Weather Forecast using Kalman Filter Algorithm with Warning System via GSM and Android Application

by

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APPROVAL SHEET

This is to certify that I have supervised the preparation of and read the thesis paper prepared by **Trexia D. Capapas, Jezzelle Joyce Clarice M. Paule, and Rochelle Lynn S. Vista** entitled **Weather Forecast using Kalman Filter Algorithm with Warning System via GSM and Android Application** and that the said paper has been submitted for final examination by the Oral Examination Committee.

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As members of the Oral Examination Committee, we certify that we have examined this paper and hereby recommend that it be accepted as fulfillment of the thesis requirement for the degree in **Bachelor of Science in Computer Engineering**.

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This thesis paper is hereby approved and accepted by the School of Electrical, Electronics and Computer Engineering as fulfillment of the thesis requirement for the degree in **Bachelor of Science in Computer Engineering**.

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ABSTRACT

The Kalman Filter Algorithm filters the sensor's data and process data which are used for predicting the next state or value. The algorithm is used in this study to predict the weather condition on an hourly basis for a given location. The goal is to implement the processes and the equations of the basic Kalman Filter Algorithm in order to produce a forecast based on the given set of available data used to train the system. The device uses a microcontroller, specifically PIC16F877A and is integrated with different sensors for each parameter and wireless technology for the data transfer. The sensors include LM35 for temperature, the capacitive humidity kit for humidity, MPX114AP for measuring the pressure and Zigbee technology for wireless data transfer. The system includes methods for alerting people by using GSM and Android application through Bluetooth. The tests conducted show that the sensors integrated in the device for measuring temperature, pressure and relative humidity produced almost the same measurements as the instruments used for measuring the actual value of the said parameters. Furthermore, statistical tests show that the system forecast is accurate as evidenced by the small per cent difference between the predicted and the actual values obtained from measurements.

Keywords: Kalman filter, weather forecasting

Chapter I

INTRODUCTION

The weather is basically a condition of the atmosphere at a certain time and place and is measured by several parameters that contribute to it. Some of the weather parameters are temperature, dry and wet bulb, amount of rainfall, dew point, humidity, pressure and wind. This study will focus on forecasting a weather condition at a certain time in the future wherein a warning system will be used to inform the people of incoming weather condition in the specific area. Forecasting deals with the prediction of the upcoming weather condition and varies from different time and location. Weather forecasts can be made using statistical dependencies, which use predictor variables to extrapolate the weather situation, or simulations to gain information about the possible state of the weather in the future. The prediction of weather conditions will be based on the measurements gathered from the sensors of different parameters that affect weather. The device containing the sensors will be placed in one location in the chosen locality.

Weather forecasting is considered as one of the objectives in a research dealing with the atmosphere. K. Lerner and B. Lerner stated in the year 2003 that some methods used in forecasting are: Climatology Method, Analog Method, and Numerical Weather Prediction (NWP). The Climatology Method is a simple way of forecasting and involves average statistics that are gathered in many years. The Analog Method is a forecasting method that is more complicated compared to the Climatology Method. This method basically examines the present forecast and compares it to the past forecasts which actually look familiar or form an analogy. Basically, the forecaster would assume that the forecast would behave in the same as the weather did in the past. On the other hand, Numerical Weather Prediction (NWP) is an algorithm the that uses a computer for forecasting. Forecast models run on supercomputers which show the prediction on weather parameters such as temperature, humidity, pressure, rainfall and wind. The features predicted by the supercomputers which interact with each other are examined by the forecaster and used to produce the present weather.

There are some downsides in the existing prediction method. The said method is only effective when most of the data gathered are the same with the expected data in a specific time of the year. Thus, if the values were different at that time, climatology method will not succeed, which will result in a difference between the previous and current time. In addition, NWP’s equation in predicting certain parameters leads to a low precision and low accuracy, especially when the previous data are completely unknown. From the dissertation of Hester Gerbrecht Marx in 2008, "Forecasts generated by Numerical Weather Prediction (NWP) models are imperfect due to errors in the initial and boundary conditions that are fed into the model. Therefore, there is a need to apply statistical post-processing techniques in modeled forecast fields to improve forecast quality and value”.

The objective of this study is to design a system for weather prediction with a warning system via GSM and Android Application.. Specifically, it aims to achieve the following: (i) to design and implement a device that will measure and monitor actual basic weather parameters such as temperature, pressure and relative humidity, (ii) to develop and apply an algorithm for predicting weather conditions, (iii) to write a program for the algorithm and use 80% available data sets to train the system, (iv) to use 20% of the available data sets to validate the system, (v) to simulate the system by applying available initial conditions such as those provided by the device for monitoring actual weather conditions, (vi) to test the system and determine in terms of the limits of its capabilities in predicting weather conditions, (vii) to develop an application program to provide access by the general public to the predicted values.

This study will be significant in informing an individual or group of people with the information on the anticipated weather over forthcoming one to three days for sites in the areas so that they may take necessary precautions from a coming danger in the chosen locality. Thus, in these cases, forecasts are one of the main aspects that may help save lives or prevent damage, which could be avoided by preventive arrangements. The warning will be based on the predicted weather due to different parameters at a specific date or time. Furthermore, the device will use an algorithm in predicting the weather by analyzing vital parameters such as probabilities of temperature, atmospheric pressure, and relative humidity. Data regarding weather conditions on a specific locality from PAGASA will be monitored in order to produce accurate and valid weather forecast.

Since the weather is continuous, multidimensional, dynamic and chaotic, and hence difficult to predict, the results will not be very accurate. Due to these circumstances, weather is observed to be changing simultaneously, which leads to a conclusion that forecast can be out of date easily. Hence, the algorithm will determine the limits of the predicted weather condition rather than its accuracy. Moreover, Quezon City will be the chosen locality wherein data measured by the sensors located in the said locality will be processed using an algorithm that is not being used by PAGASA such as the Kalman filter. The wireless device would basically send the data measured using the sensors into the data logger. After that, measured parameters will be used in the application of the algorithm for prediction purpose. Using the algorithm, parameters used by PAGASA can also be predicted. These include rainfall, maximum and minimum temperature, dew point, vapor pressure, relative humidity, mean sea level pressure, prevailing winds and cloud. Selected parameters such as temperature, atmospheric pressure and relative humidity will utilize the historical data and sensor data for prediction in the application of the algorithm. Developing an application program to provide access by the general public to the predicted values will be limited only in sending text messages to selected people such as the barangay officials and through an Android Application using Bluetooth.

CONCEPTUAL FRAMEWORK

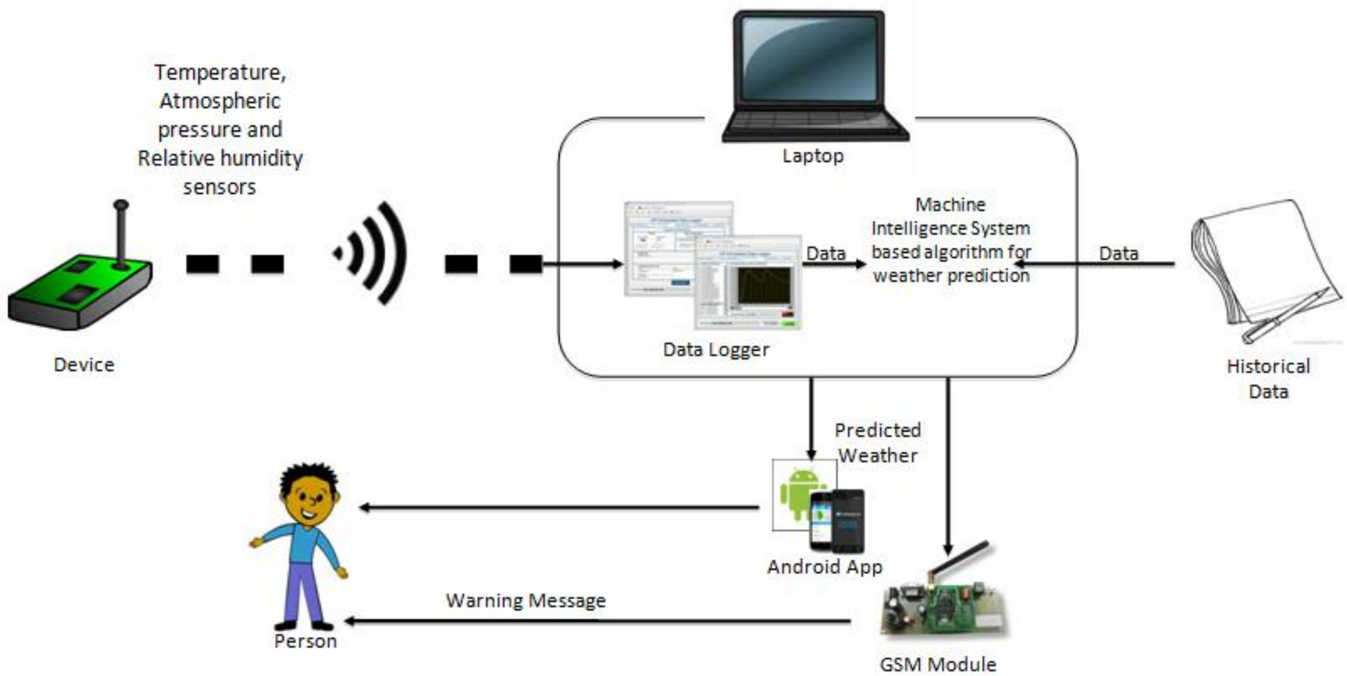


Figure No. 1.1 Conceptual Framework

Chapter 2

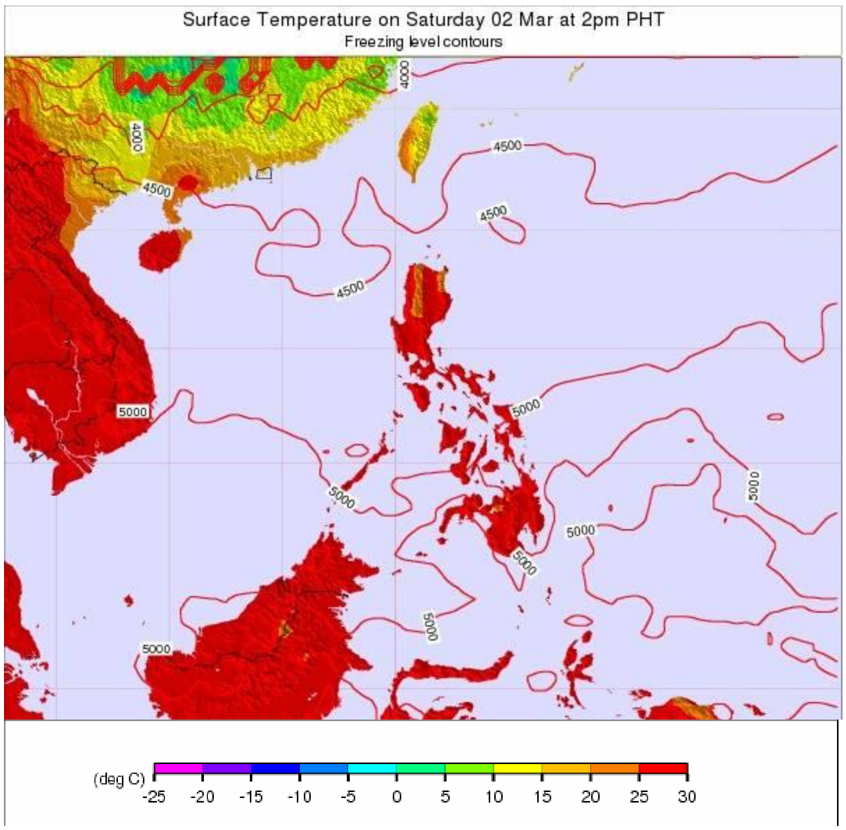
REVIEW OF RELATED LITERATURE

Statistical post-processing techniques are used to remove the systematic bias in modelled data (Marxs, H.G., 2008). There are actually common features that characterize several methods for weather prediction. The said features are sensors data acquisition, assimilation, processing of received data and post-processing the result, and finally, representing the obtained results and forecasts.

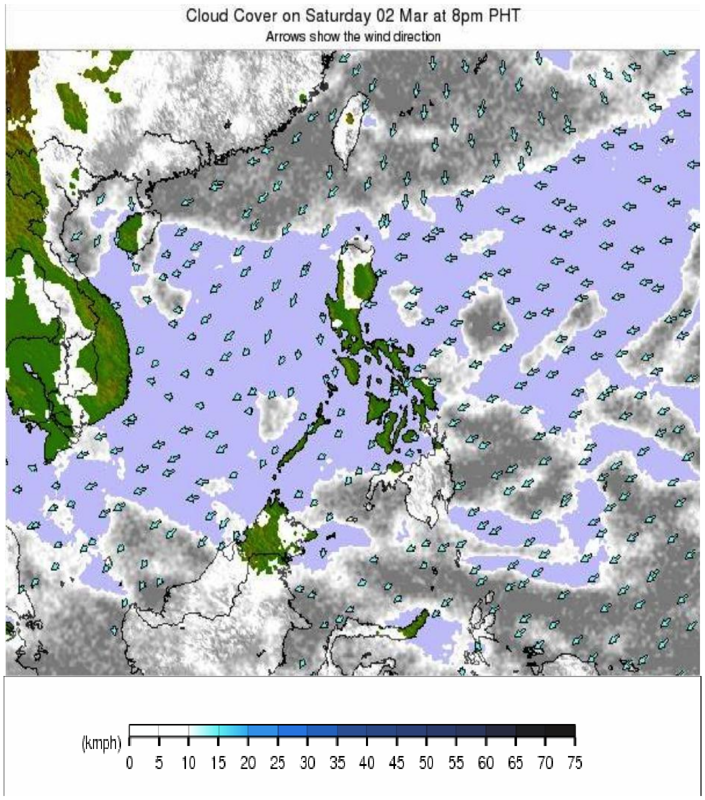
In sensors data acquisition, there are specialized sensors and sensor modules in collecting data for typical meteorological parameters of the atmosphere. It has been said that processing received data is made with the help of a previously created mathematical model of a combination of thermodynamic equations which describe the state of the atmosphere in a given location in any moment of time, and analysis of numerical statistical data (I. Simeonov, H. Killifarev and R. Ilarionov, 2006).

From the Daily Weather Forecast of Kidlat Pagasa, in the Philippines, the following weather parameters have interest to the users of the forecast, cloudiness, rainfall and wind. Basically, weather maps such as surface maps and upper-air maps, are used by weather forecasters since they depict the distribution patterns of temperature, pressure, humidity and wind at different levels of the atmosphere. Furthermore, there are five standard levels of the upper-air maps that are constructed twice daily at twelve-hourly interval. The surface maps are made four times daily at six-hourly intervals. On the surface maps, the distribution patterns of rain or other forms of precipitation and cloudiness can also be delineated. The figures below show the different weather maps: (a) the surface temperature, (b) cloud cover, (c) surface wind and, the (d) upper air map.

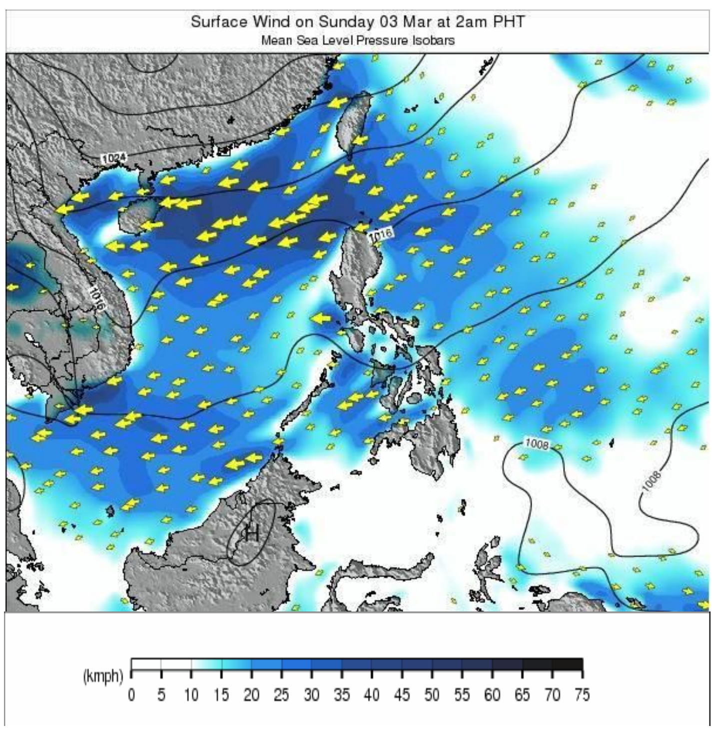
Philippines Weather Map



(a) Surface Temperature on Saturday 02 Mar at 2pm PHT

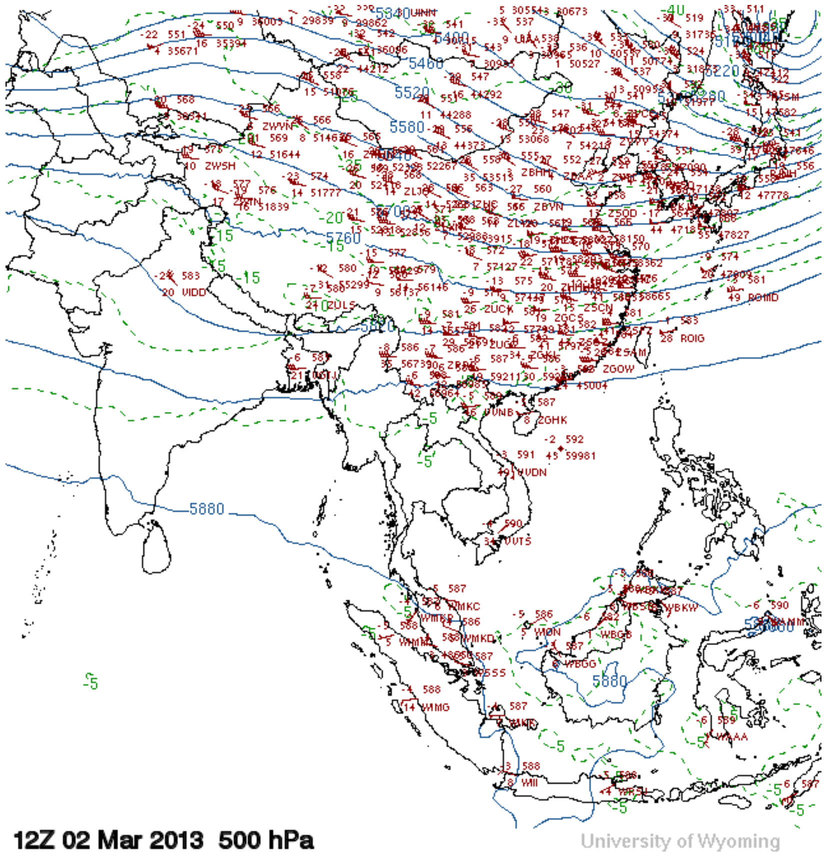


(b) Cloud Cover on Saturday 02 Mar at 8pm PHT



(c) Surface Wind on Sunday 03 Mar at 2am PHT

Image (a), (b), and (c) from http://www.weather-forecast.com/



(d) Upper air map of Southeast asia

Image from http://weather.uwyo.edu/upperair/uamap.html

2.1 Sensors

From an article, “What forces affect our weather?” in Annenberg Learner and Foundation, 2013; it has been stated that devices are required in order to view large weather system specifically on a worldwide scale. From this point, satellites are considered as invaluable which shows large weather events and other global weather systems. For every satellite, two types of sensors were used such as the imager and the sender which is a visible light sensor and an infrared sensor that reads temperature, respectively.

