZTD ANFIS Model was generated using the Matlab™, it is

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embedded in the system to determine of ZTD value using the surface meteorological data (Pressure (P), Temperature (T) and relative Humidity (H)) as inputs. The ZTD ANFIS Model is developed using the sugeno Fuzzy Inference System (FIS). The Sugeno Model has three main parts, fuzzification, rule evaluation and defuzzification as shown in Fig. 1.

The first stage is fuzzification process. The input of surface meteorological data that enter to FIS will be transformed from crisp values into a degree of membership function for linguistic terms of fuzzy set. There are three membership functions were embedded in the system for each input. This model is using the Gaussian membership function to transform them. The second stage is a rule of evaluation. There are three rules to get firing strength (α_1, α_2 and α_3) of each rule. The AND operator (T-norm) is used to obtained the output. For example; if P is x AND T is y AND H is z, then $\alpha_1 = f(P, T, H)$ where (P, T and H) are variable input, (x, y and z) are degree of membership value for each the input and f (P, T, H) is a crisp function in the consequent. The third stage is defuzzification process. After receiving the inputs, the values are presented in fuzzy set by the fuzzification process. In order to get the output in state crisp value, the defuzzification process is applied. The weighted average is used to produce crisp value in the defuzzification process. Figure 2-4 presented the design of fuzzification, a rule of evaluation and defuzzification of ZTD Model in this system, respectively. In Fig. 2, the input value is normalized and then enters to a membership function to transform crisp value into a degree

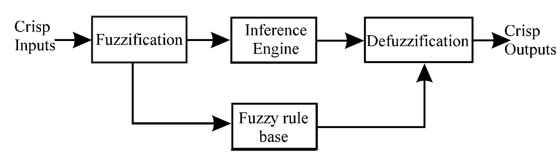


Fig. 1: Fuzzy Inference System (FIS)

