Web-Based Fuzzy Time Series for Environmental Temperature and Relative Humidity Prediction

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***Abstract* - In this research, we develop a web-based instrument for air temperature amplitude (T) and relative humidity (RH) predictions using internet connection. There are decisive factors of climate on Earth related to climate change and global warming. Additionally, air temperature amplitude and relative humidity play important roles for the health of the Earth. We developed a wireless sensor system that transmits data to the web server via online internet connection. Semiconductor air temperature and humidity sensors are installed in remote terminal stations. Acquired data were transformed from analog to digital using a converter circuit, and the results were stored in a local database. A computer application is developed to send data online and in real time to a web server using an internet modem. Transmitted data are received and saved on a web hosting database service. For prediction of air temperature amplitude and relative humidity, a Fuzzy Time Series Algorithm induced by Markov transition matrix is used and is pre-installed in the web server. Performance testing for air temperature amplitude and relative humidity measurements showed encouraging results that correspond well with correlation coefficient (R) close to 1. Those testing revealed values R of temperature is 0.9987 and R of RH =0.9946, with minor errors of T=0.18 Celsius degree and RH=1.43%. Results of temperature amplitude and humidity predictions are displayed real time on the dashboard for one day ahead. Testing results also indicated major deviations between actual and predicted data whenever there are sudden fluctuations in the readings of temperature amplitude and relative humidity. Subsequent test results showed that the Fuzzy Time Series-Markov model has an error of 4.6% for temperature and 2.76% for relative humidity prediction, respectively. When further calculations using mean absolute percentage error (MAPE) were carried out, these error values further varied, depending on the number of data and the data characteristics themselves.**

Keywords — web-based; internet connection; prediction; actual; error

I. Introduction

Temperature and humidity have important roles in human life. In the field of health, temperature and humidity measurements can be used to predict the spread of diseases. Amplitude of maximum air temperature and relative humidity are the main factors in the spread of dengue fever. Predicting temperature and humidity is very important in the effort of reducing the number of death caused by climate change [1]. A mathematical model that depends on time is needed to model predictions of temperature and humidity. A prediction model has been developed here and is able to predict the future based on data from the past. One of the tools required for the prediction model is fuzzy time, which is a concept of fuzzy set theory with linguistic variables and fuzzy logic to perform mathematical predictions [2]. Once a prediction model is made, a variant method known as Fuzzy Time Series (FTS) is employed. This method was developed into Adaptive Fuzzy Time Series and was once implemented to predict the number of tourists in Taiwan [3].

Time series development includes the Fuzzy Time Series with time-invariant introduced by Song and Chissom, and the Fuzzy Time Series Based on Fuzzy Clustering Method developed by Cheng et al. [4]. A prediction model based on these has been implemented to predict the productivity of plants of uncertain production pattern in India. From these studies, we can conclude that Fuzzy Time Series can be utilized in the field of agribusiness management [5]. A Fuzzy Time Series has also been successfully used to predict daily stock index on the Shanghai Compound Index (SCSI). This particular research led to an important conclusion that interval length affects the number of fuzzy sets that in turn also affects results in the formation of Fuzzy Relationship [6].

In the field of environmental monitoring, information technology is needed for the measurement, control and processing of environmental data. The use of wireless sensors to measure physical parameters of the environment allows data from the field to be obtained in real-time [7]. Wireless sensor technology has many advantages such as low-cost, minimal maintenance, and wide range of monitoring abilities [8]. The use of wireless sensor can be integrated into a computer so that a model prediction algorithm can be developed [9].

Real-time data gained from a source can be implemented in early warning systems by using a microblogging monitoring system. Input data can be used for a decision support system using a knowledge-based framework. The amalgamation