2.2 Weather Instruments

In the Climate Education for K12 by McKemy, weather instruments are used to measure weather parameters and to describe the local weather. Thus, in measuring temperature, a thermometer is used. An electronic temperature sensor is used to measure the outside air temperature. Devices that use the said sensor is contained within a vented unit since it allows air to flow across the sensor. After that, the temperature is measured while the thermometer is protected from the direct heat of the sun.

(a)Image from NOAA (b)Image from Wikimedia Commons (c) Image from NASA

Figure No. 2.1 Weather Instruments (a) Electronic Temperature Sensor, (b) Modern Aneroid Barometer, and (c) Sling Psychrometer

Image from http://www.nc-climate.ncsu.edu/edu/k12/.instruments

Moreover, in order to measure relative humidity, a hygrometer is used. Another common instrument that meteorologists used to determine relative humidity is the Psychrometer which is whirling around while being held. Thus, after whirling the said instrument, the dew point and the relative humidity can be obtained by using the Psychrometer chart based on the wet and dry bulb.

For atmospheric pressure, barometers are used in order to measure the said parameter. One of the most common types of barometer is an aneroid barometer which uses a sealed can of air to detect changes in atmospheric pressure. The concept of using this instrument is that as the atmospheric pressure goes up, it pushes in on the can, and the can is slightly reduced in volume, moving an indicator needle towards higher pressure. If the atmospheric pressure goes down, the can expands slightly and the needle indicates lower pressure. Nowadays, the electronic signal containing the trends of the pressure is reported for a computer which is then plotted in a computer monitor instead of using special graph paper in tracking the change in pressure.

2.3 GSM

Suriya Shopna stated that GSM, which stands for Global System for Mobile Communications, is developed by the European Telecommunications Standards Institute (ETSI). It is also a set which is usually used to describe the protocols used by mobile phones for the second generation digital cellular networks. Also, it was developed in order to replace first generation (1G) analog cellular networks (2013).

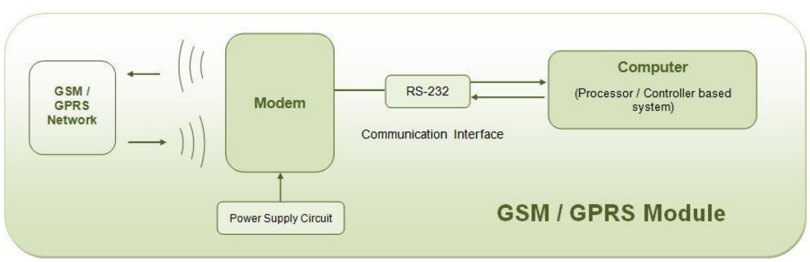


Figure No. 2.2 GSM/GPRS Module Framework
Image from http://www.engineersgarage.com/articles/gsm-gprs-modules

GSM can be connected to control panels to provide the following facilities: report system events via text messaging to mobile telephones, remotely arm, disarm and obtain the current status of the alarm system via text messaging, high-speed modem communication for upload/download and backup signalling path for digital communicator (Telexecom).

2.4 Weather Parameters

The PAGASA deals with the measurement of almost fifteen (15) weather parameters. Weather parameters are determined directly by human observation, by instruments, or by a combination of both. These parameters are shown below.

	TEMPERATURE															GUSTINESS			TSLTG (code)	
DAY	MAX	MIN	MEAN	DRY	WET	DEW	RH %	VP	STN. PRESS.	MSLP	RAINFLL	CLD	SUN DUR	PREV DIR	AVE SPD	SPD	DIR	TIME		
	(°C)	(°C)	(°C)	BULB (°C)	BULB (°C)	PT (°C)		(mbs)	(mbs)	(mbs)	AMT (mm)	(okt)	(min)	16pt	mps	(mps)	(16pts)	(gmt)		

PAGASA described the parameters as follows: maximum temperature is the maximum temperature in ℃ recorded for the day, which occurs in the early afternoon while the minimum temperature is the minimum temperature in ℃ recorded for the day, usually occurring during the early hours of the morning (before sunrise). To compute for the mean temperature, get the average of the maximum and minimum temperature. The dry bulb temperature gave the air temperature in ℃ at the time of observation and the wet bulb temperature gives the temperature in ℃ that an air parcel would have if cooled to saturation at constant pressure by evaporating water in it. The dew point temperature is the temperature in ℃ at a given pressure, wherein the air must cool down for it to saturate. Also, this parameter is the temperature when the moisture begins to condense causing the formation of dew on objects.

Relative humidity is the ratio of the amount of water vapor actually in the air to the maximum amount the air can hold at that temperature (Schlatter T.,2010). Vapor pressure must also be included that denotes the partial pressure of water vapor in the atmosphere. As the water evaporates, additional water vapor is introduced into the space above and pressure increases slightly as the new vapor is added. The increasing pressure is due to an increase in the partial pressure of water vapor. Mean Sea Level Pressure or MSLP is also considered the atmospheric pressure at mean sea level and is the force which is exerted per unit area at the mean sea level through the weight of the atmosphere.

The rainfall describes the amount of precipitation and is usually expressed in millimeters. The cloud can also be a weather variable that depicts the amount of cloud present in the sky, expressed in oktas of the sky cover. Prevailing wind direction is most frequently observed during a given period while the average wind speed in meters per second is the arithmetic average of the observed wind speed.

2.5 Predictive Algorithm

Kalman Filter

Theoretically, the Kalman filter is an estimator for what is called the linear-quadratic problem, which is the problem of estimating the instantaneous “state” a linear dynamic system perturbed by white noise—by using measurements linearly related to the state but corrupted by white noise. The resulting estimator is statistically optimal with respect to any quadratic function of estimation error (M. Grewal and A.P Andrews, 2008).

Thus, according to K. Sreedhar, A. Venu, and A. Hriprasad, the Kalman Filter consists of two steps: the prediction and the correction. This procedure is repeated for each time step with the state of the previous time step as initial value. Therefore, the Kalman Filter is called as a recursive filter (2013).

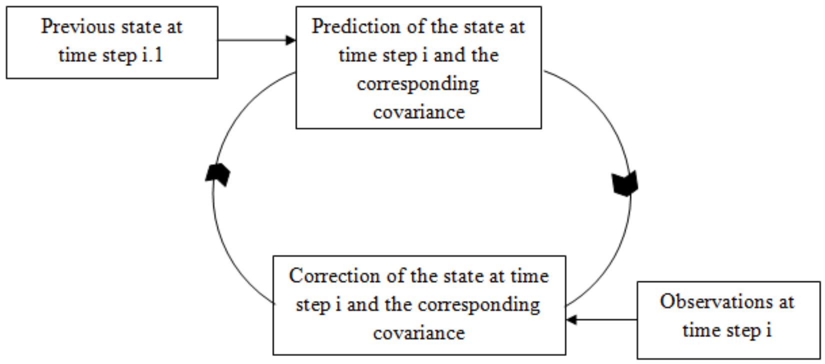


Figure No. 2.3 Circuit of the Kalman Filter

Kleinbauer stated in 2004 that the basic components of the Kalman Filter are the state vector, the dynamic model and the observation model. State vector contains the variables of interest. It describes the state of the dynamic system and represents its degrees of freedom. The variables in the state vector cannot be measured directly, but they can be inferred from the values that are measurable (Subash, J.,2012). The state vector has two values, such as the priori value x^- which represents the predicted value before the update, and the posteriori value$^+$ which is the corrected value after the update.

It is said that the significant advantages of Kalman filter are that it combines measured data as well as previous knowledge about the system and measuring devices to produce an optimal estimate of the desired variables. Also, compared to other filters, it minimizes the error significantly (Vij V. and Mehra R.,2011) s.

However, Graham Hesketh stated that Kalman Filter is computationally complex, especially for large numbers of sensor channels, it requires conditional independence of the measurement errors (sample-to-sample). It also requires linear models for state dynamics and observation processes, and getting a suitable value for Q (a.k.a. tuning) can be something of a black art (2000).

2.6 PIC16F877A Microcontroller

In the study of Ibrahim Al-Adwan and Munaf S. N. Al-D entitled "The Use of ZigBee Wireless Network for Monitoring and Controlling Greenhouse Climate", they used PIC16F877A microcontroller for the purpose of storing the instantaneous values of the environmental parameters they focused on and the Zigbee for wireless communication. The environmental parameters include the temperature, humidity and light or solar radiation. According to them, "sensors provide input information for the automation system by measuring the climate variables of the greenhouse. Sensor-generated signals are acquired and conditioned by a PIC16F877A microcontroller. These sensors are connected to a PIC16F877A microcontroller which consists of embedded ADCs." They also used a ZigBee transceiver which is directly connected to the microcontroller to provide a wireless connection with the central station.

From the study, “A Low-Cost Microcontroller-based Weather Monitoring System” of Kamarul Noordin, Chow Onn and Mohamad Isamail, they measure temperature, atmospheric pressure and relative humidity remotely by using the appropriate sensors that are not only important in environmental or weather monitoring but also crucial for many industrial processes.

The analogue outputs of the sensors are connected to a microcontroller specifically PIC16F877A through an ADC for digital signal conversion and data logging.

2.7 Summary

According to the research paper entitled, "Correcting Temperature and Humidity Forecasts using Kalman Filtering: Potential for Agricultural Protection in Northern Greece" of Manolis Anadranistakis, Kostas Lagouvardos, Vassilik Kotroni and Helias Elefteriadis, the application of the Kalman theory, filtering can substantially reduce errors of the near-surface temperature and humidity forecasts provided for 2-3 days ahead in time. Based on the corrected forecasts, farmers can then schedule their fungicide spraying programs according to the expected weather, thus reducing the cost and the ecological impact of frequent preventive spraying interventions. Also, the success of the method is also supported by the fact that after correction and for both parameters, the mean error decreases to values close to zero, showing that the method is able to provide almost unbiased corrected forecasts, while the standard deviation of the error also decreases by 50%.

Similar to the researchers' proposed device, it mainly focused on forecasting weather parameters such as temperature and humidity using Kalman Filter Algorithm. An additional weather parameter, pressure, is also being measured by the device. The work of Manolis Anadranistakis, Kostas Lagouvardos, Vassilik Kotroni and Helias Elefteriadis has been motivated by the importance of meteorological conditions for the protection of potato cultivation from mildew. On the other hand, the proposed device has a warning system to inform the people of the possible damage that the forthcoming weather might bring. GSM for emergency text and an Android Application are used as a warning system for easy transmission of data.

Chapter 3

Abstract

The Kalman Filter Algorithm filters the sensor's data and process data which are used for predicting the next state or value. The algorithm is used in this study to predict the weather condition on an hourly basis for a given location. The goal is to implement the processes and the equations of the basic Kalman Filter Algorithm in order to produce a forecast based on the given set of available data used to train the system. The device uses a microcontroller, specifically PIC16F877A and is integrated with different sensors for each parameter and wireless technology for the data transfer. The sensors include LM35 for temperature, the capacitive humidity kit for humidity, MPX114AP for measuring the pressure and Zigbee technology for wireless data transfer. The system includes methods for alerting people by using GSM and Android application through Bluetooth. The tests conducted show that the sensors integrated in the device for measuring temperature, pressure and relative humidity produced almost the same measurements as the instruments used for measuring the actual value of the said parameters. Furthermore, statistical tests show that the system forecast is accurate as evidenced by the small per cent difference between the predicted and the actual values obtained from measurements.

Keywords: Kalman filter, weather forecasting

Introduction

The objective of this study is to design a system for weather prediction with a warning system via GSM and Android Application.. Specifically, it aims to achieve the following: (i) to design and implement a device that will measure and monitor actual basic weather parameters such as temperature, pressure and relative humidity, (ii) to develop and apply an algorithm for predicting weather conditions, (iii) to write a program for the algorithm and use 80% available data sets to train the system, (iv) to use 20% of the available data sets to validate the system, (v) to simulate the system by applying available initial conditions such as those provided by the device for monitoring actual weather conditions, (vi) to test the system and determine in terms of the limits of its capabilities in predicting weather conditions, (vii) to develop an application program to provide access by the general public to the predicted values.

This study will be significant in informing an individual or group of people with the information on the anticipated weather over forthcoming one to three days for sites in the areas so that they may take necessary precautions from a coming danger in the chosen locality. Thus, in these cases, forecasts are one of the main aspects that may help save lives or prevent damage, which could be avoided by preventive arrangements. The warning will be based on the predicted weather due to different parameters at a specific date or time. Furthermore, the device will use an algorithm in predicting the weather by analyzing vital parameters such as probabilities of temperature, atmospheric pressure, and relative humidity. Data regarding weather conditions on a specific locality from PAGASA will be monitored in order to produce accurate and valid weather forecast.

Since the weather is continuous, multidimensional, dynamic and chaotic, and hence difficult to predict, the results will not be very accurate. Due to these circumstances, weather is observed to be changing simultaneously, which leads to a conclusion that forecast can be out of date easily. Hence, the algorithm will determine the limits of the predicted weather condition rather than its accuracy. Moreover, Quezon City will be the chosen locality wherein data measured by the sensors located in the said locality will be processed using an algorithm that is not being used by PAGASA such as the Kalman filter. The wireless device would basically send the data measured using the sensors into the data logger. After that, measured parameters will be used in the application of the algorithm for prediction purpose. Using the algorithm, parameters used by PAGASA can also be predicted. These include rainfall, maximum and minimum temperature, dew point, vapor pressure, relative humidity, mean sea level pressure, prevailing winds and cloud. Selected parameters such as temperature, atmospheric pressure and relative humidity will utilize the historical data and sensor data for prediction in the application of the algorithm. Developing an application program to provide access by the general public to the predicted values will be limited only in sending text messages to selected people such as the barangay officials and through an Android Application using Bluetooth.

This chapter discusses the methods that are used to gather, analyze, interpret and report data. It defines the scope and limitations of the research design used. Furthermore, this chapter is divided into three sections. The first section includes the data gathering to be performed which discussed the processes used to come up with the data. The next section is about the processes performed and analysis of the collected data and lastly, the validation of the results.

Methodology

3.1 Design and Implementation of the Device

The basic weather parameters such as temperature, atmospheric pressure and relative humidity will be measured using a device designed to gather these parameters. It uses specific sensors for each parameter to collect data. The sensors will be integrated into one device to have the capability to measure these three basic weather parameters approximately every 10 seconds for the real time purposes. The measurements from the sensors will then be sent wirelessly using Zigbee technology. The data logger will be implemented using MATLAB to read, collect and gather data that will be received from the sensors. The data logger will display 10 samples of measurement from each parameter.

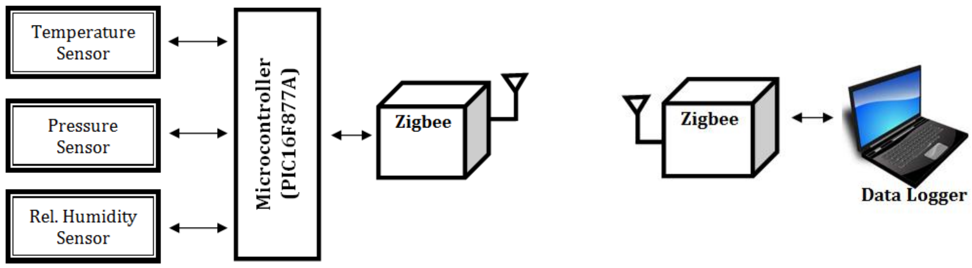


Figure No. 3.1 Block Diagram of the Device

The block diagram of the device is shown in Figure3.1. Sensors for each parameter and the Zigbee module for wireless data transfer were connected in the microcontroller. The specific sensors and components listed in Table 3.1 are used to design and implement the device. The sensors used were affordable and light in size, thus, making the device cheap and handy.

Table No. 3.1 List of Components

Component
PIC 16F877A
Temperature Sensor (LM35)
Humidity Sensor (Capacitive Humidity Kit)
Atmospheric Pressure Sensor (MPX114AP)
GSM Module

As shown in Figure3.1, the PIC16F877A microcontroller was used to connect the three sensors and the standard Zigbee for the wireless data transfer. This microcontroller was used because it has an advantage over other microcontrollers which is easy to use attributable to its large number of peripherals which was approximately 40 pins. For the humidity sensor, a capacitive humidity sensor kit was used. Taranovich stated in 2011 that a capacitive humidity sensor is more appropriate to use than a resistive humidity sensor kit because the capacitive kit ranges its percent relative humidity from 0 to 100 while in a resistive sensor kit; it only ranges from 20 to 90 percent only.

The schematic diagram for the Zigbee connection is shown in Figure3.2. It has been said that ZigBee is more advantageous to use than other wireless technologies because it requires low consumption of power and low data rates (Scheneider Electric Industries SAS, 2011). Basically, two Zigbee modules were used in the design wherein one will serve as the transmitter and the other will serve as the receiver. The transmitter is used to transfer data coming from the sensors into the data logger which is implemented in MATLAB. The receiver is used to read the data coming from the microcontroller which are parameter measurements.