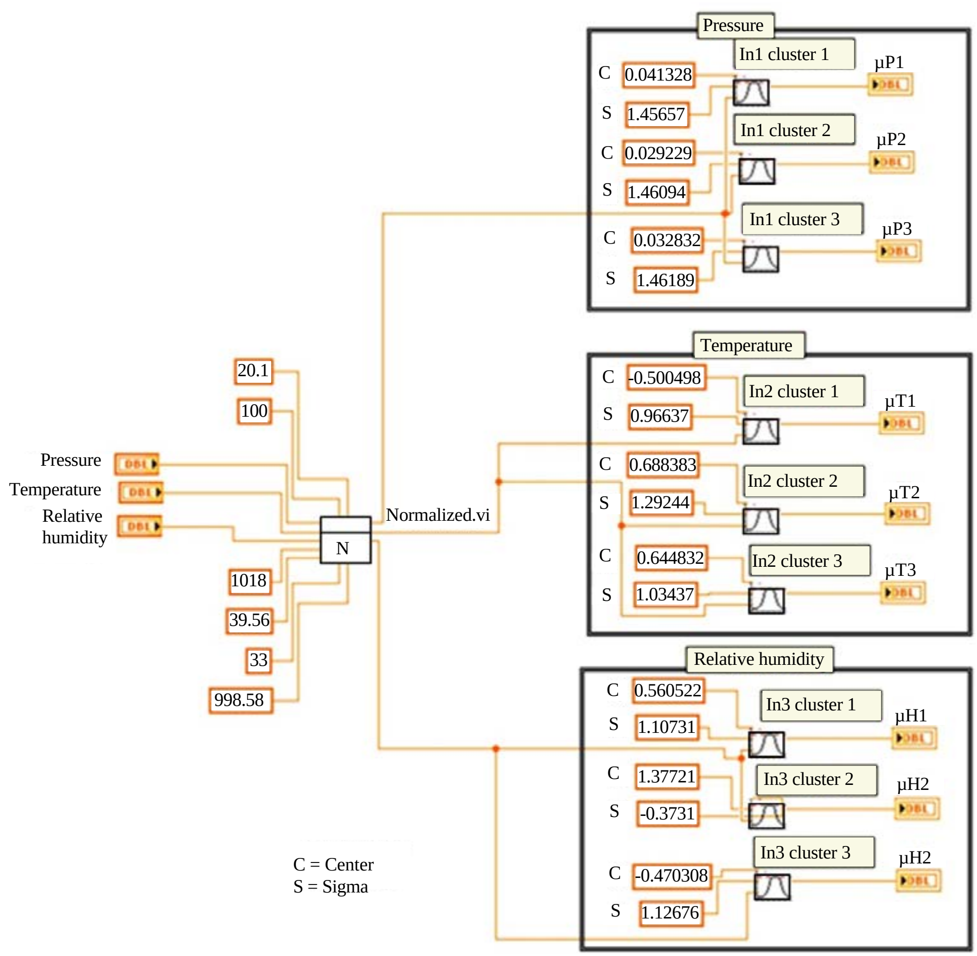


Fig. 2: Fuzzification block diagram of ZTD ANFIS Model in LabView

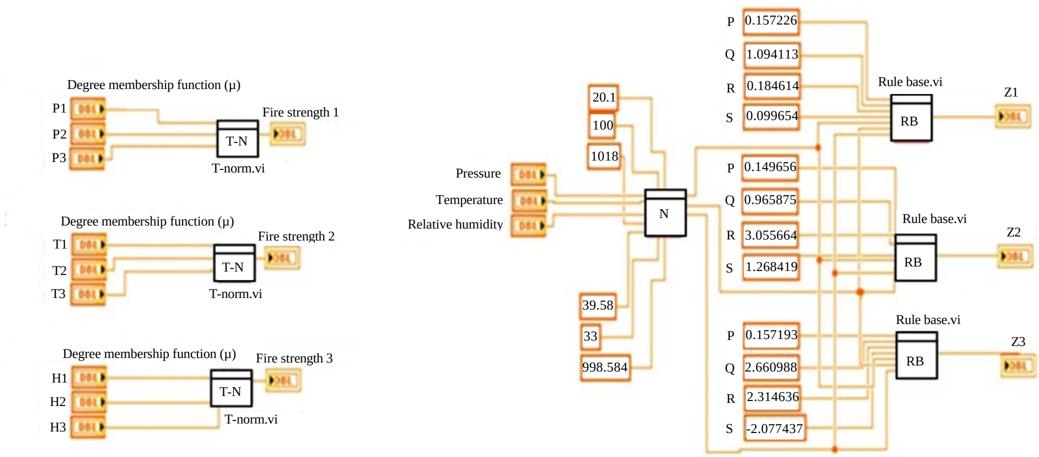


Fig. 3: A rule of evaluation block diagram of ZTD ANFIS Model in LabView

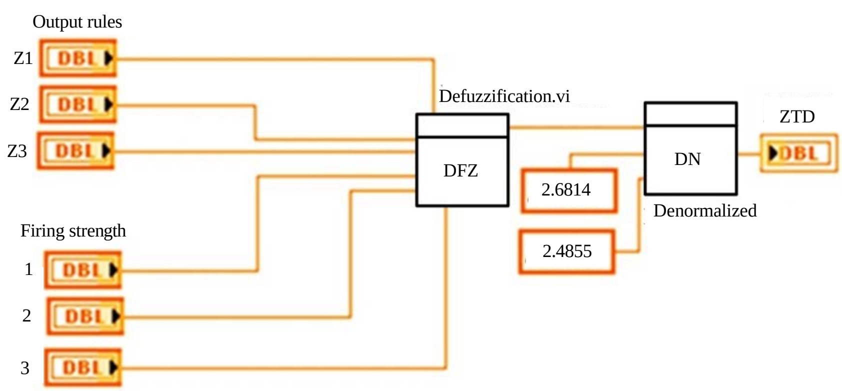


Fig. 4: Defuzzification block diagram of ZTD ANFIS model in LabView

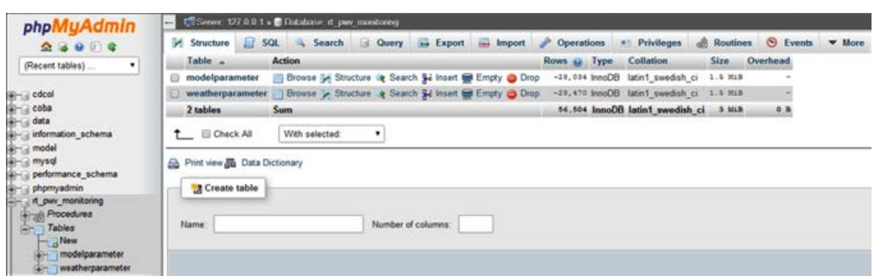


Fig. 5: Two tables of MySQL database in phpMyAdmin tool; WeatherParameter and ModelParameter

membership function. The membership functions and the degree membership functions are labeled with "in cluster" and "μP, μT and μH", respectively. From Fig. 3, the values of degree membership functions are evaluated with operator T-norm to get the firing strength value. The linear equations with consequent parameter (P, Q, R and S) are used to get the output level value (Z1, Z2, and Z3) of each rule. Since, each rule has a crisp output, the final ZTD output is obtained via weighted average where the output level (Z1, Z2 and Z3) of each rule is weighted by the firing strength as shown in Fig. 4.

Labview communication with mysql database: In this system, MySQL database is used as the database management storage. There are some steps must to be prepared, before the integrated between MySQL and LabView. The first step, a computer was used as a server with installing the XAMPP software version 1.8.2 or 1.8.3 into computer. In the XAMPP software, the MySQL database is derived with activating the phpMyAdmin tools and localhost is set using port 3306. In the database, two tables were setup for the storage data measurement, WeatherParamater and ModelParameter as shown in Fig. 5. The second step is to install the Driver Open