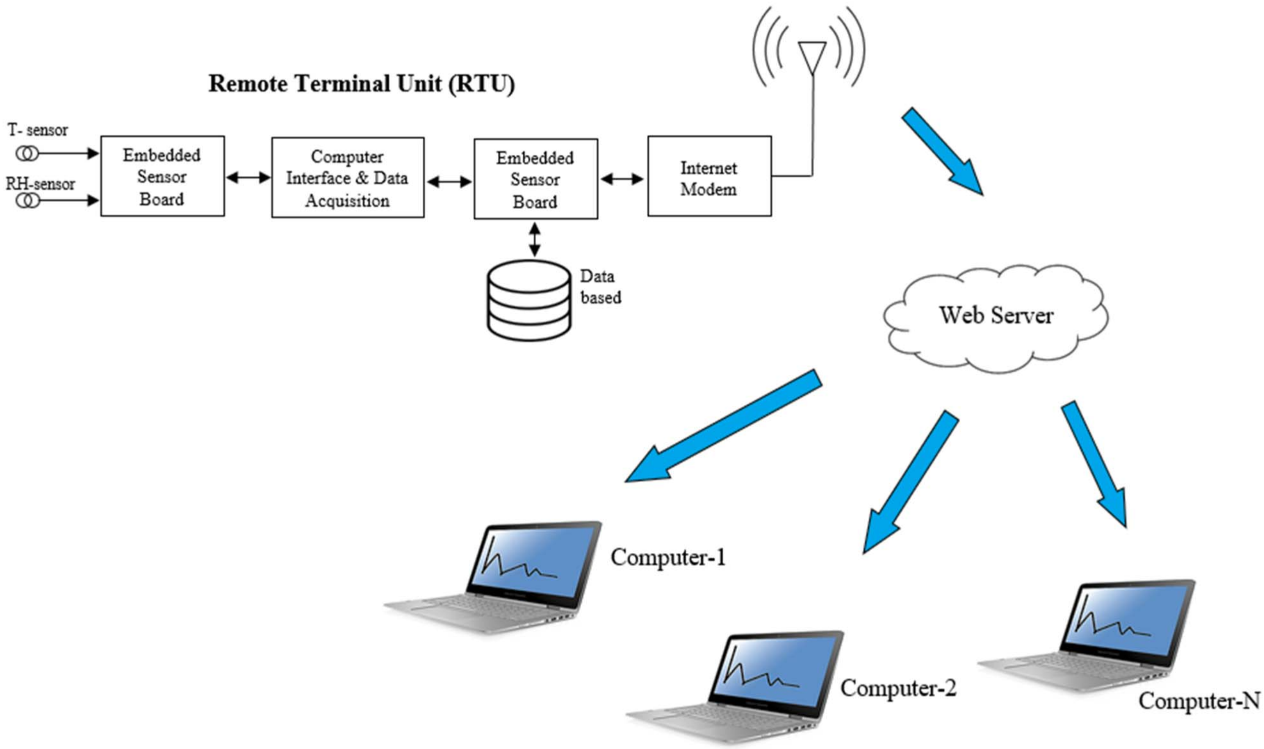


Fig. 1. Overview of an online temperature and relative humidity *wireless* sensor system.

between the artificial intelligence techniques of high-level and low-level analysis systems can generate a flexible system with better resistance [10].

Prior research has been conducted temperature prediction using Sing Fuzzy Time Series and Multivariate Markov Chain [11]. In the study, computation was not done using online system. In this study, we find a method for an online wireless data acquisition of physical quantities of temperature and humidity using broadband internet. This prediction system has the advantage of being able to make predictions based on cloud computing. The developed system has a wide range of measurement and prediction areas. In the system instrument, an integrated algorithm fuzzy time series induced by Markov transition matrix, which is called fuzzy-Markov time series, is used to predict the amplitude of air temperature and relative humidity on a daily basis. The *transition probability* on *fuzzy logic relation group* is used for variable movements between the time in the past the prediction of the variables for the future.

II. Realization of a Temperature and Relative Humidity Wireless Sensor System

A temperature and relative humidity *Wireless Sensor System* consist of sensors that convert physical parameters in the remote terminal unit (RTU) and wirelessly send readings to the web server. Wireless sensor network is advantageous in that ata acquisition can be conducted in real- time. Sensors in the wireless sensor are equipped with a wireless interface that enables them to communicate with one another in order to create a network. The main components of a temperature and relative humidity *Wireless Sensor System* are a sensor node, a base station, a database, and a web server. The base station receives measurement data from the sensor node that is periodically distributed and then these data are forwarded to the server database for storage and management [12]. An overview of an online temperature and relative humidity *Wireless Sensor System* is shown in Fig. 1.