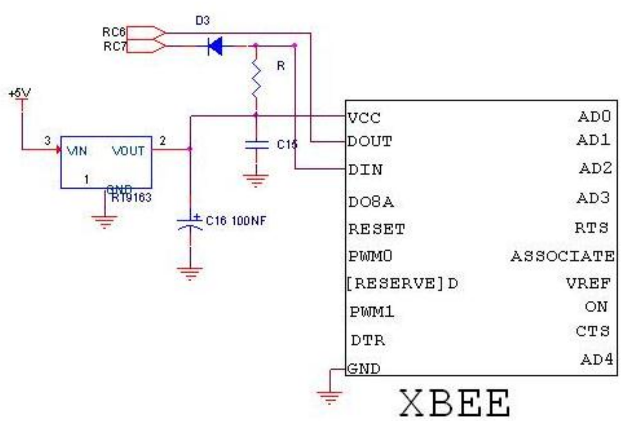


Figure No. 3.2. Zigbee – Schematic Diagram

For the temperature sensor, LM35 is used, which is depicted in the schematic diagram shown in Figure3.3. In this study, PIC16F877A is used as the microcontroller which has 8 channels (A0-A5 and E0-E2) of 10 bit resolution ADC (analog-to-digital converter) module (Microchip,2012). Since the input voltage is 5V which is the maximum value, the range of voltages starting at 0V and ended by 5V needs to be separated into equal steps starting from 000 up to 1023.

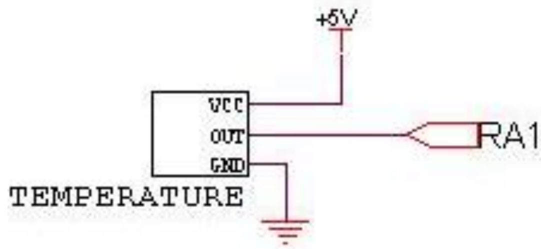


Figure No. 3.3 Temperature Sensor – Schematic Diagram

The ADC step can be calculated using equation 3.1:

$$ADC\ Step = \frac{Vref}{1024} w_t \qquad \textbf{(3.1)}$$

Solving for the ADC step, a value of 4.883 mV is calculated wherein it is the minimum voltage that the ADC can read. To change or convert the ADC reading to Celsius degrees, the input voltage is divided by 10mV/C which is the sensor's sensitivity. Thus,the equation used is shown below:

$$Temperature\ in\ ℃ = (Reading * 4.883)/10w_t \qquad \textbf{(3.2)}$$

Figure 3.4 shows the schematic diagram for the pressure sensor. In addition to the sensing element, a capacitor of 0.1 F is connected. Connecting a capacitor to the ground will filter unwanted frequencies from the input voltage.

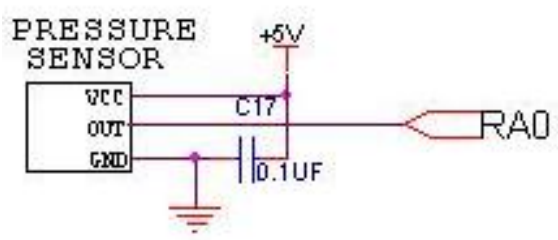


Figure No. 3.4. Pressure Sensor – Schematic Diagram

As observed in the schematic diagram of humidity sensor in Figure3.5, a 22KΩ resistor is connected to the sensor element. This sensor will produce an analog voltage which will go into an analog-to-digital converter or ADC of the microcontroller. Then, it will generate a digital voltage output for humidity. Almost same process will be performed on the other sensors: temperature sensor and pressure sensor.

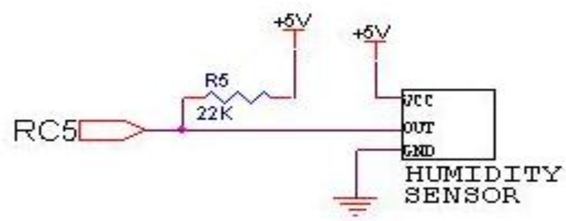


Figure No. 3.5. Humidity Sensor – Schematic Diagram

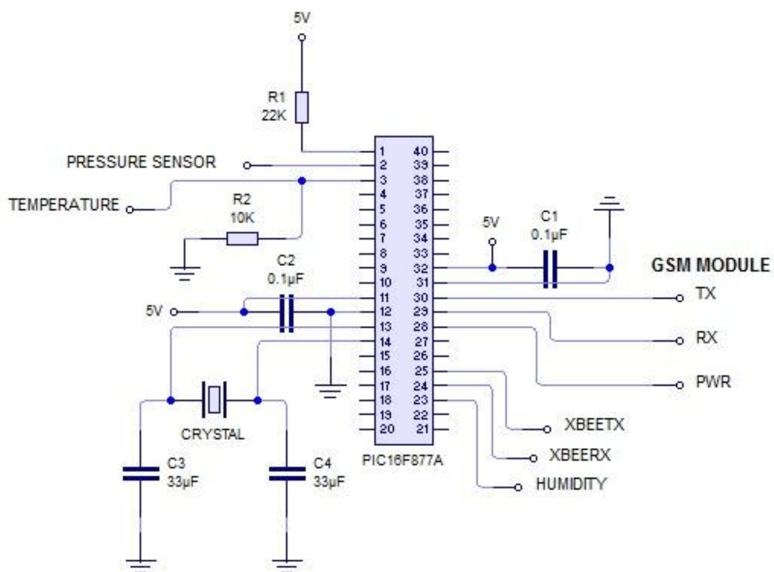


Figure No. 3.6. Schematic Diagram of PIC16F877A Microcontroller

Figure3.6 shows the schematic diagram for the PIC16F877A microcontroller. As illustrated in the previous schematic diagrams, the temperature, pressure and relative humidity sensors are directly connected to the RA0, RA1, and RC5 pin of the PIC16F877A microcontroller respectively. The transmitter Zigbee and receiver Zigbee are connected to pin 25 and pin 24 of the microcontroller, respectively. A crystal oscillator is connected to PIC16F877A microcontroller because it has no internal oscillator which is one of its disadvantages.

3.2 Applying the Algorithm for the Prediction of Weather Conditions

Kalman Filter is commonly referred as an optimal recursive computation of the least-squares algorithm. It is a subset of a Bayes Filter where the premise of a Gaussian distribution and that the current state is linearly dependent upon the previous state are imposed (Dhar S., et.al, 2010). It is optimized in a way that the Kalman filter minimizes the mean square error of the estimated parameters of all noise that is Gaussian (Mastro, 2013).

In this study, the Kalman filter algorithm equations will be applied by using a simple one-dimensional signal. The information that will be used in this study are accessible from the historical data based on the last known measurements of temperature, relative humidity, and pressure and current reading of measurements of the three parameters in the area. The data from the two sources such as current measurements and historical data, are combined and processed together to make the best possible estimate of the temperature, relative humidity, and pressure.

The Kalman Filter algorithm converges the estimation of a value into correct estimations. Thus, assuming a poor estimated Gaussian noise parameter present in a signal will be corrected. "The better you estimate the noise parameters, the better estimates you get" (Esme B., 2009). Figure3.7 shows the step by step process in Kalman Filter which will be discussed further in the various steps in dealing with Kalman Filter.

Basic Linear Kalman Filter

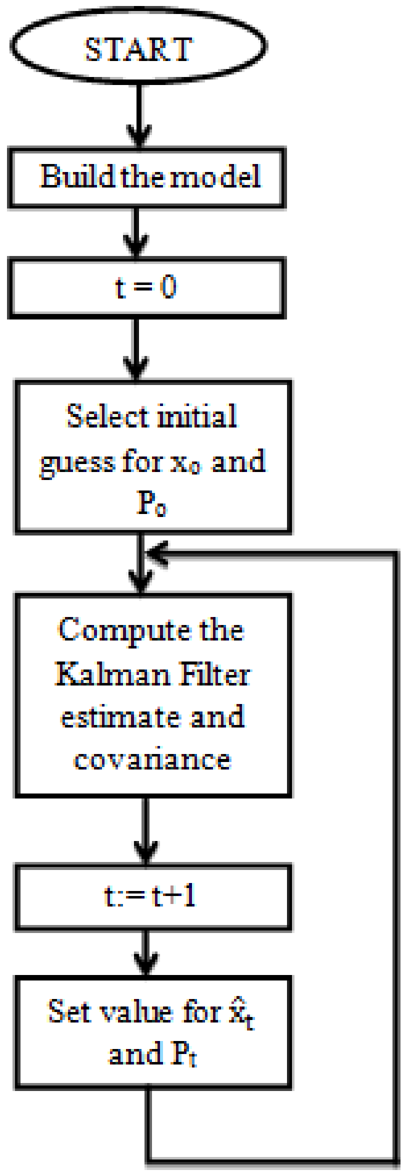


Figure No. 3.7 Process in Kalman Filter

Ramsey Faragher stated in 2012 that there are two models associated with the Kalman filter. Equations 3.3 to 3.9 and the corresponding function or significance are presented in the said IEEE magazine. The Kalman filter model assumes that the state of the system during time t evolved at time $t-1$ because of the prior state which is expressed in equation 3.3.

$$x_t = A_t x_{t-1} + B_t u_t + w_t \tag{3.3}$$

where

- x_t is the state vector containing the terms of interest for the system (temperature, relative humidity and pressure) at time t.
- u_t is the vector containing any control inputs
- A_t is the state transition matrix which applies the effect of each system state parameter at time $t-1$ on the system state at time t
- B_t is the control input matrix which applies the effect of each control input parameter in the vector u_t on the state vector
- w_t is the vector containing the process noise terms for each parameter in the state vector. The process noise is assumed to be drawn from a zero mean multivariate normal distribution with covariance given by the covariance matrix Q_t

The measurements of the system can be performed by using the equation (3.4) which represents the second model

$$z_t = H_t x_t + v_t \tag{3.4}$$

where

- z_t is the vector of measurements

- H_t is the transformation matrix that maps the state vector parameters into the measurement domain
- v_t is the vector containing the measurement noise terms for each observation in the measurement vector. Like the process noise, the measurement noise is assumed to be zero mean Gaussian white noise with covariance R_t.

The Kalman filter has two states: the prediction and correction state (or measurement update). The basic Kalman filter equations for the prediction state are

$$\hat{x}_t^- = A_t\hat{x}_{t-1} + B_t u_t \tag{3.5}$$

$$P_t^- = A_t P_{t-1} A^T + Q_t \tag{3.6}$$

The correction state equations are given by

$$K_t = P_t^- H^T (H_t P_t^- H^T + R_t)^{-1} \tag{3.7}$$

$$\hat{x}_t = \hat{x}_t^- + K_t(z_t - H_t\hat{x}_t^-) \tag{3.8}$$

$$P_t = (1 - K_t H_t)P_t^- \tag{3.9}$$

Where

$\hat{x}_t$ = estimate of x at time t

$\hat{x}_t^-$ = the prior estimate

P_t = error covariance

P_t^- = the prior error covariance

K_t = Kalman gain (Ramsey Faragher,2012)

Steps in using the Kalman Filter Algorithm

Step 0: Build the model. The derivations will consider a simple one-dimensional signal. Thus, the entities in the model are represented in numerical value and not in matrix form. The original equation is shown in equation (3.3) and the reduced equation is given in equation (3.10).

$$x_t = A_t x_{t-1} + B_t u_t + w_t \tag{3.3}$$

$$x_t = x_{t-1} + w_t \tag{3.10}$$

The value of A_t is equated to a value of 1 since the next value will be the same as the previous one due to its recursive part which is the nature of Kalman filter. Then, the $\mathrm{u_t}$ parameter equates to a value of 0 and eliminated from the equation since no control signal was involved in this study.

$$z_t = H_t x_t + v_t \tag{3.4}$$

$$z_t = x_t + v_t \tag{3.11}$$

The equation (3.4) shows the linear combination of the measurement value and the signal value. This equation is then brought down to simpler equation which is shown in equation (3.11) by having the parameter H equated to a value of 1 because in real life, state value and some noise are present in measurable value (Esme B., 2009).

Step 1: Set t = 0, then select the initial guess for x_0 and P_0. For the initial guess, let $x_0 = 0$ and $P_0 = 1$. The variable P_0does notequated to a value of 0 because this would mean that there is no noise in the environment which is not true and impractical. Letting $P_0 = 1$ would lead all the consequent $\hat{x}_t$ to be zero.

Step 2: Compute the Kalman Filter estimate and covariance:

A. Compute the Kalman Gain

$$K_t = \frac{P_t^-}{P_t^- + R} \tag{3.12}$$

B. Compute the estimate

$$\hat{x}_t = \hat{x}_t^- + K_t(z_t - \hat{x}_t^-) \tag{3.13}$$

C. Compute the estimate covariance

$$P_t = (1 - K_t)P_t^- \tag{3.14}$$

Step 3: Update $t := t + 1$

Step 4: Set value for the evolution model prior estimate $\hat{x}_t$ and prior error covariance $P_t$and repeat step 2

A. Set $\hat{x}_t^- = \hat{x}_{t-1}$ **(3.15)**

B. Set $P_t^- = P_{t-1}$ **(3.16)**

3.3 Write a program and train the system

Write a program for the Algorithm

The program for weather prediction using Kalman Filter is implemented in MATLAB. It is a high-level language and interactive environment for numerical computation, visualization, and programming. The MATLAB allows analysis of data, developing algorithms and creating models and applications (The MathWorks Inc., 2013). The step by step procedures in dealing with Kalman Filter that were discussed earlier are implemented in MATLAB. The program flowchart implemented for the system is presented in Figure 3.8.

Training of the System

Accuweather is a company that produces forecasts for places everywhere in the US and other locations worldwide including the Philippines. Thus, Accuweather is considered as the World's Weather Authority. In this study, the historical data needed to train the system are obtained from the Accuweather site. 80% of the available data is used to train the system while the remaining 20% data is used to validate the system. The gathering of data is based on the short range (hourly forecast) which will be used in testing the system. For the short range, the gathering of data was based on an hourly forecast of the Accuweather for Quezon City which was the target location for the testing of the system.

The collected data include only the parameters used in this study such as the temperature, pressure and, relative humidity. The data will be arranged in order by time and tabulated in a CSV file, then saved in the folder where the Kalman Filter.Fig and m file are located. In executing the program, MATLAB is used which contains the processes and equations of Kalman Filter, the program will first ask for a CSV file. After selecting the specific CSV file, the system will then calculate for the parameters such as the prior estimate, prior error covariance, Kalman gain, estimate, and estimate covariance which will be essential in forecasting the next state of weather condition.

Software Development

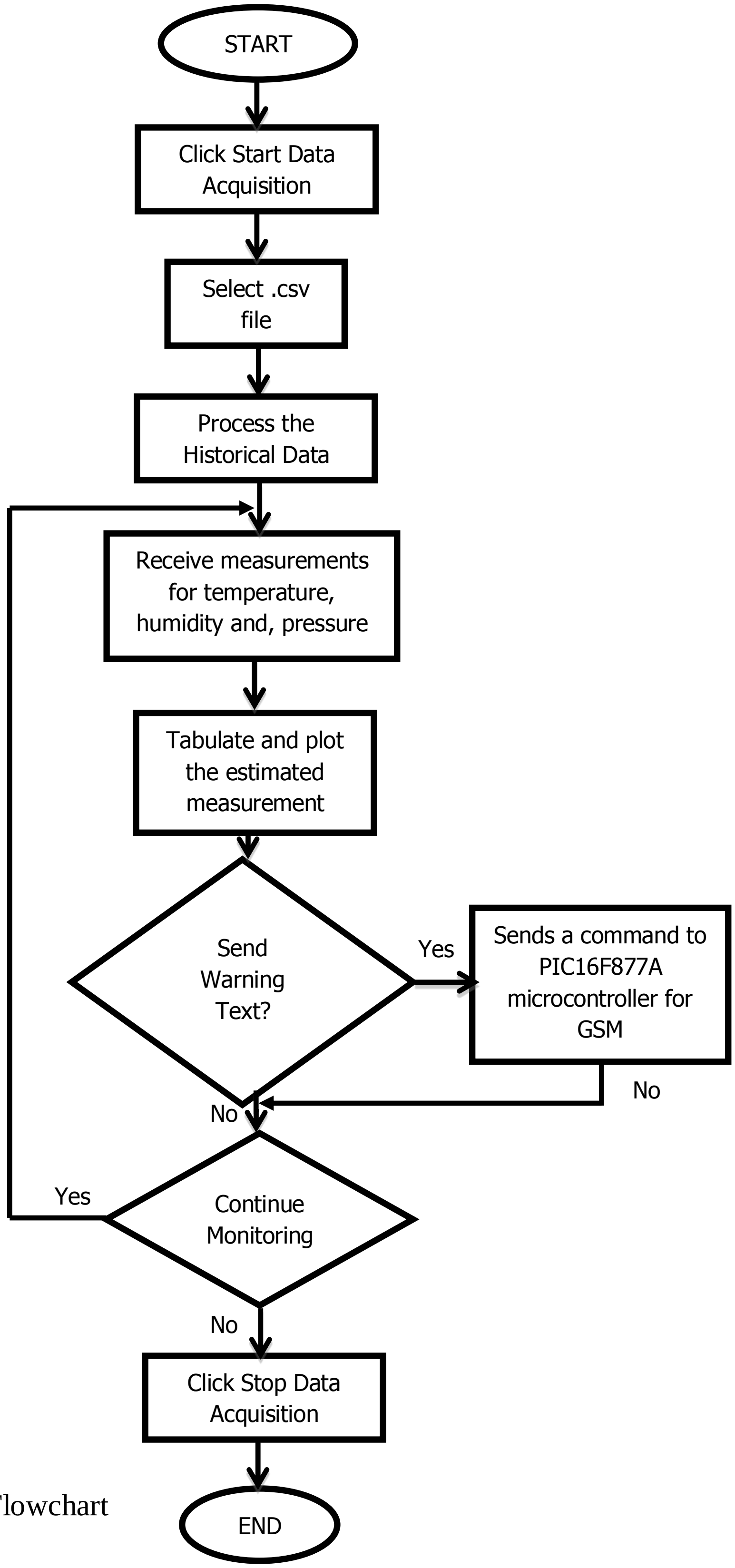


Figure No. 3.8 Program Flowchart

3.4 Validating, Testing and Determining the Accuracy of the System

The validation of the device ensured that the system meets the requirements and specifications stated in Chapter 1. It includes the following parts: (1) the device can measure and monitor the actual basic weather parameters and (2) the prediction of the three weather parameters (temperature, pressure and relative humidity) using the Kalman Filter algorithm. A test will be conducted in each part to validate the method.

3.4.1 Procedures to be followed in measuring the accuracy of measurements of the device

The test required only the data logger part of the program which is responsible for gathering, monitoring, and displaying the measurements received by the laptop from the sensors integrated in the device. Each parameter was subjected to a scenario wherein two types of measurements were acquired: true value using the right instrument for measuring a certain weather parameter and measured value using the measurements of the device displayed in the data logger. Instruments used in the test for measuring the true value are the digital thermometer for the temperature, electronic barometer for pressure and the Accuweather site for the relative humidity. The differences between the measured value to the true value were expressed by the calculating percent difference.