Database Connectivity (ODBC) server MSI for MySQL database. Since, LabView database connectivity tools can not directly communicate with the MySQL database, they need OLE DB provider for ODBC. Figure 6 shows the hierarchical relations between these concepts (National Instrument Cooperation, 2008).

After the installation the ODBC driver completed, the LabView is ready to connect with the MySQL database. Figure 7 shows that the block diagram for read and write database using the LabView database connectivity tool. In this system, DB Tools Open Connection.vi, DB Tools Select Data.vi, DB Tools Insert Data.vi and DB Tools Close Connection.vi were used to operate the read and write database in LabView. DB Tools Open Connection.vi has a function to open the communication with various databases by using the specific of Data Name Source (DNS). As shown in Fig. 7, the "Connection Reference" to DNS is written by string "MYDB". To read the data from the database, LabView has provided the DB Tools Select Data.vi which needs the specific "table name" to return data from table in the database. DB Tools Select Data.vi allow to read and limit the returned data by writing the specific name in "columns string array" as shown in Fig. 7a and b. The similar technique was used to insert or write data to the database in LabView. DB Tools Insert Data.vi needs the specific "table name" to access the table and column in the database. DB Tools Insert Data.vi accepts any types of data input. As shown in Fig. 7, the input type data is cluster which it consists of numerical with floating number and date time string.

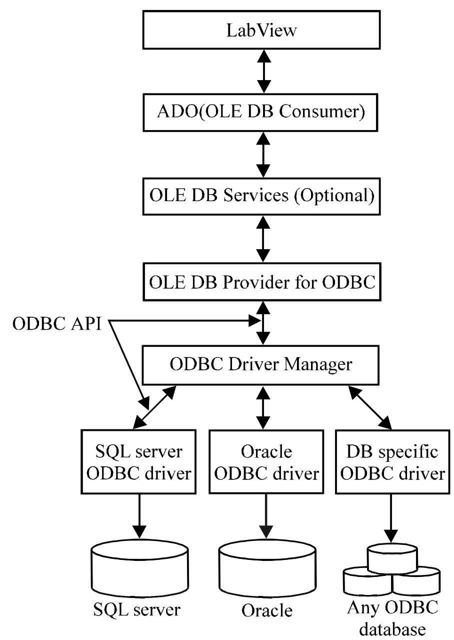


Fig. 6: Hierarchical relationship between LabView and a database using OLE DB provided for ODBC