In this study, we use the embedded electronic temperature sensor (T) and Relative Humidity (RH) which alter the physical quantities of temperature and relative humidity into electrical signals. The sensor has been equipped with signal conditioning, Analog to Digital Converter (ADC) and a microprocessor for data communication with external devices. The sensor has been calibrated by the vendor and has been equipped with a data communication system using a I2C (Inter-Integrated Circuit). To read the data we use the data acquisition device that serves to retrieve the data of temperature and relative humidity. The data acquisition system is also used as a sensor interface device that connects to a computer.

The functions of RTU computer are to acquire sensor data, store those data, and send them via broadband internet. A socket programming is embedded into the RTU computer to read temperature and Relative Humidity data which are sent to the microcontroller. The computer and microcontroller themselves are connected to a UART serial protocol via a

COM1 port. Then the data acquisition system is run by a socket programming.

Data acquisition system between the computer and microcontroller is conducted using MASTER – SLAVE serial communication in which each microcontroller is in idle mode and waits for an order from the computer. Once the computer sends an order, the microcontroller acquires data of temperature and Relative Humidity concentration and sends those to the computer via a UART protocol. After that, the computer keeps the results of data acquisition in the database. Subsequent data acquisitions are conducted after the computer finishes storing data in the database and send those data to a web server using internet connection.

Data on the system display are sent from local databases. In the local host computer, an internet modem is installed to connect the online host. Connection is possible with the use of computer programming on the apache webserver that processes data from the local host to the online database. The apache is also installed on the online webserver and it activates a library link on the webserver in order to communicate with the local host. In this research, data are sent with the help of a function that processes data sending.

On the webserver, an online database has been created and a receiver and storage application scripts have been written. Data communication verification is done by giving feedbacks and validating data, as to avoid error and redundancy.

III. Realization of Prediction by Fuzzy Time Series-Markov Chain

The steps of the Fuzzy Time Series-Markov Chain have been realized in the computer program and installed on the webserver. Computational results have been displayed on the dashboard and has been accessible on every computer that has internet network connection. In order to build the software for prediction system of air temperature and relative humidity based on Fuzzy Time Series-Markov Chain algorithm, we use PHP and MySQL database management systems. In the Fuzzy Time Series-Markov Chain, the transition matrix is applied to the weighted process so that the predicted outcome can be adjusted by displacement state of the Fuzzy Logic Relationships Groups. The steps of modeling predictions of air temperature and relative humidity by using Fuzzy Time Series-Markov Chain are described as follow [4]:

Step 1 : Determine the *universe discourse U* from historical data of daily air temperature and relative humidity.

Step 2 : *Partition* the *universe discourse U* into *intervals* with the same length. This is done to get a linguistic value in some intervals.

Step 3 : Determine the *Fuzzy Sets* in the *universe discourse U*.

Step 4 : Fuzzy the historical data of air temperature and relative humidity environment. This step is performed to find the equivalent of each input data so that Fuzzy Logical Relationships of each of the fuzzy process result can be determined.

Step 5 : Based on the results of previous steps then the fifth step is grouping Fuzzy Logical Relationship and hence a Fuzzy Logical Relation Group is obtained. After that, a Markov transition matrix with n x n dimension is made.

Step 6 : Adjust the tendency of predictive value.

Step 7 : Determine prediction results by using the formula.

To measure the deviation of the models that have been built, we use the Mean Absolute Percentage Error (MAPE) concept as shown in equation (1):

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{Actual\ \ value(t) - Forcast(t)}{Actual\ \ value(t)}\right| \quad (1)$$

A flowchart showing the determination of amplitude of air temperature and relative humidity is shown in Fig. 2.