3.4.1.1 Temperature

The steps in the procedure for temperature measurements are listed below,

1. Set up the devices and the laptop in a room. Plug in the device (bigger one) and connect the other device (smaller one) in the laptop using USB to serial port cable.
2. Place the digital thermometer and the device (bigger one) within a box.
3. Run the M-file of the Kalman Filter algorithm using MATLAB.
4. Using a blower, heat up the temperature inside the box. Set the measurement of the true value to 43°Celsius.
5. Click the Start Data Acquisition button found in the GUI of the program.
6. Record the measured value of the temperature which is exhibited in the data logger of the system. Since the program will output 10 samples, compute its mean and record under the Measured Value column. At the same time, record the measurement displayed in the digital thermometer under the True Value column.
7. Make 10 trials of the test and record the collected data. In the succeeding trials, let the temperature inside the box cool down. Set the 10^{th} trial to have a measurement of 29° Celsius for the True Value.
8. Compute the percentage difference using the equation

$$\%PD = \frac{|\text{True Value} - \text{Measured Value}|}{\frac{\text{True Value} + \text{Measured Value}}{2}} * 100$$

3.4.1.2 Relative Humidity

1. A similar procedure as in the previous test is used to install the devices and laptop in this test which was taken in Las Pinas City.

2. Visit the website of Accuweather or go to the link below and select the Las Pinas link button. Click the Hourly Forecast link button on the left side of the window.

   http://www.accuweather.com/en/ph/philippines-weather

3. In the Accuweather site, the forecast measurements of relative humidity per hour are displayed. Record 10 measurement samples and its corresponding time for the true value, which will be used as the reference for conducting the measurement using the device.

4. Compute the percentage difference of the measured value to the true value using the equation used in the previous test.

3.4.1.3 Pressure

1. The trial was conducted in Mapua Institute of Technology wherein the device was positioned on each floor after each trial from higher to lower altitude.

2. For every step, record the change of value in pressure which is reflected in the data logger. This data will be recorded under measured value. In assessing the true value of pressure, an electronic barometer was applied.

3. Calculate the percentage difference of the measured value to the true value using the equation used in the previous test.

3.4.2 Procedures to be followed in examining the system for the prediction of the three weather parameters using a Kalman Filter algorithm

1. To begin, install the two devices and the laptop. Plug the device (bigger one) and plug the other device (smaller one) into the laptop using USB to serial port cable.

2. Run the M-file of the Kalman Filter program using a MATLAB software.

Note: The version of MATLAB to be used in executing the M-file must support the table property.

3. Select the CSV file that contains the 80% available data that will be used for training the system. See Appendix A for more information on a CSV file.

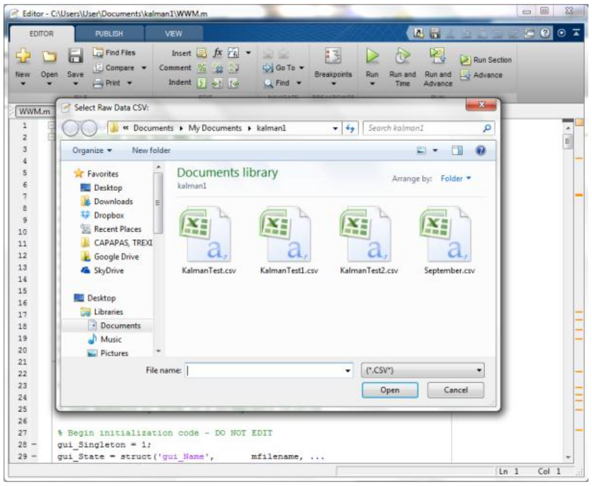


Figure No. 3.9 Selection of CSV file

4. Open the Android Application and establish the Bluetooth connection between the laptop and cell phone.
5. Click the Start Data Acquisition button found in the bottom right portion of the program.

   Note: The recording time of data for system forecast must be an hour before the forecast time stated in the table to have consistency in the time of two forecasts.

6. Collect and tabulate the system forecast by having a column name (in order) such as Forecast, Time, Accuweather Forecast (unit), System Forecast (unit), Actual Measurement (unit) and Percent Difference (%). Make at least ten hours of continuous simulation of the system.

Note: The collection of measurements for the two forecasts (system forecast and Accuweather forecast) must be every hour and the actual measurement is collected in the Accuweather site by clicking the Now tab in the same window for Hourly Forecasts during the time stated in the forecast time.

7. Plot the system and Accuweather forecast and actual measurements to visually represent the results of the three sets of parameters.

8. Compute the percentage difference to determine the accuracy of system forecast to the Accuweather forecast and system forecast to actual measurements.

$$\%PD = \frac{|\text{Sample1} - \text{Sample2}|}{\frac{\text{Sample1} + \text{Sample2}}{2}} * 100 \quad \textbf{(3.17)}$$

9. Compare the means of the two forecasts using a statistical tool, the calculation of t-test must be performed. Below are the steps in dealing with t-test:

   a. State the null and alternative hypotheses

   b. Determine the significance level

   c. Compute for T value

   d. Calculate the Degrees of Freedom

   e. Determine the p-value

Results and Discussion

3.4.1 Determining the Accuracy of the Measurement of the Device

Temperature:

Table No. 3.2 Tabulated Data for Temperature

TRIAL	Measured Value (°C)	True Value (°C)	Percentage Difference (%)
1	43.4320	43.5	0.1564%
2	42.8421	42.7	0.3322%
3	40.5400	40.5	0.0987%
4	37.8000	38.0	0.0528%
5	36.1126	35.9	0.5905%
6	34.6480	34.7	0.1500%
7	33.1840	32.9	0.8595%
8	32.6960	32.6	0.2940%
9	31.7290	31.5	0.7244%
10	29.2800	29.0	0.9609%

Table 3.2 shows the collected data in testing the accuracy of the temperature measurement of the device to the digital thermometer. The use of blower allowed the temperature in the box to be controlled. Based on Table 3.2, the two measurements produced almost the same value for every trial resulting in small percentage difference. This indicates that the device can produce accurate measurements of the temperature like the digital thermometer.

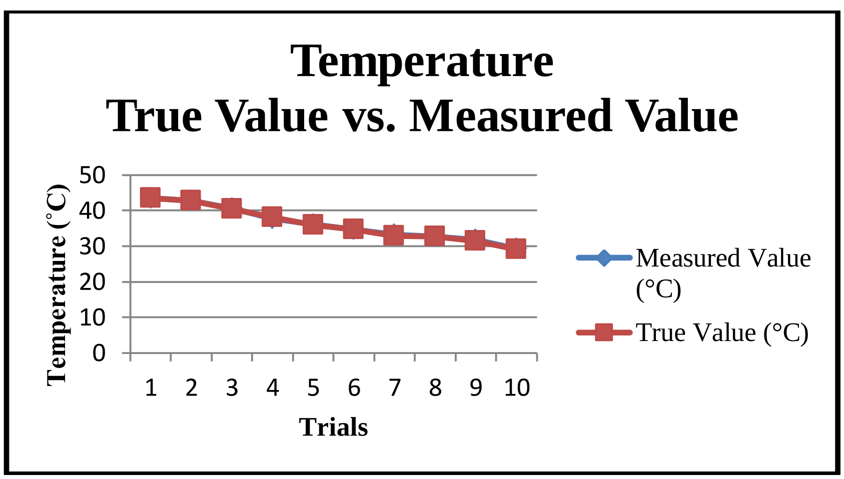


Figure No. 3.10 Temperature – True Value vs. Measured Value

Relative Humidity:

As shown in Table 3.3, most of the readings showed a 100% relative humidity. The relative humidity is based on the location and on the condition of the atmosphere. A high percentage relative humidity indicates that the air is holding the maximum water it can hold at the current temperature and any additional moisture will result in condensation. If the measured relative humidity is low, it indicates that the atmosphere in the area is dry and can hold more moisture at that value of temperature. Results show that when the temperature decreases, the relative humidity goes up due to the small amount of moisture that cooler air can hold for the current temperature and vice versa (NASA, 2013).

Table No. 3.3 Tabulated Data for Relative Humidity

TRIAL	Date & Time Aug 19, 2013	Measured Value (%)	True Value (%)	Percentage Difference (%)
1	12:00 AM	100	99	1.0050%
2	3:00 AM	100	99	1.0050%
3	5:00 AM	100	100	0%
4	11:00 AM	100	100	0%
5	2:00 PM	100	100	0%
6	5:00 PM	100	100	0%
7	6:00 PM	100	99	1.0050%
8	7:00 PM	100	96	4.0816%
9	10:00 PM	100	100	0%
10	11:00 PM	100	100	0%

Figure 3.11 presents the differences between the measured and true values of humidity. These differences are within the acceptable range of values since small differences are calculated. This proves that the humidity sensor used to measure the parameter in the device produced almost same performance in measuring humidity as that of the Accuweather. The Accuweather website stated that it provides a commercially accepted measurement of certain parameters which can be used for testing purposes.

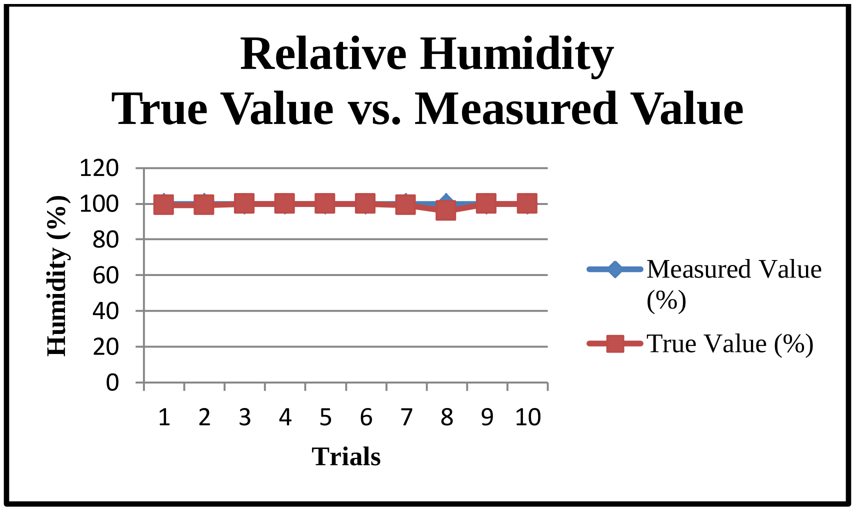


Figure No. 3.11 Relative Humidity – True Value vs. Measured Value

Pressure:

Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air molecules above that surface (WW2010,2010). The measured and true value of pressure change only in small part due to the fact that this parameter does not easily alter its value unlike other parameters. The percentage difference in each trial is close to zero percent, suggesting that the device can accurately assess the pressure in a given location.

Table No. 3.4 Tabulated Data for Pressure

TRIAL	Measured Value (kPa)	True Value (kPa)	Percentage Difference (kPa)
1	100.9295	100.9	0.02923%
2	100.9297	100.9	0.02943%
3	100.9297	100.9	0.02943%
4	100.9300	100.9	0.0297%
5	100.9381	100.9	0.0378%
6	100.9381	100.9	0.0378%
7	100.9381	100.9	0.0378%
8	100.9382	100.9	0.0379%
9	1009382	100.9	0.0379%
10	100.9382	100.9	0.0379%

Figure 3.12 proved that the measured value and true value are almost equal and the percentage acquired in the percent difference does not contribute significantly to the trend of the measurement of pressure. A constant value of about 100.9 for air pressure was noted during the time of the testing which indicates that precipitation is less likely. Otherwise, if the measured pressure is lower, there is an indication that a low pressure system or front is approaching.

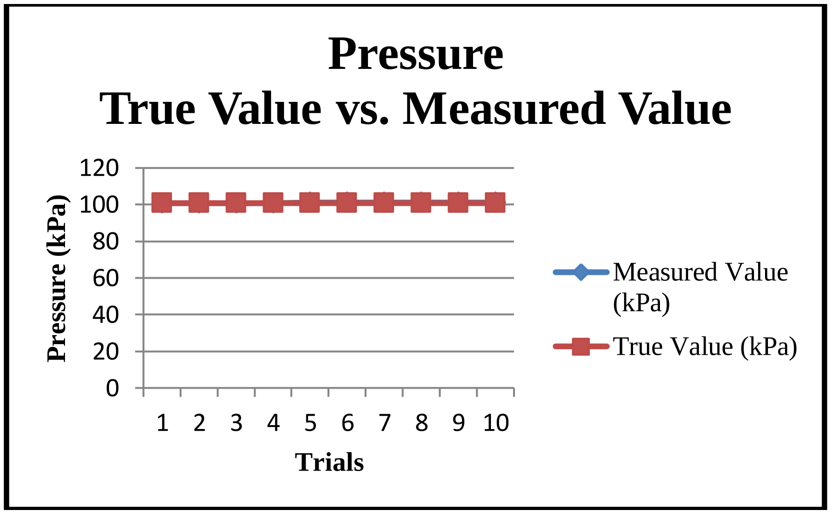


Figure No. 3.12 Pressure – True Value vs. Measured Value

3.4.2 Determining the Accuracy of System Forecasts to Accuweather Forecasts and Actual Measurements

Hourly Forecasts of Temperature

Table 3.5 illustrates the collected data for temperature of the system forecast and Accuweather forecast. As shown in the table, the forecast temperatures in the Accuweather range from 24 C° - 31 C° during the testing, which reflect the actual weather condition at that time in Quezon City which is a cloudy day.

Table No. 3.5 Comparison of Temperature Forecast between the System and Accuweather

Forecast Time	**Accuweather Forecast (C°)**	**System Forecast (C°)**	**Percent Difference (%)**
2:00 PM	29	26.86	7.66
3:00 PM	29	27.22	6.33
4:00 PM	29	27.18	6.48
5:00 PM	31	27.18	13.13
6:00 PM	29	27.08	6.85
7:00 PM	28	26.86	4.16
8:00 PM	26	26.78	2.96
9:00 PM	24	26.71	10.69
10:00 PM	26	26.60	2.28
11:00 PM	26	26.54	2.06
Average Percentage Difference:			6.26

The data under the system forecast show little changes on its temperature forecast because the estimation of values depends on the actual measurement of the temperature on the area of testing and historical data. The system forecast increases its value if and only if the present estimated forecast value is lower than the actual temperature of the area. Otherwise, the system forecast decreases. A value of 6.26 was computed for the average percentage difference of the 10 trials in which it does not affect the capability of KF as an algorithm for weather forecasting since the

Accuweather forecast considered the whole area of Quezon City while in the system forecast, it was based on the specific location in the area.

Table No. 3.6 Comparison of System Temperature Forecast to Actual Temperature Measurement

Forecast Time	Actual Temperature Measurement (C°)	System Forecast (C°)	Percent Difference (%)
2:00 PM	27	26.86	0.52
3:00 PM	29	27.22	6.33
4:00 PM	27	27.18	0.66
5:00 PM	27	27.18	0.66
6:00 PM	27	27.08	0.30
7:00 PM	27	26.86	0.52
8:00 PM	27	26.78	0.82
9:00 PM	26	26.71	2.69
10:00 PM	26	26.60	2.28
11:00 PM	26	26.54	2.06
Average Percentage Difference:			1.684

It is observed in Table 3.6 that the actual temperature has a range within 26-29 Celsius during the test which was accepted in the range of measurements for a cloudy day. The computed average difference between the two variables (system forecast and actual measurement) is equal to 1.684%, which is lower compared to the average difference of the system forecast and Accuweather forecast. These slight differences were acceptable since the location of the test was not on the same location of the weather station of Accuweather.

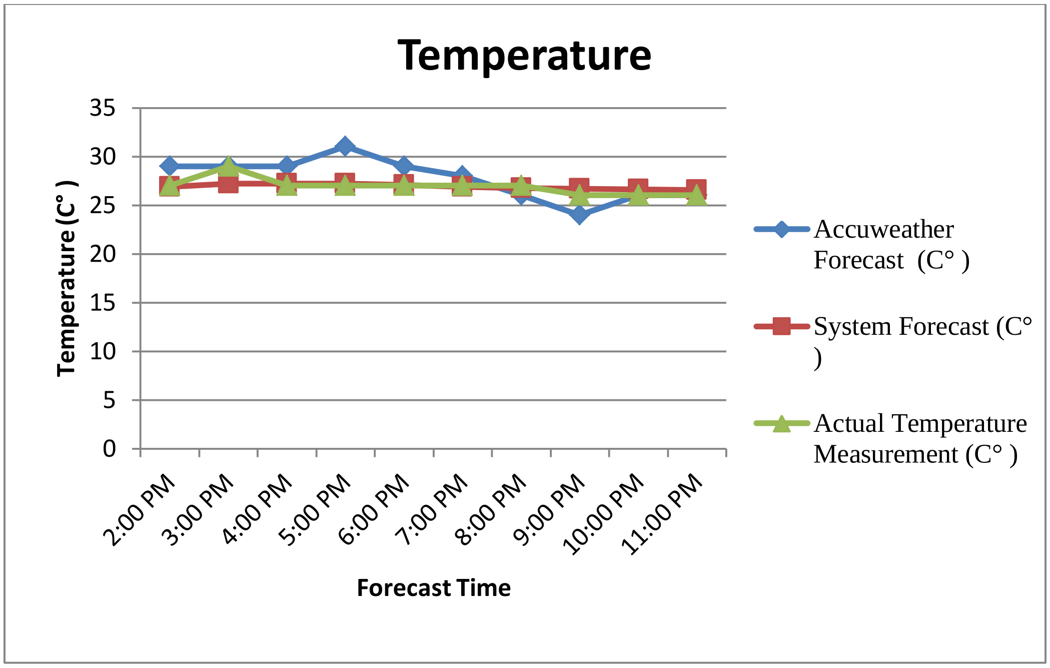


Figure No. 3.13 Temperature

Figure 3.13 presents the visual representation of the system forecast, and the Accuweather forecast and, actual measurement. It shows that the system forecast is close to the actual measurement at any given time during the time of testing compared to the Accuweather forecast. It is observed that the time between 2:00 PM to 11:00 PM, the system forecast temperature (red line) showed an increasing change in its value considering its previous value from the previous hour. It is caused by the measured temperatures, which is essential in calculating the forecast as discussed earlier in this chapter. However, the Accuweather forecast showed fluctuations in its temperature forecast resulting to an observation that during the test, the system forecast values were closer to the actual measurements.