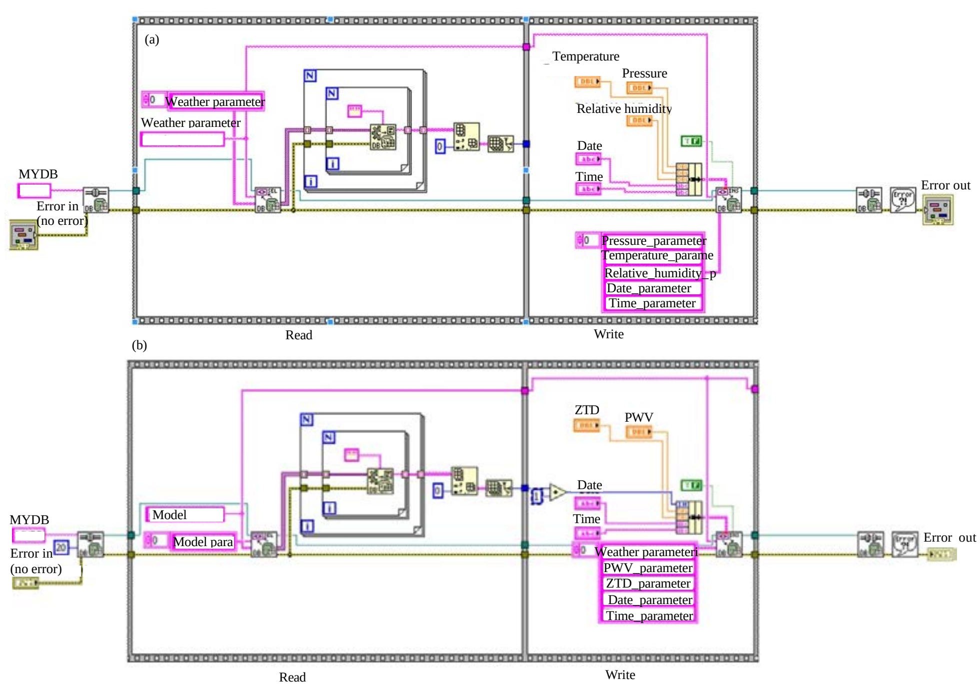


Fig. 7: Block diagram of read and write database using LabView for: a) WeatherParameter and b) ModelParameter in creating a table

RESULTS AND DISCUSSION

The output of the program is shown in Fig. 8. The different view between the old program and the updating program, the system has two pages for selecting view of results. The first page is used to see the trend of sensor meteorological data measurements such as pressure, temperature and relative humidity) and calculation results for ZTD and PWV models. For the basic statistic analysis and analog display, the user can open the second page "Analog and Statistic".

After updating progress, the system now has the capability to estimate ZTD value directly in the atmosphere in a real-time condition. In this system, the estimation of ZTD value does not need the GPS data for processing. They use only the surface meteorological data (P, T and H) to get the ZTD value. In the system, the surface meteorological data is supported by MET4A sensor. The MET4A sensor is supported the surface meteorological data which is included in the system.

According to Fig. 8, the trend of ZTD value is almost similar to PWV trend. Both trends for area of UKM Bangi depend on the fluctuation of H. ZTD decreased dramatically after reaching the highest daily reading when the H dropped drastically.

In the management of data storage, the old system has the capabilities to storage the data automatically into the disk in computer. The data will be saved in the form ".txt" file with the format name is YYMMDD.txt where the YY is the year, MM is the month and DD is the day. Now, the system has been facilitated with the database storage in the management storage. The purpose of embedded a database management system is to make easier the users around the word to get data from everywhere. To activate database in the system, the user needs a click switch on database. A LED colour indicator will be changed to blue when the system has been connecting with database.