IV. Result and Discussion

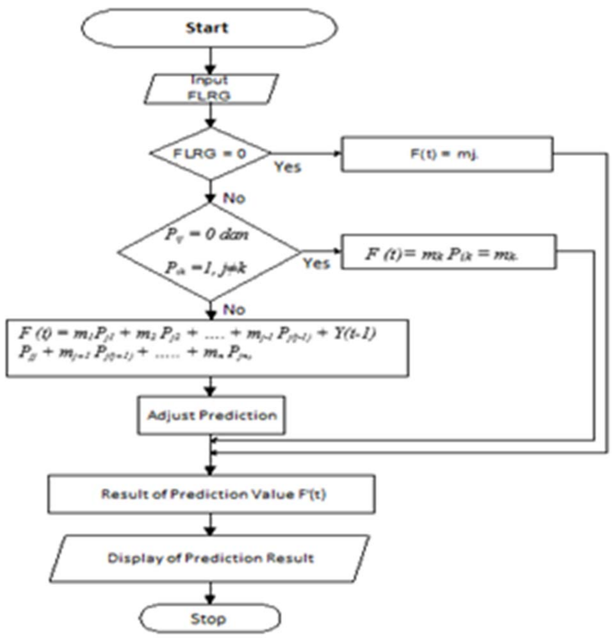


Fig. 2. Flowchart showing the determination of temperature amplitude and relative humidity prediction

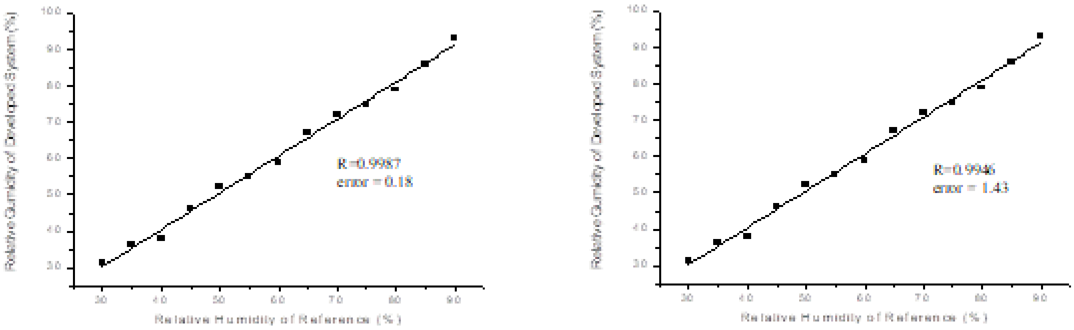


Fig. 3. Performance testing graphs of the temperature and humidity prediction system developed.

This research tested the performance of the measurement and prediction system developed. Testing was first carried out against the performance of the temperature and humidity measurement system. These testing were conducted by comparing measurement values from the system against those of standard measurements done in the field. Results of these testing are shown in the graphs of Fig. 3.

Efficacy of the system developed is shown by values of correlation coefficient (R) and mean deviation [13]. Value of R close to 1 indicates compatibility with standard equipment close to 100%. Other than this, system efficacy is also indicated by error values, which shows the gap between values from standard measurements and those of the system developed. This discrepancy directly reveals error values for temperature (T) and relative humidity (RH). Measurements for these two values show values R of T = 0.9987 and R of RH = 0.9946. These mean that the system developed has excellent performance as the error value is close to 1. On the other hand, calculations of mean deviation revealed values temperature amplitude is 0.18 Celsius degree and relative humidity is RH=1.43%. These minor deviations further prove that the system developed is of great performance to be used for predictions of temperature amplitude and relative humidity. On-line Fuzzy Time Series-Markov for air temperature amplitude and relative humidity prediction can be accessed via an internet network. The web design of prediction results and the comparison between predicted and actual results are shown in Fig. 4.

Data information that can be accessed from this website include: maps for sensors, acquisition time, and values of temperature and relative humidity. Data communication system testing is performed on the transmission time between the database servers at the local host to an online webserver of any coded ID data. Values of online measurement results, real-time temperature, and relative humidity are saved in a server database. In addition, accuracy of data transmission between the concentration of local host database and online database was also checked. It can be seen that the system is very accurate because there is no difference between the data connections that have been sent and received.