Hourly Forecasts of Relative Humidity

Relative humidity is an important weather parameter used in forecasting weather. Humidity indicates the possibility of dew, fog or precipitation. When the recorded measurement of humidity is high, it makes people feel hotter outside in the summer because it reduces the effectiveness of sweating to cool the body by preventing the evaporation of perspiration from the skin. This effect is calculated in a heat index table (McEntee et. al.,2009)

Table No. 3.7 Comparison of Humidity Forecast between the System and Accuweather

Forecast Time	Accuweather Forecast (%)	System Forecast (%)	Percent Difference (%)
2:00 PM	68	88.11	25.76
3:00 PM	66	73.23	10.39
4:00 PM	71	90.09	23.70
5:00 PM	64	89.25	32.95
6:00 PM	69	85.58	21.45
7:00 PM	75	92.87	21.29
8:00 PM	79	91.42	14.58
9:00 PM	93	96.89	4.10
10:00 PM	90	97.17	7.66
11:00 PM	84	98.45	15.84
		Average Percent Difference:	17.772

Table 3.7 shows the forecasts from two different sources: the Accuweather site and the system using KF algorithm. The average difference calculated is equal to 17.772%, which is relatively high. However, it did not affect the capability of the KF algorithm since, the study focused more on the determination of the accuracy between system forecast and actual measurement.

Table No. 3.8 Comparison of System Humidity Forecast to Actual Humidity Measurement

Forecast Time	Actual Humidity Measurement (%)	System Forecast (%)	Percent Difference (%)
2:00 PM	88	88.11	0.12
3:00 PM	69	73.23	5.95
4:00 PM	94	90.09	4.25
5:00 PM	88	89.25	1.41
6:00 PM	83	85.58	3.06
7:00 PM	88	92.87	5.39
8:00 PM	88	91.42	3.81
9:00 PM	94	96.89	3.03
10:00 PM	94	97.17	3.32
11:00 PM	94	98.45	4.62
		Average Percent Difference:	3.496

The system forecast and actual measurement for relative humidity were recorded and tabulated as shown in Table 3.8. The percentage difference included in the table depicts how much the system forecast differs from the actual data. Based on the calculation, small values of differences were recorded which means that the system forecasts are almost equal to the actual measurements at any given time. Moreover, the average percent difference recorded is equal to 3.496%, which was acceptable and the results proved that the Kalman filter can be applied as an algorithm for weather forecasting. Figure 3.14 shows the differences between the system forecast to the Accuweather forecast and actual measurements. It was easily observed that the system forecast were almost closer to the actual value compared to the Accuweather forecast at any given of time during the testing period.

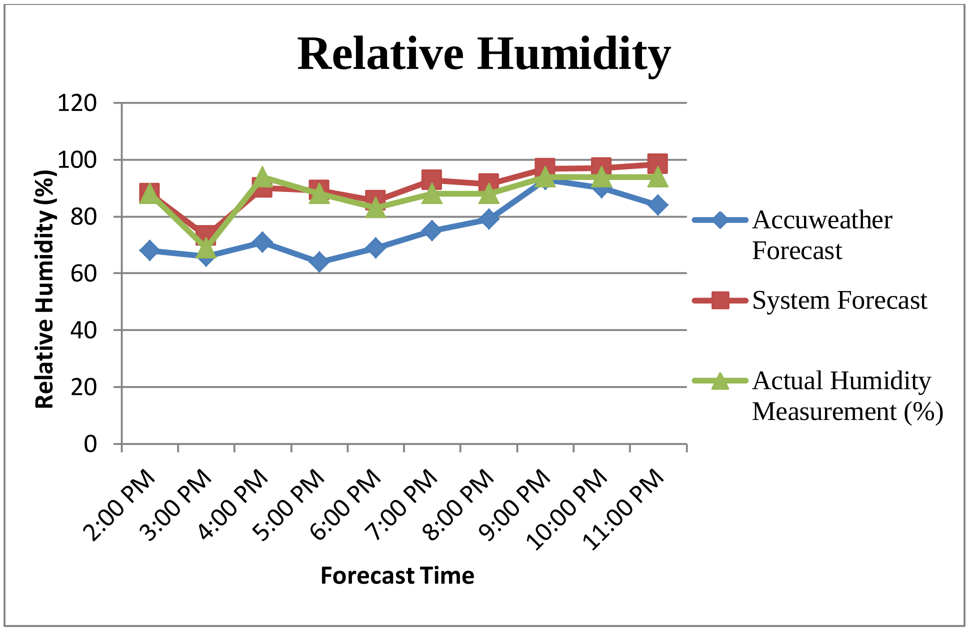


Figure No. 3.14 Relative Humidity

Hourly Forecasts of Pressure

Atmospheric pressure is an important parameter that is essential in monitoring the weather condition. Table 3.9 presents that the differences in hour-to-hour changes in the atmospheric pressure are caused by the movement and development of pressure systems affecting the country very often (MET ÉIREANN). These forecasts proved that the pressure did not change its value quickly compared to the two previous parameters. Thus, there is no available forecast on pressure for all weather forecast companies like Accuweather.

Table 3.9 Comparison of Pressure Forecast between the System and Accuweather

Forecast Time	**Accuweather Forecast (kPa)**	**System Forecast (kPa)**	**Percent Difference (%)**
2:00 PM	101.3	100.79	0.50
3:00 PM	101.2	100.82	0.38
4:00 PM	101.1	100.80	0.30
5:00 PM	101.0	100.80	0.20
6:00 PM	101.0	100.84	0.16
7:00 PM	101.1	100.85	0.25
8:00 PM	101.1	100.89	0.21
9:00 PM	101.2	100.92	0.28
10:00 PM	101.3	100.92	0.38
11:00 PM	101.3	100.94	0.36
		Average Percentage Difference:	0.302

The system forecast on pressure were almost equal to the Accuweather forecast as observed in the table 3.9. The present measurement of the pressure affects the prognosis for the next hour. Thus, there are small difference between the Accuweather and System Forecast. Also, the test showed that the algorithm may reach a certain point wherein it will be difficult to converge or estimates the present estimate value due to the consistent values in the measured parameters.

Table No. 3.10 Comparison of System Pressure Forecast to Actual Pressure Measurement

Forecast Time	**Actual Pressure Measurement (%)**	**System Forecast (%)**	**Percent Difference (%)**
2:00 PM	101.2	100.79	0.41
3:00 PM	101.1	100.82	0.28
4:00 PM	101.0	100.80	0.20
5:00 PM	101.0	100.80	0.20
6:00 PM	101.1	100.84	0.26
7:00 PM	101.1	100.85	0.25
8:00 PM	101.2	100.89	0.31
9:00 PM	101.3	100.92	0.38
10:00 PM	101.3	100.92	0.38
11:00 PM	101.3	100.94	0.36
Average Percentage Difference:			0.303

Similar to the previous table, the system forecasts on pressure were almost similar to the actual pressure for any given time during the testing period. In this test, it is expected that relatively minor differences will be calculated pressure does not change its value as quickly as other parameters do. As a result, this visual representation of the differences between the system forecast to the Accuweather forecast and actual measurements were almost equal to each other as shown in Figure 3.15. These data proved that using the Kalman filter algorithm, the forecast for pressure are similar to what Accuweather forecasts produced and the measurement of the actual data.

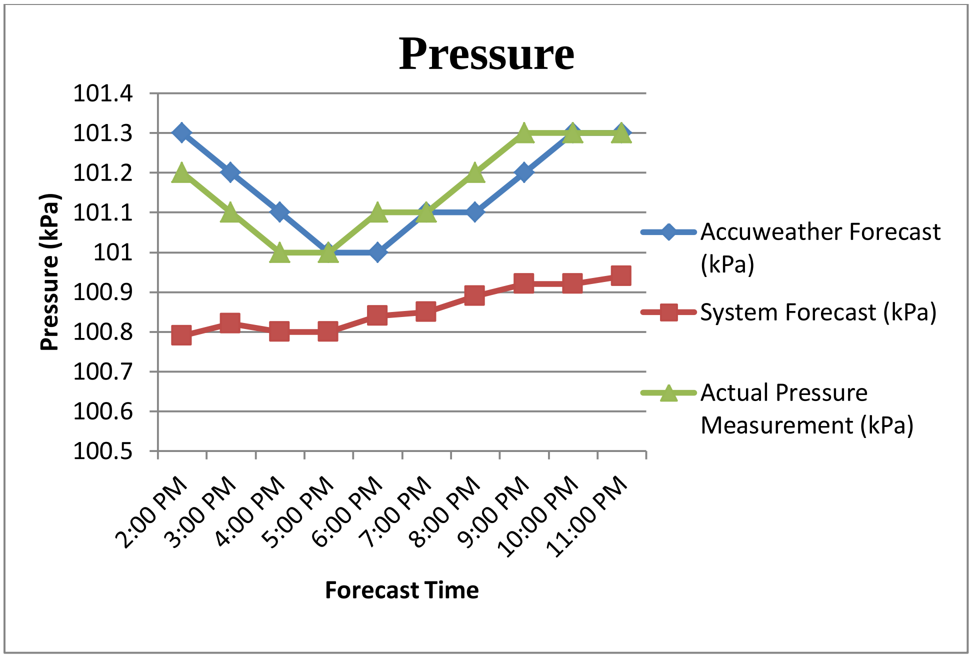


Figure No. 3.15 Pressure

Statistical Tool

<u>Test 1: Temperature – System Forecast and Actual Measurement</u>

Using the collected data presented in Table 3.5, the value for mean, variance, standard deviation, and standard error are as follows:

Table No. 3.11 T-Test for Temperature

Forecast Time	Actual Temperature Measurement (C°)	System Forecast (C°)
2:00 PM	27	26.86
3:00 PM	29	27.22
4:00 PM	27	27.18
5:00 PM	27	27.18
6:00 PM	27	27.08
7:00 PM	27	26.86
8:00 PM	27	26.78
9:00 PM	26	26.71
10:00 PM	26	26.60
11:00 PM	26	26.54
Mean	26.9	26.901
Standard Deviation	0.8756	0.2505
Standard Error Mean	0.277	0.079

A two-sided t-test is appropriate to use in determining the difference in the average temperature measurements of system forecasts and Accuweather forecasts. The hypotheses for this test are as follows:

Null Hypothesis: The mean temperature of the weather condition is same for the two measurements: system forecast and actual measurements.

Alternative Hypothesis: The mean temperature of the weather condition differs for the two measurements: system forecast and actual measurements.

The computation of important parameters are shown below:

Standard Error of the Difference (se): $se = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{0.8756^2}{10} + \frac{0.2505^2}{10}} = \mathbf{0.288}$

Degrees of Freedom (DF) : $df = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}} = \mathbf{10}$

95% Confidence Interval for the Difference: **(-0.6427 , 0.6407)**

T- Value: $T = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \mathbf{-0.0035}$

P Value: $p = \mathbf{0.9972}$

Observation: A two tailed unequal variance test was conducted to determine the difference of the temperature forecast produced by the system and actual measurement. The result showed that there was not a significant difference between the system forecast (M = 26.901; SD = 0.2505) and the actual measurement (M = 26.9; SD = 0.8756); two sample t (10) = -0.0035, p= 0.9972. The direction of the difference in the sample means is reflected by the sign (positive or negative) of the t-value. At the 0.05 significance level and 95% confidence level, it turned out that the null hypothesis is true so fail to reject the null hypothesis. The mean temperature of the weather condition is same for the two measurements: system forecast and actual measurements.

Test 2: Relative Humidity – System Forecast and Actual Measurement

The value for mean, variance, standard deviation, and standard error for the two sources are as follows:

Table No. 3.12 T-Test for Relative Humidity

Forecast Time	**Actual Humidity Measurement (%)**	**System Forecast (%)**
2:00 PM	88	88.11
3:00 PM	69	73.23
4:00 PM	94	90.09
5:00 PM	88	89.25
6:00 PM	83	85.58
7:00 PM	88	92.87
8:00 PM	88	91.42
9:00 PM	94	96.89
10:00 PM	94	97.17
11:00 PM	94	98.45
Mean	88	90.306
Standard Deviation	7.6739	7.3372
Standard Error Mean	2.427	2.32

The hypotheses for this test are as follows:

Null Hypothesis: The mean relative humidity of the weather condition is same for the two measurements: system forecast and actual measurements.

Alternative Hypothesis: The mean relative humidity of the weather condition differs for the two measurements: system forecast and actual measurements.

The computation of important parameters are shown below:

Standard Error of the Difference (se): $se = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{7.6739^2}{10} + \frac{7.3372^2}{10}} = \mathbf{3.3574}$

Degrees of Freedom (DF) : $df = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}} = \mathbf{17}$

95% Confidence Interval for the Difference: **(-9.3894 , 4.7774)**

T- Value: $T = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \mathbf{-0.6868}$

P Value: $p = \mathbf{0.5014}$

Observation: A two tailed unequal variance test was conducted to determine the difference of the relative humidity forecast produced by the system and actual measurement. The result showed that there was not a significant difference between the system forecast (M = 90.306; SD = 7.3372) and the actual measurement (M = 88; SD = 7.6739); two sample t (17) = -0.6868, p= 0.5014. The direction of the difference in the sample means is reflected by the sign (positive or negative) of the t-value. At the 0.05 significance level and 95% confidence level, it turned out that the null hypothesis is true so fail to reject the null hypothesis. The mean relative humidity of the weather condition is same for the two measurements: system forecast and actual measurements

Test 3: Pressure – System Forecast and Actual Measurement

The value for mean, variance, standard deviation, and standard error for the two sources are as follows:

Table No. 3.14 T-Test for Pressure

Forecast Time	Actual Pressure Measurement (%)	System Forecast (%)
2:00 PM	101.2	100.86
3:00 PM	101.1	100.97
4:00 PM	101.0	100.90
5:00 PM	101.0	100.90
6:00 PM	101.1	100.97
7:00 PM	101.1	101.01
8:00 PM	101.2	101.20
9:00 PM	101.3	101.23
10:00 PM	101.3	101.23
11:00 PM	101.3	101.23
Mean	101.16	101.05
Standard Deviation	0.1174	0.1546
Standard Error Mean	0.037	0.049

The hypotheses for this test are as follows:

Null Hypothesis: The mean pressure of the weather condition is same for the two measurements: system forecast and actual measurements.

Alternative Hypothesis: The mean pressure of the weather condition differs for the two measurements: system forecast and actual measurements.

The computation of important parameters are shown below:

Standard Error of the Difference (se): $se = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{0.1174^2}{10} + \frac{0.1546^2}{10}} = \mathbf{0.061}$

Degrees of Freedom (DF) : $df = \frac{\left[\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}\right]^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1-1}+\frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2-1}} = \mathbf{18}$

95% Confidence Interval for the Difference: **(-0.0190 , 0.2390)**

T- Value: $T = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}}} = \frac{0.799}{0.6722} = \mathbf{1.7918}$

P Value: $p = \mathbf{0.0900}$

Observation: A two tailed unequal variance test was conducted to determine the difference of the pressure forecast produced by the system and actual measurement. The result showed that there was not a significant difference between the system forecast (M = 101.05; SD = 0.1546) and the actual measurement (M = 101.16; SD = 0.1174); two sample t (18) = 1.7918, p= 0.0900. At the 0.05 significance level and 95% confidence level, it turned out that the null hypothesis is true so fail to reject the null hypothesis. The mean pressure of the weather condition is same for the two measurements: system forecast and actual measurements.

Conclusions

A measuring and monitoring device for weather parameters such as temperature, pressure and, relative humidity is designed and implemented in this study. The objective is achieved by using a sensor for each parameter and is integrated to the microcontroller. Such sensors are the LM35 for temperature, capacitive humidity kit for humidity, and MPX114AP for measuring the pressure. Zigbee technology is also included which allows the transmission of measurements wirelessly from the device to the laptop or PC. Also, PIC16F877A microcontroller is used for collecting and processing of the gathered measurements. Since the device is real time, it sends measurements every 10 seconds.

The Kalman Filter Algorithm is proposed and applied by the researchers to provide weather forecast. It is applied and implemented using MATLAB based on its equations to perform the correction and prediction state. This algorithm uses two data, historical and present data. The combination of the past and present information in Kalman filter produced possible estimate of the parameters for the prediction of the next state of weather condition.

The program developed for Kalman Filter Algorithm required the system to be trained by inputting the 80% available data sets or the historical data. These data are gathered in Accuweather and presented in a CSV file format. The remaining 20% available data are used in the validation of the system. A high percentage of available data are allocated in the historical data in order to fully develop the system in the given set of measurements for each parameter.

The testing of the system is divided into two parts: determining the accuracy of measurements of the device and the forecast produced by the system using KF algorithm. The results of the first part of the test show that the sensors used for measuring temperature, pressure and relative humidity produced almost the same measurements as the instruments used for measuring the actual value of the said parameters. Small differences are recorded in the percentage difference of the actual value to the experimental value for each trial in each parameter which leads to a conclusion that the device is capable of measuring and monitoring weather parameters in a specific location. The second part of the testing focused on determining the accuracy of Kalman filter in forecasting. The calculation of percentage difference and use of statistical tool such as t-test allowed the determination of the difference of the system forecast to the Accuweather forecast and to the actual measurement. Based on the results, it showed that both system forecasts and actual measurements are almost equal which implies that Kalman Filter can be used as an algorithm for weather forecasting.

An application program is developed to provide access to the general public on the predicted values by incorporating an Android application and text using GSM technology on the system. The Android application allowed the person to monitor the changes on the weather forecasts on their mobile phone. The Bluetooth has successfully allowed the transmission of data wirelessly from the computer to mobile phone. On the other hand, in case of emergency, a warning message through GSM technology is used in the system to inform the person. A command button is displayed in the graphical user interface (GUI) of the MATLAB program which allows the operator to control the sending of text messages for emergency purposes only.

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Chapter 4

CONCLUSIONS

A measuring and monitoring device for weather parameters such as temperature, pressure and, relative humidity is designed and implemented in this study. The objective is achieved by using a sensor for each parameter and is integrated to the microcontroller. Such sensors are the LM35 for temperature, capacitive humidity kit for humidity, and MPX114AP for measuring the pressure. Zigbee technology is also included which allows the transmission of measurements wirelessly from the device to the laptop or PC. Also, PIC16F877A microcontroller is used for collecting and processing of the gathered measurements. Since the device is real time, it sends measurements every 10 seconds.

The Kalman Filter Algorithm is proposed and applied by the researchers to provide weather forecast. It is applied and implemented using MATLAB based on its equations to perform the correction and prediction state. This algorithm uses two data, historical and present data. The combination of the past and present information in Kalman filter produced possible estimate of the parameters for the prediction of the next state of weather condition.