Figure 8 and 9 showed the result for data measurement in MySQL database. In our database, we have two tables for the data storage. "WeatherParameter"

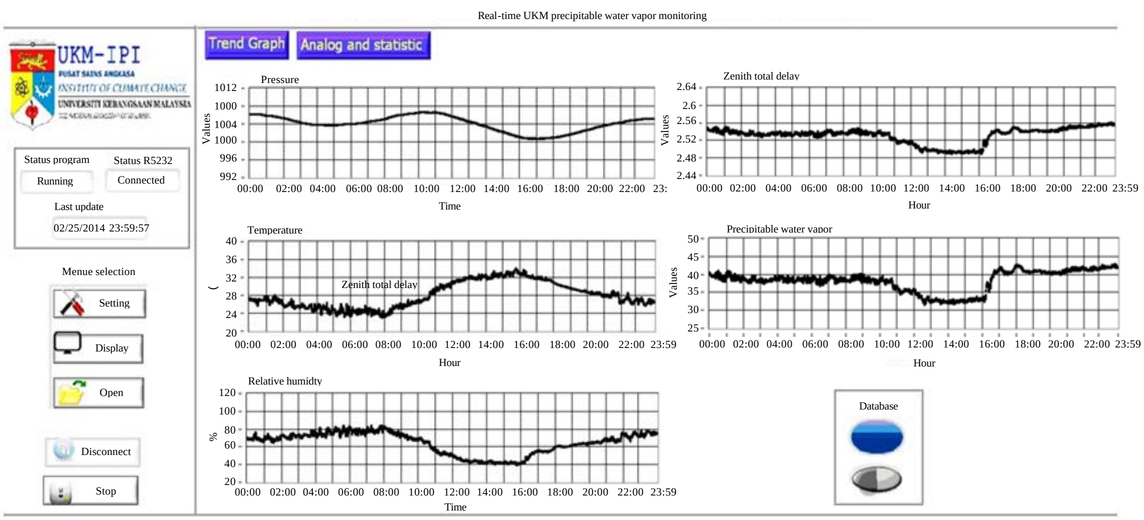
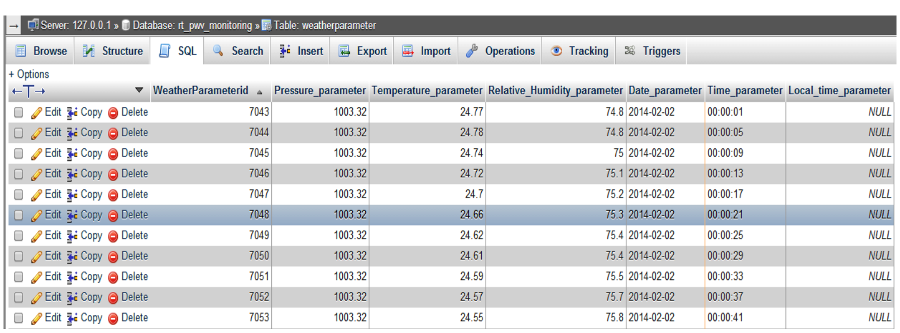


Fig. 8: The result of updating real-time UKM precipitable water vapor monitoring for 14 February 2014

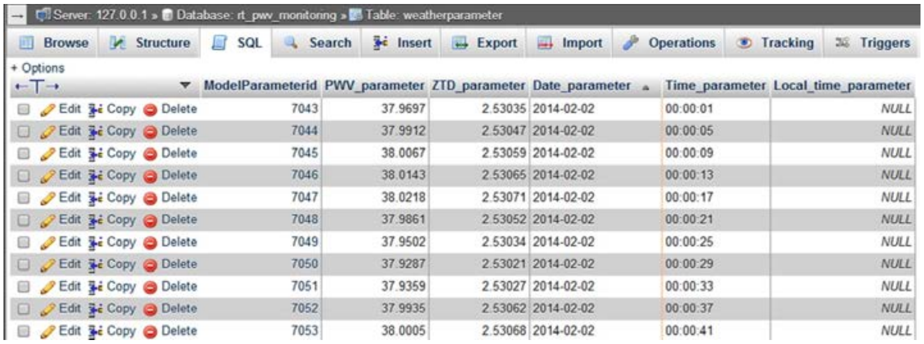

Server: 127.0.0.1 » Database: rt_pwv_monitoring » Table: weatherparameter

Browse | Structure | SQL | Search | Insert | Export | Import | Operations | Tracking | Triggers