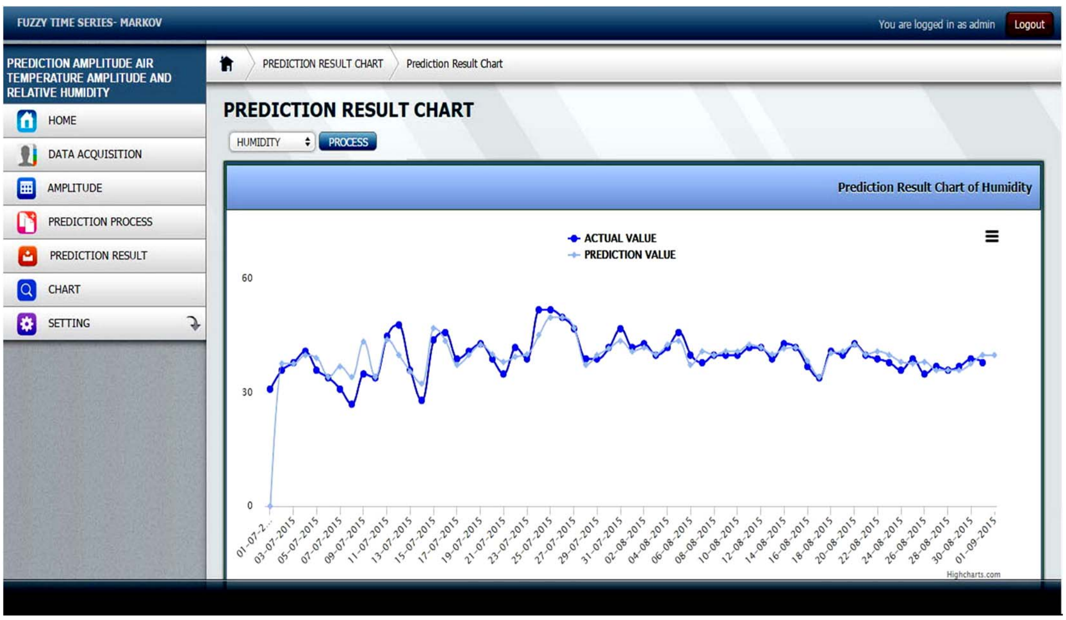
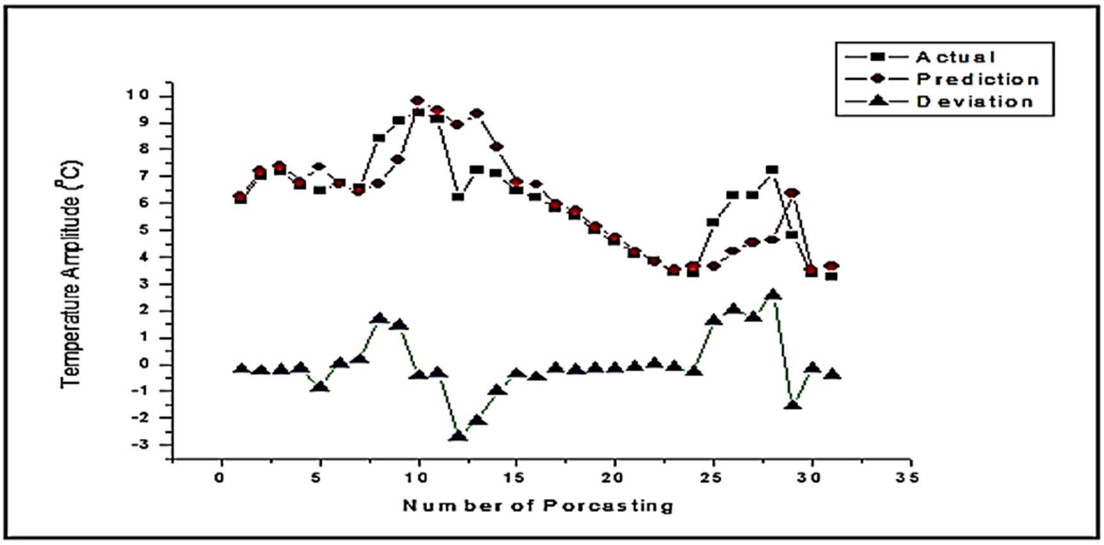
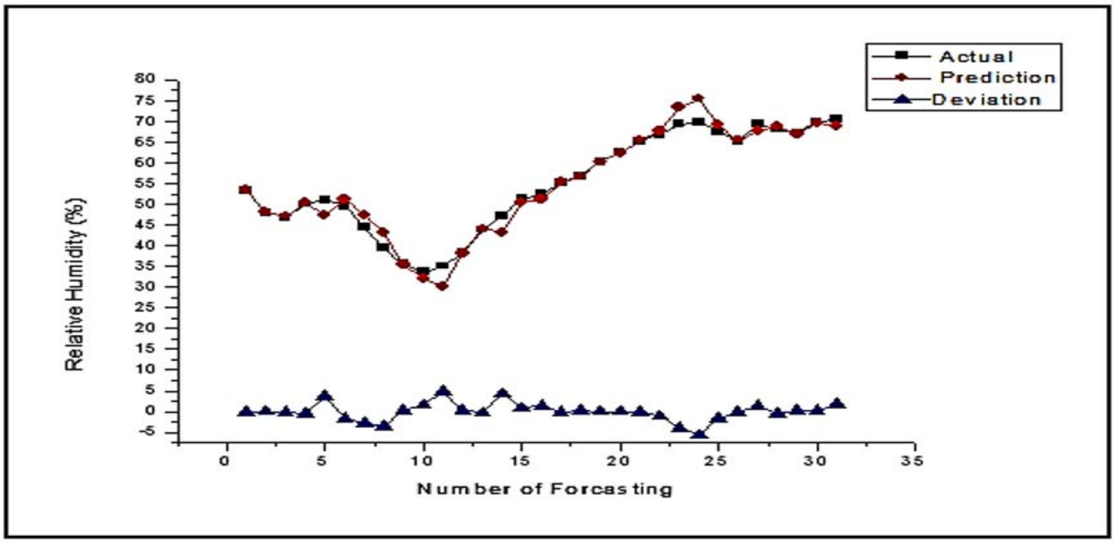