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An application program is developed to provide access to the general public on the predicted values by incorporating an Android application and text using GSM technology on the system. The Android application allowed the person to monitor the changes on the weather forecasts on their mobile phone. The Bluetooth has successfully allowed the transmission of data wirelessly from the computer to mobile phone. On the other hand, in case of emergency, a warning message through GSM technology is used in the system to inform the person. A command button is displayed in the graphical user interface (GUI) of the MATLAB program which allows the operator to control the sending of text messages for emergency purposes only.

Chapter 5

RECOMMENDATIONS

The study focused on the implementation and testing of Kalman filter as an algorithm for predicting weather condition. It is proposed that the testing of the system must be performed and exercised on the exact location where the weather station of the data to be compared is located. This is to have a more appropriate observation and comparisons on the system forecast to the forecast of the chosen weather station.

In Chapter 3 of this study, it is noted that the KF algorithm is a recursive algorithm which denotes that the calculation of the present value is dependent upon the previous calculated value of it. Thus, the system must have the capability to store the previous value for each parameter used. It is reached solely by throwing the whole system turned on for the continuous simulation. For the future researchers who will continue to improve this study, it is recommended that a database must be implemented in MATLAB to achieve ease of usage of the system.

Furthermore, the device capability to send information efficiently and faster can be achieved by embracing new technologies as a substitute for the components employed in this study. Some technologies for wireless data communication can be used as a substitute for the GSM technology and Bluetooth such as WI-Fi. The standard Zigbee used in the device can be upgraded to a Pro Zigbee, which has more advantages like faster transmission of measured data for the data logger purposes. This will allow the user to observe the changes easily occurred on each parameter since the system exhibits real time.

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APPENDIX A

Operation's Manual

1. System Requirement

   - Operating System: Windows 7 64-bit

2. Installation Procedure

   Installing the software for the drive:

   1. Open the Other Software folder in the provided CD.
   2. Double click the CH341SER64Bit.
   3. A window will be displayed like as shown below.

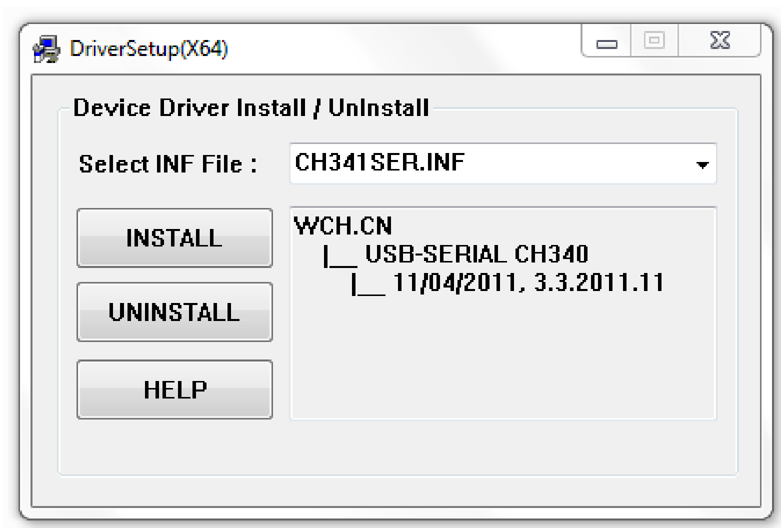

Figure No. 3.16 Driver Setup(x64)

   4. Click the Install button.
   5. A prompt will be displayed telling that the drive is successfully completed.

Installing the MATLAB software:

1. Insert the CD for installing MATLAB.
2. Double click setup.
3. A window will be displayed similar to the figure below. See Figure 3.17.

Figure No. 3.17 MathWorks Installer

4. Choose Install manually without using the Internet. Then, click Next.
5. In the License Agreement, choose Yes. Then, click Next.
6. In the File Installation Key window, choose "I have the File Installation for my license:"

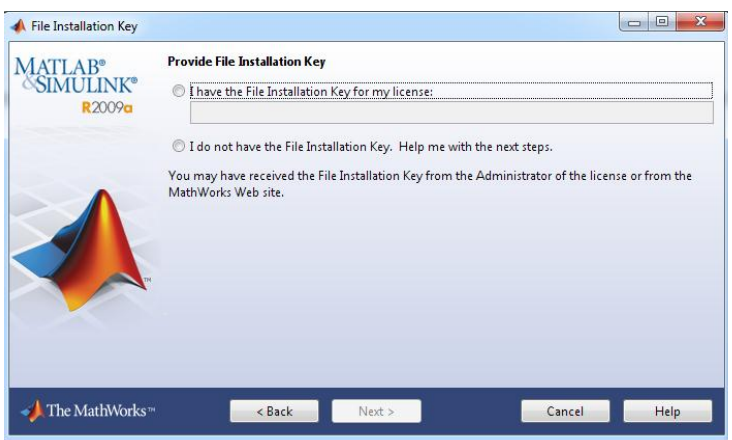

Figure No. 3.18 File Installation Key Window

7. In order to get the installation key, open the crack folder in the CD. Open the notepad file named “install”.

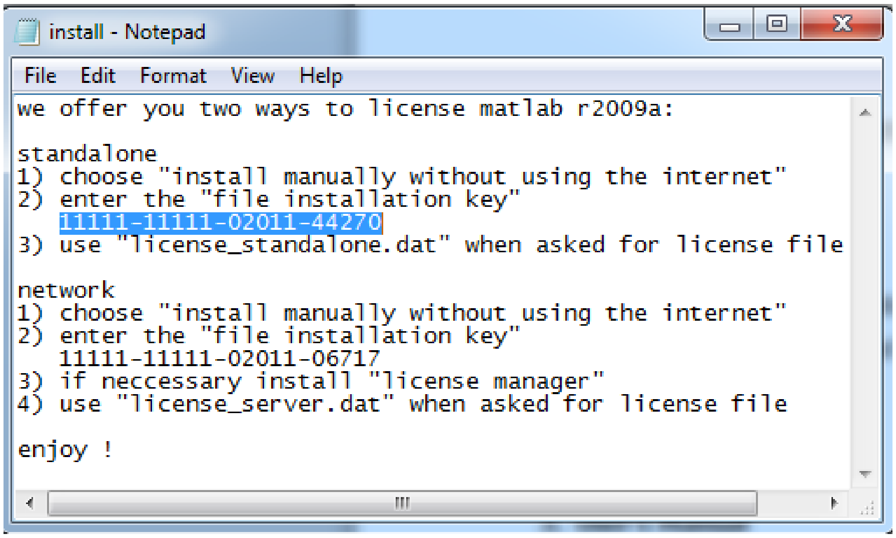

Figure No. 3.19 File Installation Key

8. Copy the file installation key on the space provided. Then, click Next.

9. Choose “Typical”. Click Next.

10. Specify the folder where you want to install MATLAB. Click Next.

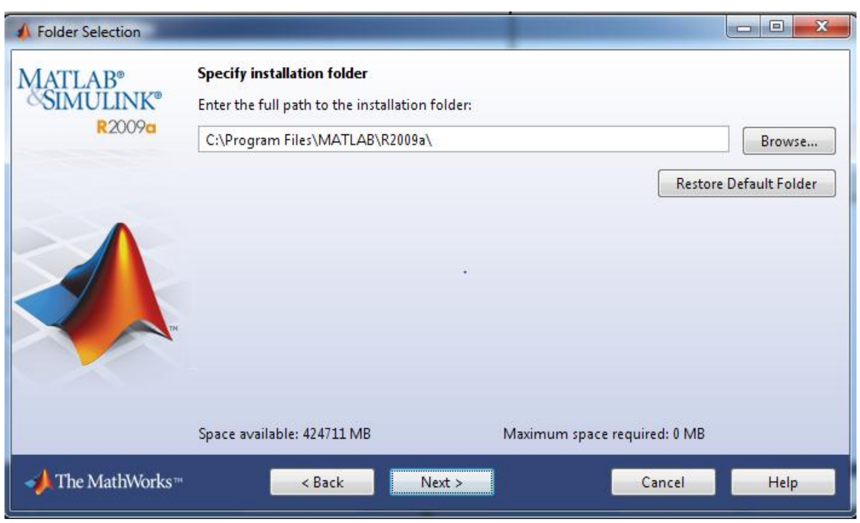

Figure No. 3.20 Folder Selection

11. Click Install. The installation procedure will start.

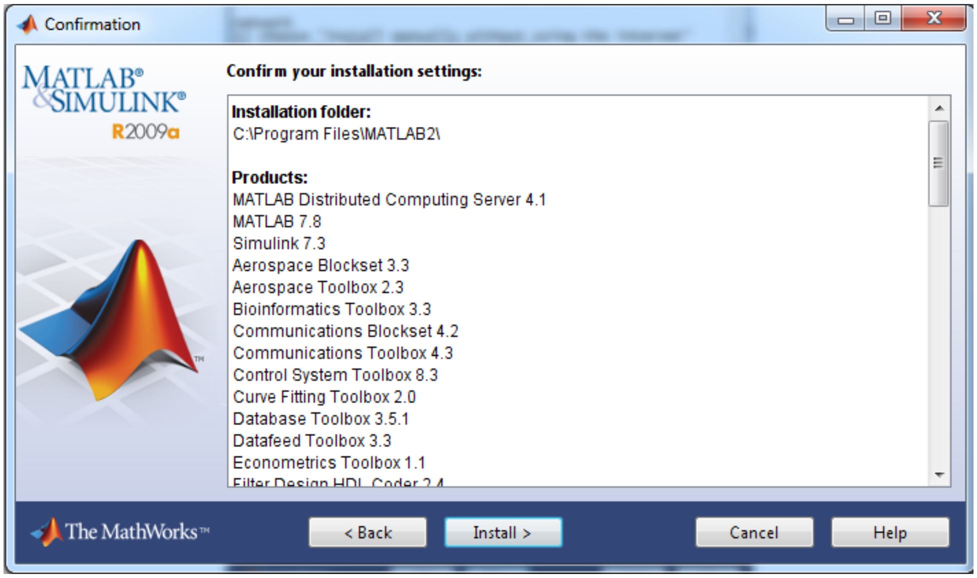

Figure No. 3.21 Installation Confirmation

12. After installing, activate MATLAB and click Next. After that, click Finish.

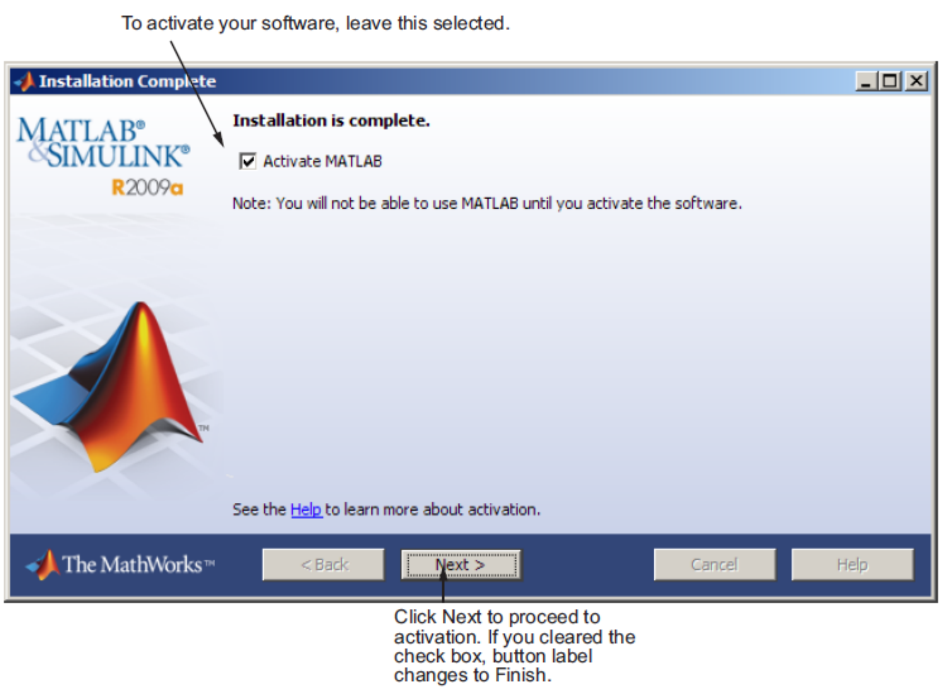

Figure No. 3.22 Installation Complete

Installing the Android application of Kalman Filter:

1. Connect your cellphone to the PC or laptop via Bluetooth.

   Note: Most laptops and desktops do have Bluetooth. If yours doesn't, a USB Bluetooth adapter can be used.

2. Enable Bluetooth on your cell phone.

3. Go to Control Panel under the Start Menu and then go to the Hardware and Sound. From there, choose Devices and Printers and click Add a Bluetooth device as shown in the Figure 3.23 below.

Figure No. 3.23 Add a Bluetooth Device

4. Scan for devices on your PC or laptop and choose your device name.

   Note: Make sure that your Bluetooth status is discoverable in order for the computer to detect your device.

5. Once your device is paired with your PC or laptop, transfer the Kalman. Ape file provided to your cell phone.

   Note: Open the Apps folder, and then go to Objects. Right-click on the Kalman.apk file and then send to Bluetooth device. See Figure 3.24.

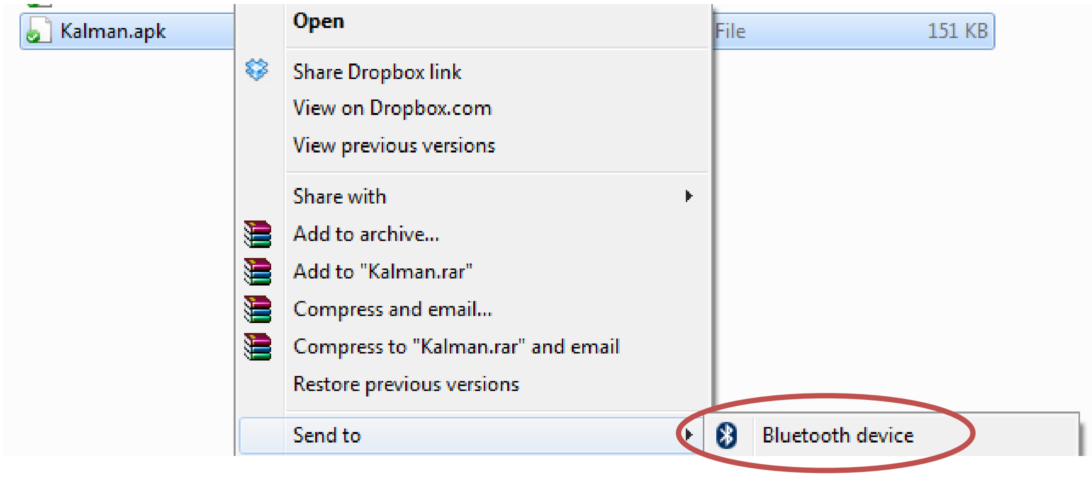

Figure No. 3.24 Kalman.apk

6. Open the Kalman.apk file on your cellphone.

   Note: Be sure to allow your mobile phone in installing non-Market applications. Go to Settings->Applications->Unknown sources.

7. A prompt will ask you to choose from the two options displayed in your mobile phone to complete the action. Such options include Package installer and Verify and Install. Choose Package Installer.

Figure No. 3.25 Package Installer

8. After that, the system will verify the installation of the application. Click the Install button and wait until the installation is completed.

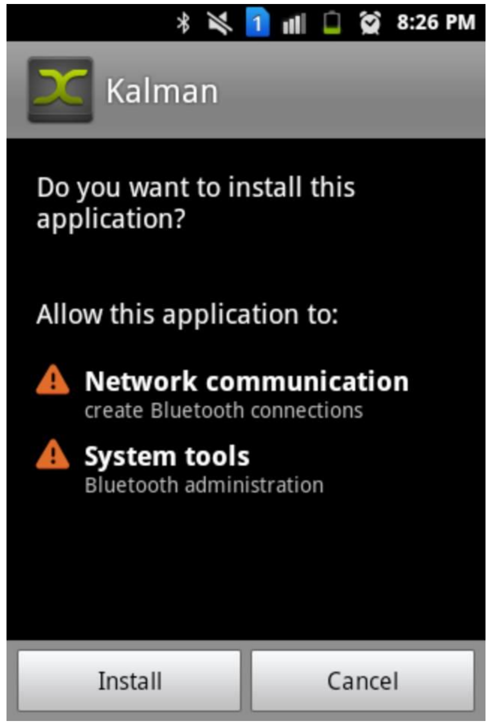

Figure No. 3.26 Kalman Installation

9. Two options will then be showed on your phone's screen: Open or Done. Open button must be selected to open the android application and Done button to exit.

   Note: Once the android application is opened in your mobile phone, it will turn on your Bluetooth connection to let the other devices (laptop or PC) to connect. Figure 3.27 shows the GUI of the android application.

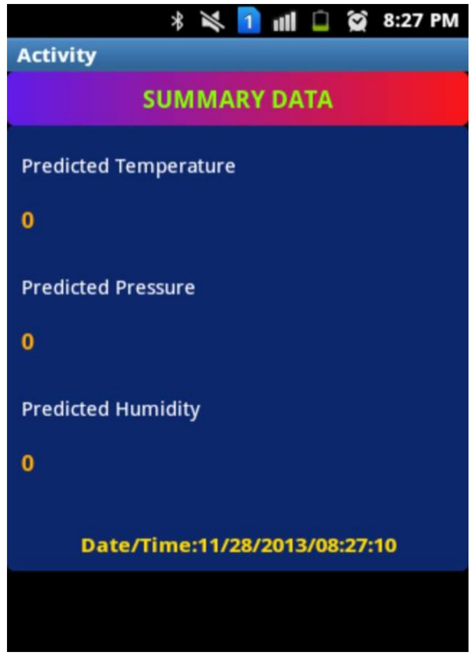

Figure No. 3.27 Kalman GUI

<u>Creating COM port for Bluetooth</u>

1. Once your mobile phone is paired on the PC or laptop, find and click the Bluetooth icon. Select the Open Settings to display the current settings of the Bluetooth on your laptop or PC.