+ Options

	WeatherParameterid	Pressure_parameter	Temperature_parameter	Relative_Humidity_parameter	Date_parameter	Time_parameter	Local_time_parameter
Edit Copy Delete	7043	1003.32	24.77	74.8	2014-02-02	00:00:01	NULL
Edit Copy Delete	7044	1003.32	24.78	74.8	2014-02-02	00:00:05	NULL
Edit Copy Delete	7045	1003.32	24.74	75	2014-02-02	00:00:09	NULL
Edit Copy Delete	7046	1003.32	24.72	75.1	2014-02-02	00:00:13	NULL
Edit Copy Delete	7047	1003.32	24.7	75.2	2014-02-02	00:00:17	NULL
Edit Copy Delete	7048	1003.32	24.66	75.3	2014-02-02	00:00:21	NULL
Edit Copy Delete	7049	1003.32	24.62	75.4	2014-02-02	00:00:25	NULL
Edit Copy Delete	7050	1003.32	24.61	75.4	2014-02-02	00:00:29	NULL
Edit Copy Delete	7051	1003.32	24.59	75.5	2014-02-02	00:00:33	NULL
Edit Copy Delete	7052	1003.32	24.57	75.7	2014-02-02	00:00:37	NULL
Edit Copy Delete	7053	1003.32	24.55	75.8	2014-02-02	00:00:41	NULL

Fig. 9: WeatherParameter table in phpMyAdmin tool



	ModelParameterid	PWV_parameter	ZTD_parameter	Date_parameter	Time_parameter	Local_time_parameter
Edit Copy Delete	7043	37.9697	2.53035	2014-02-02	00:00:01	NULL
Edit Copy Delete	7044	37.9912	2.53047	2014-02-02	00:00:05	NULL
Edit Copy Delete	7045	38.0067	2.53059	2014-02-02	00:00:09	NULL
Edit Copy Delete	7046	38.0143	2.53065	2014-02-02	00:00:13	NULL
Edit Copy Delete	7047	38.0218	2.53071	2014-02-02	00:00:17	NULL
Edit Copy Delete	7048	37.9861	2.53052	2014-02-02	00:00:21	NULL
Edit Copy Delete	7049	37.9502	2.53034	2014-02-02	00:00:25	NULL
Edit Copy Delete	7050	37.9287	2.53021	2014-02-02	00:00:29	NULL
Edit Copy Delete	7051	37.9359	2.53027	2014-02-02	00:00:33	NULL
Edit Copy Delete	7052	37.9935	2.53062	2014-02-02	00:00:37	NULL
Edit Copy Delete	7053	38.0005	2.53068	2014-02-02	00:00:41	NULL

Fig. 10: ModelParameter table in phpMyAdmin tool

table is used to storage the measurement of surface metrological data and “ModelParameter” table is used to storage the calculation results of ZTD and PWV models. The statement of “Select *from table name” is written in “Run SQL query” command to operate the corresponding database and get the content of data table. As shown in Fig. 10, the “WeatherParameter” table has eight columns and the “ModelParameter” table has six columns. The system was successfully connecting with database and storage data to MySQL database in real-time.

However, since the adding of new database management storage, the capability of the system in generating data measurements has decreased. Before the updating, the system can generate data with interval 4 sec. Now the system stabilized generates data with interval 10 sec. It happens maybe the system has taken a lot of time to communicate with the database for synchronization time interval.

CONCLUSION

The progress of the development of a real-time of UKM Precipitable Water Vapor (PWV) has successfully been updated by adding monitoring of the Zenith Total Delay (ZTD) and develop storage management database. This system has been tested and has the capability to monitor directly the amount of PWV and ZTD in real time by using the surface meteorological data as the input. More than that by using the LabView database connectivity toolkit, the system has the capability to connect with the MySQL database for storing the data measurements.

For future work, real-time monitoring system data will be published in the website and their development is being carried out. With this system, data can be easily generated by users elsewhere.

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