Fig. 4. Web-based graphic display of the wireless sensor system.



(a)



(b)

Fig. 5. Performance testing graphs for prediction results: (a) temperature, and (b) relative humidity.

Testing for prediction performance using Fuzzy Time Series were carried out by comparing values of prediction against those of actual measurements obtained for the next one step. In this system, the interval is set for one day. Graphs showing performance testing results are given in Fig. 5.

The graphs consist of three charts of predicted data, actual data for the next day, deviation between predicted and actual data. Both prediction results underwent fluctuations in their deviations. The greatest deviation was observed when there is abrupt major interval changes in short time. These abrupt changes prevent the Fuzzy Time Series system from making accurate predictions. Both prediction results also show that relative humidity values are smoother as relative humidity measurements did not undergo abrupt fluctuation.

The difference between actual data of air temperature amplitude and relative humidity with data of predicted results is measured by the Mean Absolute Percentage Error (MAPE). By applying formula (1) to the different categories of data, we obtained their Mean Absolute Percentage Error as shown in Table 2. Furthermore, the average error for temperature is 4.6%, whereas for relative humidity is 2.76%. This research tested the effects of the number of data on MAPE value prediction. Testing was carried out on temperature data that vary for 1 to 7 months. Table 1 shows the trend of MAPE value that decreases along with the addition of data forecasting.

TABLE 1. MAPE FROM VARIOUS EXPERIMENTS

Data Period	Number of Data	MAPE (%)
September 2016	30	5.5
October 2016	61	5.4
November 2016	91	4.8
December 2016	122	4.6
January 2017	153	4.1
February 2017	182	4.0
March 2017	213	3.9
Average		4.6

V. CONCLUSION

Data of environmental temperature amplitude and relative humidity can be obtained online, and then processed and displayed on a website with the help of an internet network. The measurement developed in this research possesses high correlation coefficient R close of 1 in relation to reference measurement instruments. The Fuzzy Time Series-Markov Chain could be used to predict the amplitude of environment temperature and relative humidity for one day ahead. The prediction period is based on the prediction theory using Fuzzy Time series which produces one step forward data. By replacing the data with monthly interval then the system has been able to produce prediction results one month ahead. The system is based on verification data sent by a local host database and accepted by a webserver. Results of predictions for temperature amplitude and relative humidity are displayed in real time on a dashboard for one day forward. Fluctuations in deviations between predicted and actual values were also observed in this research. The highest deviation was observed when there were abrupt fluctuations in the readings of temperature amplitude and relative humidity. Test results show that the Fuzzy Time Series-Markov model has an error of 4.6% for temperature amplitude and 2.76% for relative humidity. When these values were further calculated by using the mean absolute percentage error (MAPE) method, results varied, depending on the number of data and data characteristics.

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