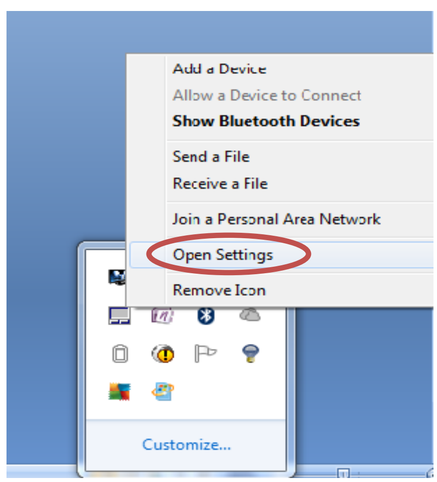

Figure No. 3.28 Opening the Bluetooth Settings

2. The Bluetooth Settings will appear as shown in Figure 3.29. Click the COM ports tab.

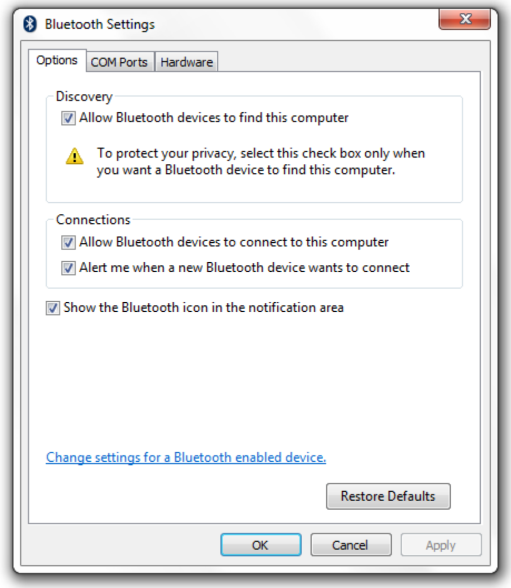

Figure No. 3.29 Bluetooth Settings Window

3. In the COM ports tab, click the Add button.

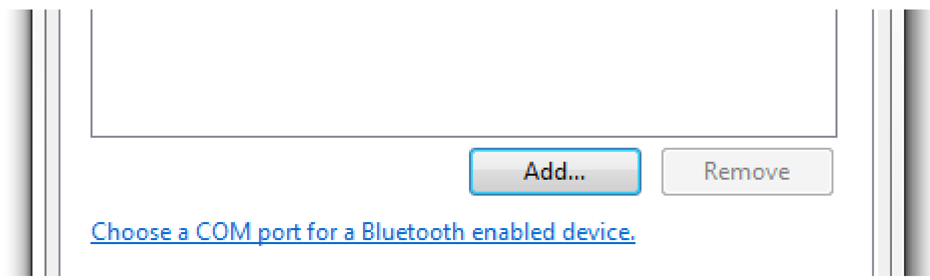

Figure No. 3.30 COM Ports

4. The Add COM port window will be displayed. Verify that the radio button for Incoming (device initiates the connection) is selected. Then click OK button.

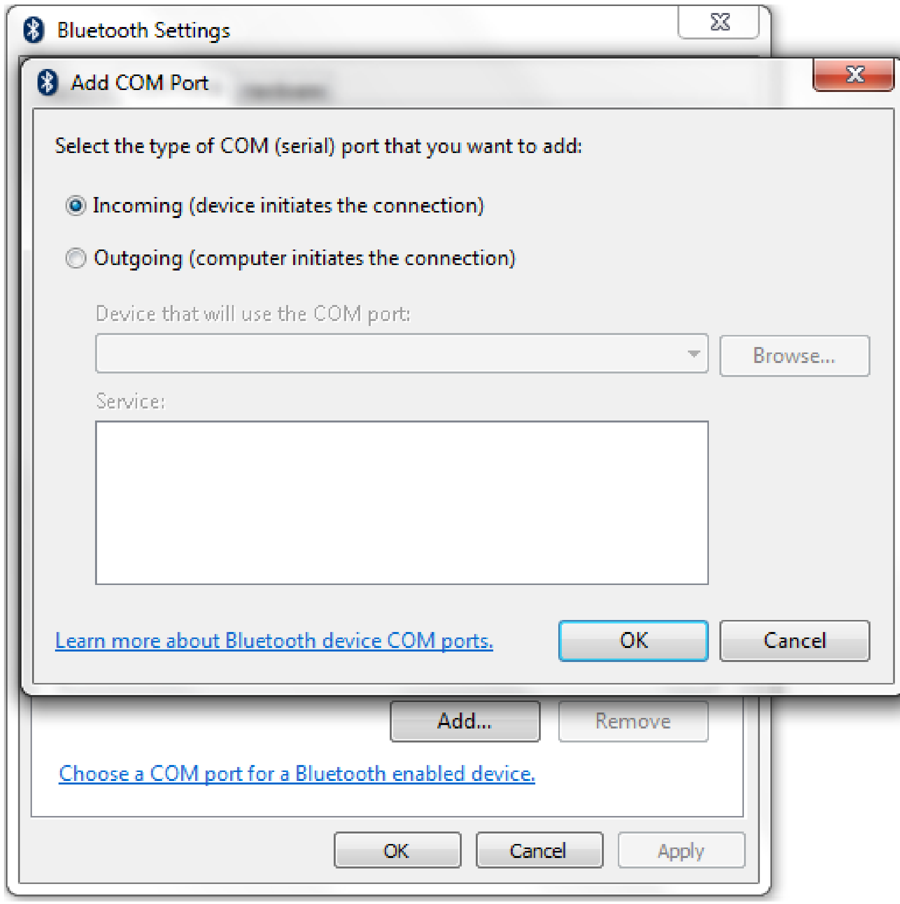

Figure No. 3.31 Add COM Port

5. A verification message will be displayed in the Taskbar informing that the device driver software was installed successfully and the COM port for Bluetooth is displayed. Then click OK in the Bluetooth Settings window.

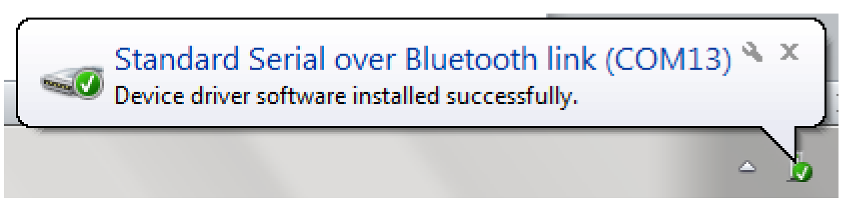

Figure No. 3.32 Standard Serial over Bluetooth link

Note: This COM port will be used and declared in the MATLAB program for Weather Prediction using Kalman Filter. Assign this port number in the COM port declaration of the code.

```
s = serial('COM13',...
    'BaudRate', 9600,...
    'TimeOut',5,...
    'Terminator',13);
fopen(s);
s.ReadAsyncMode = 'manual';
```

Figure No. 3.33 Modified COM Port

3. User's Manual

1. Connect the USB to serial port in the serial port of the device (the small one). See figure below.

Figure No. 3.34 Zigbee Serial Connection

2. In the same device, connect the two USB cable to the USB port of the PC or laptop. Be sure that the driver is installed properly. The red LED will blink to signify that it is ready to use.

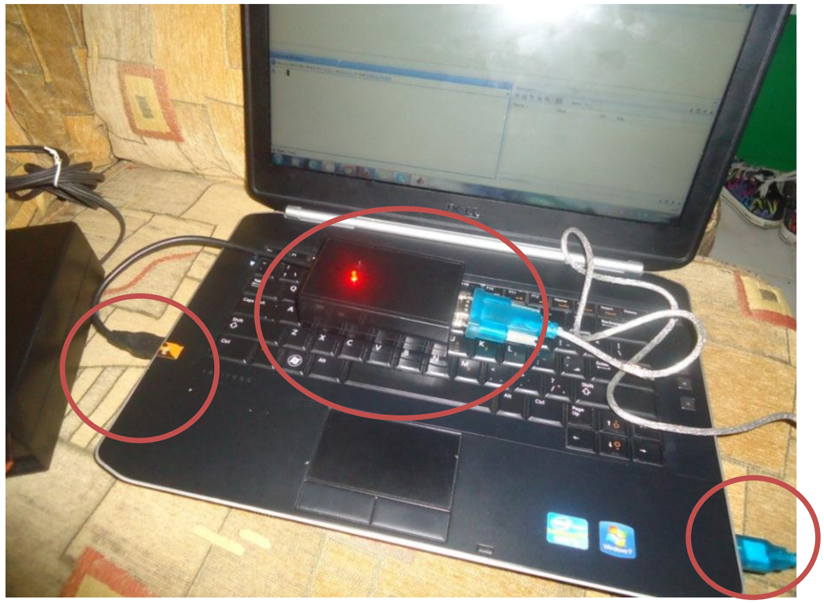

Figure No. 3.35 Complete Set-up of Zigbee

3. Plug the other device (the larger one). A red LED will light up first and then the green LED will start to blink. Wait until the light of the green LED is steady which signifies that the device is ready to use, otherwise it is in OFF mode. To turn it ON, switch the toggle switch at the back of the device.

Figure No. 3.36 Device for Measuring Weather Parameters

4. Open the MATLAB -> Click File menu -> Click New -> Select GUI -> Select Open Existing GUI then browse the Fig-File of the program. The program is provided on the CD in the Wireless Weather folder.

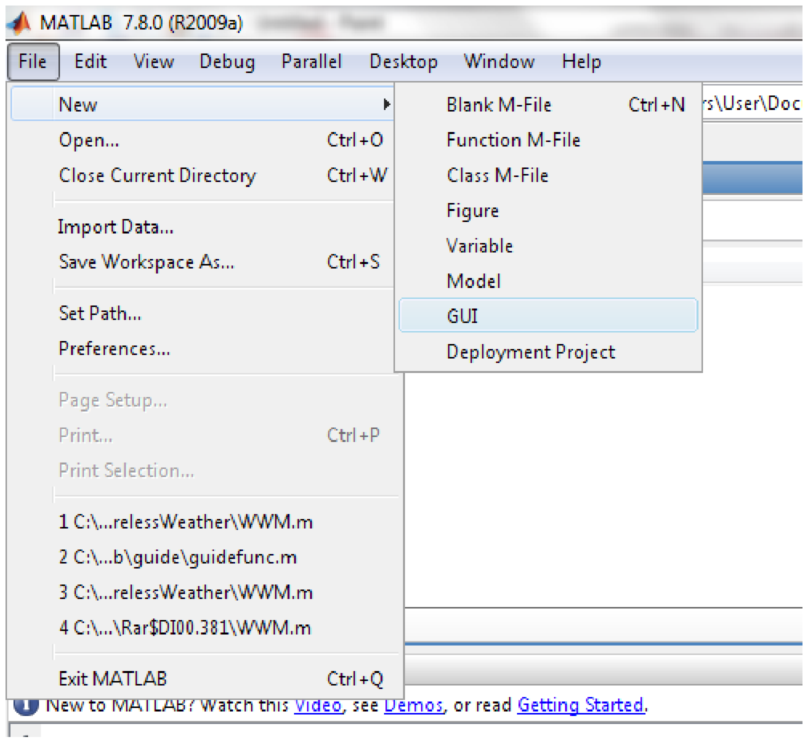

Figure No. 3.37 Opening an Existing GUI file

5. A window will appear like the figure below.

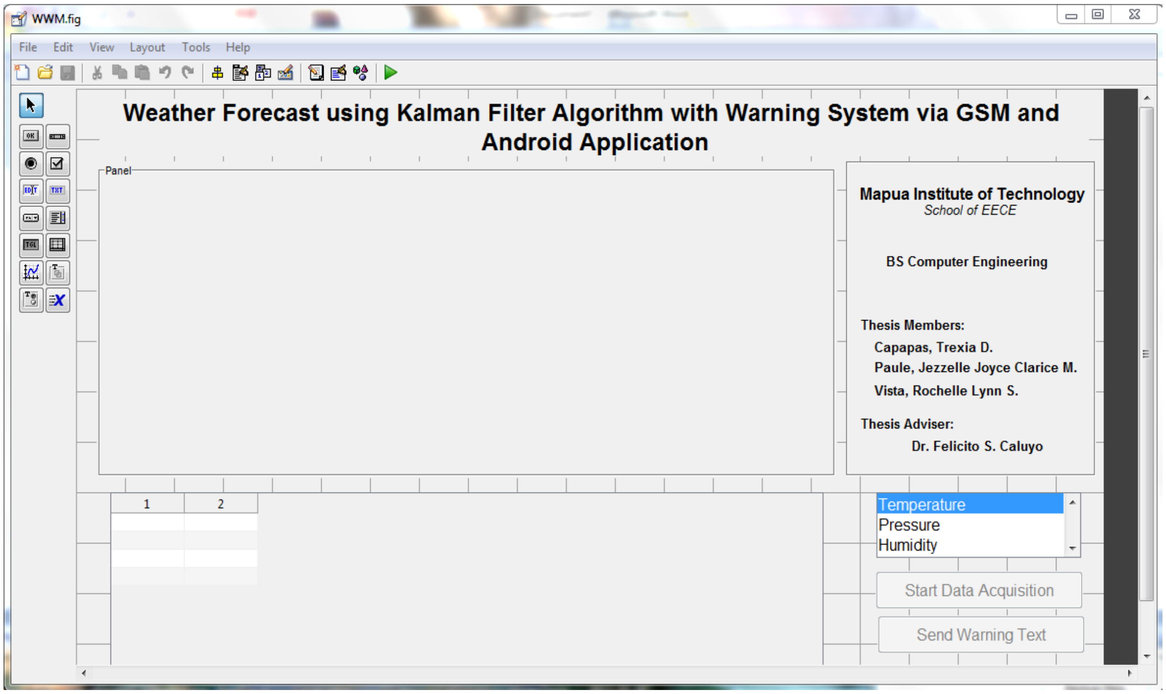

Figure No. 3.38 .fig file

6. To open the M-file, right click the Start Data Acquisition button, then select View Callbacks then Callback.

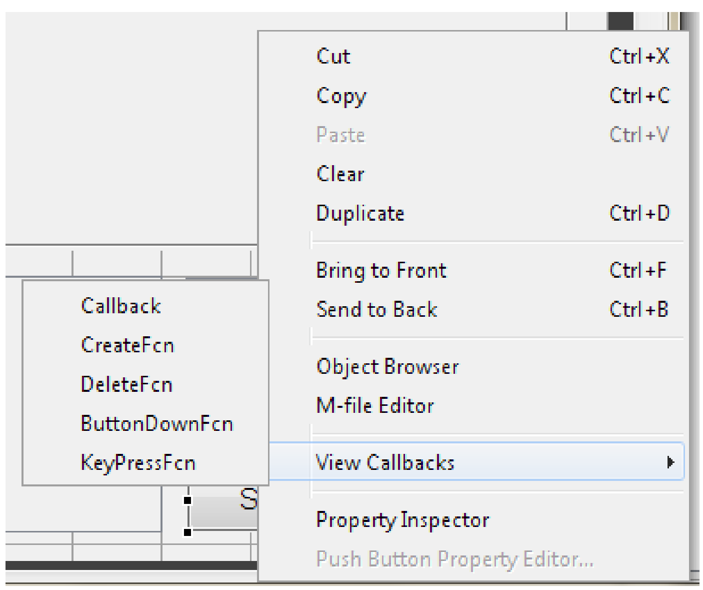

Figure No. 3.39 M-file

7. Click the Run button.

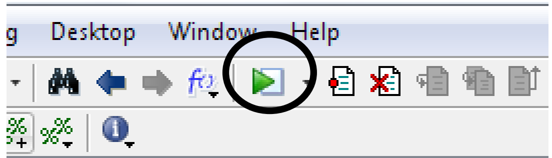

Figure No. 3.40 Run Button

8. Select a Raw Data CSV in order for the program to run.

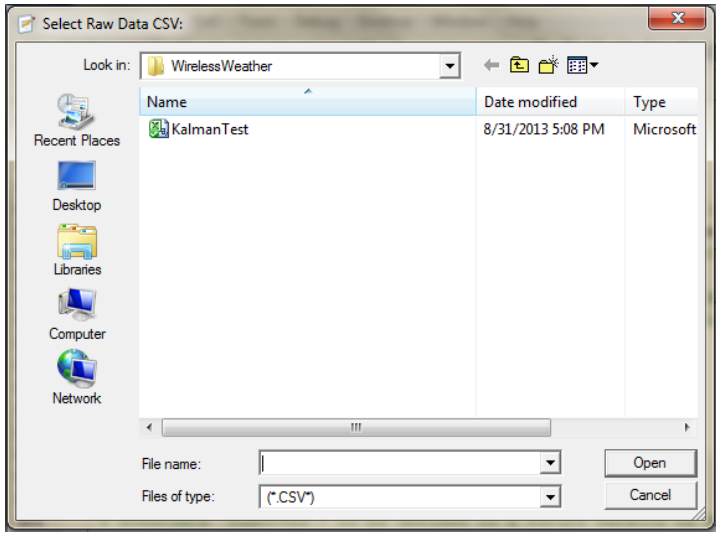

Figure No. 3.41 Selecting Raw Data

Note: A CSV file consists of any number of records, separated by line breaks of any kind; each record consists of fields, separated by some other character or string, most commonly a literal comma or tab (Babylons' English Dictionary).

9. The GUI is shown below.

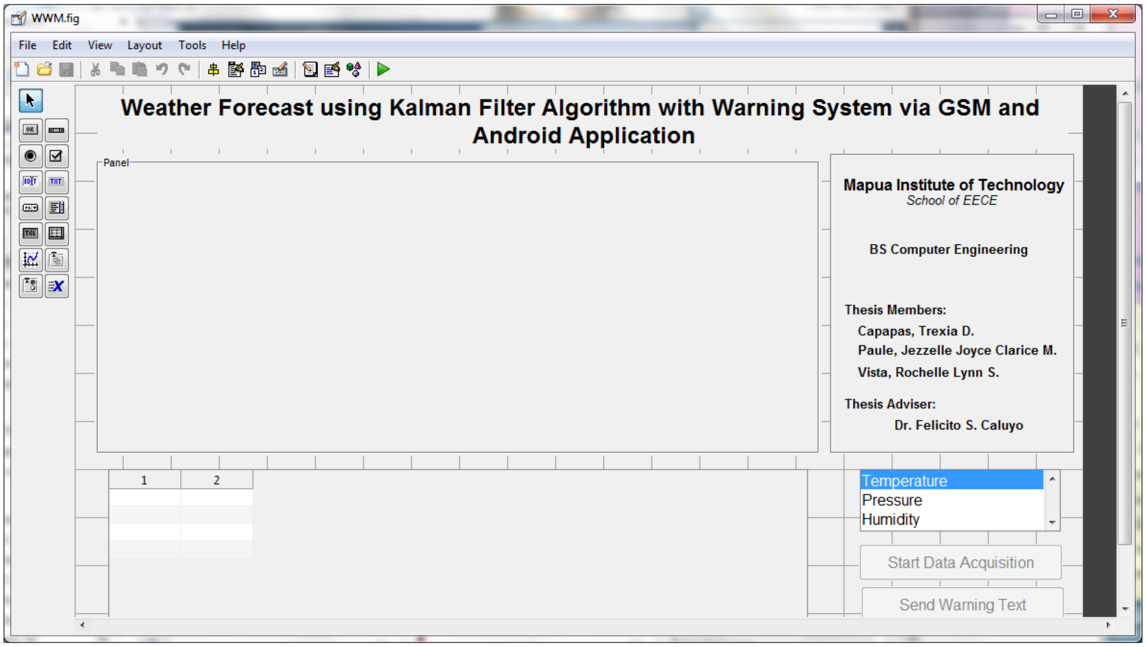

Figure No. 3.42 .fig File for Kalman Filter

10. You can choose any parameter you want to be displayed in the graph provided. Click the Start Data Acquisition. After 15 seconds, the measurements and the predicted value for the weather parameters; temperature, pressure and humidity will be displayed. Each parameter will have ten (10) samples.

4. Troubleshooting Guides and Procedures

1. Clicking the Start Data Acquisition button in MATLAB doesn't work
   a. First, make sure that the device is plugged in.
   b. Check if the serial cable is properly connected to the laptop and to the device.
   c. Open the MATLAB and the m-file again.
2. The COM port used in serial connection is not available
   a. Make sure that the serial cable is properly connected to your PC or laptop and the device.
   b. Verify the COM port number in the Device Manager by following the steps provided in the installation of Bluetooth.
   c. In the m-file, locate the COM port number used. Change it to the COM port number displayed in the pop-up window in the Taskbar.
   d. Run the M-file.

3. No COM port number displayed in the Device Manager
    a. Make sure that the serial cable is properly connected to your laptop and device.
    b. Reinstall the driver. See the Installation Procedure.
    c. Reopen the MATLAB and rerun the m-file.
    d. If same problem was encountered, the serial cable is defective. Try using another serial cable then rerun the m-file.
4. The android application cannot connect to the program via Bluetooth connection or there is an error occurred while making a connection
    a. Quit the android application of Kalman Filter.
    b. Restart the mobile phone.
    c. Open the android application and reconnect it to the laptop or PC.
    d. If the android application is still cannot connect to the laptop or PC, go to the Bluetooth settings and to the COM Ports tab.
    e. Remove the COM port number of the incoming device and add again another COM port number of the incoming device.
    f. Modify the COM port number in the MATLAB program for Kalman filter.
    g. Reconnect again the android application to the laptop or PC.
5. The COM port number for Bluetooth connection is not available
    a. Check the Bluetooth Settings for the COM port number of the incoming device.
    b. Check the COM port number declared in the MATLAB program.
    c. If the COM port number is the same for the previous steps, rewrite again the COM port number in the MATLAB program and save it.
    d. Click the Run button in MATLAB.

5. Error Definitions

1. Unhandled internal error in guidefunc - The error below simply shows that the inputted COM port number for the serial connection is not available.

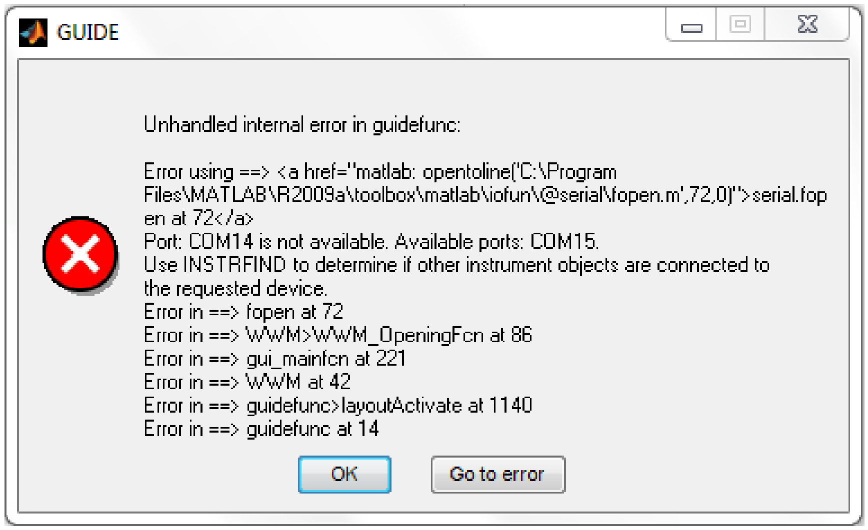

Figure No. 3.43 Unhandled Internal Error

2. Error using serial/fopen (line 72) – the COM port used for the Bluetooth connection is not available. The error shown in the figure below displays same port number for the available and not available port.

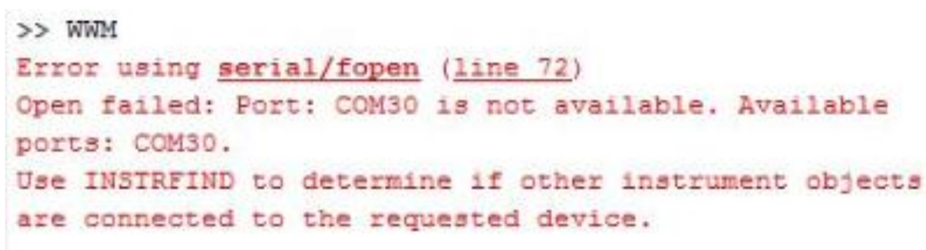

Figure No. 3.44 Error on opening serial port

3. Error – the Bluetooth connection of the laptop or PC to the android application in mobile phone is disconnected.

APPENDIX B

M-Files (Codes)

PIC16F877A

```
Device 16F877A
Declare Xtal = 20

Declare Adin_Res 10
Declare Adin_Tad  FRC
Declare Adin_Stime  50

Declare Hserial_Baud = 9600
Declare Hserial_RCSTA = %10010000
Declare Hserial_TXSTA = %00100100
Declare Hserial_Clear True

Symbol gsmPW = PORTD.5
Symbol gsmIn = PORTD.7
Symbol gsmOut = PORTD.6

Symbol LED01 = PORTD.0

Dim aRead1 As Word
Dim aRead2 As Word
Dim aRead3 As Word

Dim aReadTemp As Dword
Dim gCtr As Word
Dim uNum1[12] As Byte
Dim myCom As Byte

Dim pTemp[9] As Byte, pPres[9] As Byte, pHum[9] As Byte

ADCON1 = $80
TRISA = $FF
TRISB = $FF
TRISC = $BF
TRISD = $9E
TRISE = $07

DelayMS 50
```

```
pTemp[8] = 0 : pPres[8] = 0 : pHum[8] = 0

GoSub subs_SMS_Init

HSerOut["U"]

While 1 = 1

    HSerIn [Wait("U"), myCom]

    Select Case myCom

      Case "D"

        aReadTemp = 0

        For gCtr = 1 To 1000

          aRead1 = ADIn 0
          aReadTemp = aReadTemp + aRead1
          DelayUS 5

        Next gCtr

        aReadTemp = aReadTemp / 1000
        aRead1 = aReadTemp

        aReadTemp = 0

        For gCtr = 1 To 1000

          aRead3 = ADIn 2
          aReadTemp = aReadTemp + aRead3
          DelayUS 5

        Next gCtr

        aReadTemp = aReadTemp / 1000
        aRead3 = aReadTemp

        aRead2 = Counter PORTD.2, 900

        HSerOut ["ADC: ",Dec4 aRead3,32,Dec4 aRead1,32,Dec4 aRead2,13]
```

```
        Case "S"

            HSerIn [Wait("_"), Str pTemp\8, Wait("_"), Str pPres\8, Wait("_"), Str
pHum\8]
            GoSub subs_SMS_Send
            HSerOut["U"]

    EndSelect



    'DelayMS 1000

Wend


subs_SMS_Init:


   gsmPW = 1
   DelayMS 2500
   gsmPW = 0
   DelayMS 5000


   LED01 = 1

   SerOut gsmOut, 84, ["AT",13]
   DelayMS 2000

   LED01 = 0 : DelayMS 500 : LED01 = 1

   SerOut gsmOut, 84, ["AT+CIURC=0",13]
   SerIn gsmIn, 84,  1500, subs_SMS_InitFailed,[Wait("OK")]
   DelayMS 500

   LED01 = 0 : DelayMS 500 : LED01 = 1

   SerOut gsmOut, 84, ["AT+CNMI=3,1,0,0,0",13]
   SerIn gsmIn, 84,  1500, subs_SMS_InitFailed,[Wait("OK")]
   DelayMS 500

   LED01 = 0 : DelayMS 500 : LED01 = 1
```

```
SerOut gsmOut, 84, ["AT+CFUN=1",13]
SerIn gsmIn, 84,  1500, subs_SMS_InitFailed,[Wait("OK")]
DelayMS 500

LED01 = 0 : DelayMS 500 : LED01 = 1

SerOut gsmOut, 84, ["AT+CMGF=1",13]
SerIn gsmIn, 84,  1500, subs_SMS_InitFailed,[Wait("OK")]
DelayMS 500

LED01 = 0 : DelayMS 500 : LED01 = 1

SerOut gsmOut, 84, ["AT+CMEE=0",13]
SerIn gsmIn, 84,  1500, subs_SMS_InitFailed,[Wait("OK")]
DelayMS 500

LED01 = 0 : DelayMS 500 : LED01 = 1

SerOut gsmOut, 84, ["AT+CSDH=0",13]
SerIn gsmIn, 84,  1500, subs_SMS_InitFailed,[Wait("OK")]
DelayMS 500

LED01 = 0 : DelayMS 500 : LED01 = 1

SerOut gsmOut, 84,  ["ATE1",13]
SerIn gsmIn, 84,  1500, subs_SMS_InitFailed,[Wait("OK")]
DelayMS 500

LED01 = 0 : DelayMS 500 : LED01 = 0

For gCtr = 10 To 1 Step -1

   LED01 = ~LED01
   DelayMS 500

Next gCtr

For gCtr = 0 To 10

   uNum1[gCtr] = "0"

Next gCtr
```

```
    uNum1[11] = 0

        'retrieve admin number

        SerOut gsmOut, 84, ["AT+CPBF=",34,"ADMIN",34,13]
        SerIn gsmIn, 84,  3500, subs_SMS_InitFailed, [Wait("+CPBF:"),Wait(34),Str
uNum1\11,Wait("OK")]
        DelayMS 2000

     LED01 = 1


Return

subs_SMS_Send:


sj_SS_Start:

    LED01 = 0

    For gCtr = 1 To 3

        LED01 = ~LED01
        DelayMS 500

    Next gCtr

    LED01 = 1

    SerOut gsmOut , 84,  ["AT",13]

    DelayMS 500

    LED01 = 0 : DelayMS 500 : LED01 = 1

    SerOut gsmOut , 84,  ["AT",13]

    DelayMS 500

    LED01 = 0 : DelayMS 500 : LED01 = 1

     SerOut gsmOut , 84,  ["AT+CMGS=",34,Str uNum1\11,34,13]
```

```
    DelayMS 500

    LED01 = 0 : DelayMS 500 : LED01 = 1

    SerOut gsmOut, 84, ["Data Results:",13]
    SerOut gsmOut, 84, ["P.Temperature: ", Str pTemp\8,13]
    SerOut gsmOut, 84, ["P.Pressure: ", Str pPres\8,13]
    SerOut gsmOut, 84, ["P.Humidity: ", Str pHum\8,13]

    LED01 = 0 : DelayMS 500 : LED01 = 1

    SerOut gsmOut , 84,  [26]

    DelayMS 500

    LED01 = 1


sj_SMS_Out:

Return



subs_SMS_InitFailed:

    LED01 = 1

    While 1 = 1

        LED01 = ~LED01
        DelayMS 250

    Wend

Return

End
```

In programming the microcontroller, the researchers first define XTAL which serves as the crystal oscillator of PIC16F877A. It is the oscillator that produces electrical oscillations at a frequency determined by the physical characteristics of a piezoelectric quartz crystal (The

FreeDictionary). After that, they declared the following parameters: Adin_Res 10, Adin_Tad FRC, and Adin_Stime 50 which signifies a 10-bit result required, FRC as a chosen oscillator and allows 50µs sample time, respectively.

The next thing that must be implemented is to configure the following input ports declared as TRISA, TRISB, TRISC, TRISD, and TRISE. After that, the microcontroller would be able to read the measured data of the following sensors, temperature, pressure and humidity. Then, it will output the measured values which will then be displayed in the data logger of the MATLAB GUI.

MATLAB

```
function varargout = WWM(varargin)
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @WWM_OpeningFcn, ...
                   'gui_OutputFcn',  @WWM_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end

 handles.output = hObject;

delete(instrfindall);
movegui(hObject,'center');
if(~isdeployed)
    cd(fileparts(which(mfilename))); % From Brett
end

set(handles.figure1,'name','Weather Forecast Using Kalman Filter Algorithm');

guidata(hObject, handles);


global AcqFlag;
global grpFlag;
global sendDataF;


sampTotal = 10;
tempVal = zeros(1);
presVal = zeros(1);
humiVal = zeros(1);
%rowData = zeros(sampTotal,3);
sampCtr = 1;
```

```
grpFlag = 1;

 [CSVPath, folder] = uigetfile('*.CSV*', 'Select Raw Data CSV:');
CSVPath = fullfile(folder, CSVPath);

rawData = csvread(CSVPath,1,0);

sDevT = 0.1;
sDevP = 0.1;
sDevH = 0.1;

DataT = rawData(:,1);
DataP = rawData(:,2);
DataH = rawData(:,3);


kRep = size(DataT);

PredT = zeros(kRep);
PredP = zeros(kRep);
PredH = zeros(kRep);

lastPT = 0;
lastPP = 0;
lastPH = 0;

aVar = 0;
pVar = 1;

for i = 1 : kRep

   kVar = pVar / (pVar + sDevT);
   aVar = aVar + (kVar * (DataT(i) - aVar));
   pVar = (1 - kVar) * pVar;
   PredT(i) = aVar;
end

lastPT = pVar;


aVar = 0;
pVar = 1;
```

```
for i = 1 : kRep

    kVar = pVar / (pVar + sDevP);
    aVar = aVar + (kVar * (DataP(i) - aVar));
    pVar = (1 - kVar) * pVar;
    PredP(i) = aVar;
end

lastPP = pVar;


aVar = 0;
pVar = 1;

for i = 1 : kRep

    kVar = pVar / (pVar + sDevH);
    aVar = aVar + (kVar * (DataH(i) - aVar));
    pVar = (1 - kVar) * pVar;
    PredH(i) = aVar;
end

lastPH = pVar;


h = subplot(1,1,1,'Parent',handles.pnlGrapher);
hold on;

 %subplot(1,1);

 plot(DataT,'b');
 plot(PredT,'r');
 legend('Actual Data','Predicted Data');
 xlabel('Samples');
 ylabel('Temperature (c)');

 drawnow;
 %axes(h);

 %DataAcq Block-----------------------------------------------------------

s = serial('COM31',...
    'BaudRate', 9600,...
    'TimeOut',5,...
```

```
    'Terminator',13);
fopen(s);
s.ReadAsyncMode = 'manual';


s2 = serial('COM33',...
    'BaudRate', 9600,...
    'TimeOut',5,...
    'OutputBufferSize',1024,...
    'Terminator',13);
fopen(s2);
s2.ReadAsyncMode = 'manual';


%format the table
colNames = {'Temperature','Pressure','Humidity', 'Predicted T', 'Predicted P','Predicted
H','Heat Index'};
colData = {0,0,0,0,0,0,0};
set(handles.tblDataLogs,'data',colData,'ColumnName',colNames);
set(handles.tblDataLogs, 'ColumnWidth', {80 80 80 80 80 80 120});
drawnow;

set(handles.btnGetData,'Enable','on');


AcqFlag = 0;
sendDataF = 0;
while 1 == 1

      oras = clock;
      myDate = datestr(oras,'mmmm dd, yyyy HH:MM:SS AM');

      myTitle = sprintf('Weather Forecast Using Kalman Filter Algorithm - %s', myDate);

     set(handles.figure1,'name',myTitle);

    if AcqFlag == 1

        if sendDataF == 1

            set(handles.btnSendData,'String','Sending Data');
            set(handles.btnSendData,'Enable','off');
            drawnow;
```

```
        btString =
sprintf('US_%08.2f_%08.2f_%08.2f\n',PredT(10),PredP(10),PredH(10));
        fprintf(s,btString);

        pause(10);


         sendDataF = 0;
        set(handles.btnSendData,'String','Send Data');
        set(handles.btnSendData,'Enable','on');
        drawnow;

    end

    fprintf(s,'UD');

    [dummy,count] = fscanf(s,'%s');

    if count >= 19

       str1 = dummy(5:8);
       str2 = dummy(9:12);
       str3 = dummy(13:16);

       tempVal(sampCtr) = (sscanf(str1,'%d') * 4.88) / 10;
       presVal(sampCtr) = ((((sscanf(str2,'%d') * 4.89) / 5000) + 0.095) / 0.009)*2;
       humiVal(sampCtr) = sscanf(str3,'%d');


        if humiVal(sampCtr) > 7351
            % RH < 0 - out of range
            humBase = 101;

        elseif humiVal(sampCtr) > 7224

            %base 0
            hUpper = 7351;
            hLower = 7224;
            humBase = 0;

        elseif humiVal(sampCtr) > 7100

            %base 10
            hUpper = 7224;
```

```
    hLower = 7110;
    humBase = 10;

elseif humiVal(sampCtr) > 6976

    %base 20
    hUpper = 7110;
    hLower = 6976;
    humBase = 20;

elseif humiVal(sampCtr) > 6853

    %base 30
    hUpper = 6976;
    hLower = 6853;
    humBase = 30;

elseif humiVal(sampCtr) > 6728

    %base 40
    hUpper = 6853;
    hLower = 6728;
    humBase = 40;

elseif humiVal(sampCtr) > 6600

    %base 50
    hUpper = 6728;
    hLower = 6600;
    humBase = 50;

elseif humiVal(sampCtr) > 6468

    %base 60
    hUpper = 6600;
    hLower = 6468;
    humBase = 60;

elseif humiVal(sampCtr) > 6330

    %base 70
    hUpper = 6468;
    hLower = 6330;
    humBase = 70;
```

```
    elseif humiVal(sampCtr) > 6186

        %base 80
        hUpper = 6330;
        hLower = 6186;
        humBase = 80;

    elseif humiVal(sampCtr) > 6033

        %base 90
        hUpper = 6186;
        hLower = 6033;
        humBase = 90;

    else

        humBase = 100;

    end


switch humBase

    case 101

        humiVal(sampCtr) = 0;


    case 100

        humiVal(sampCtr) = 100;


    otherwise

        freqH = 6660;
        freqDiff = hUpper - freqH;
        freqInterval = hUpper - hLower;
        humiVal(sampCtr) = ((freqDiff / freqInterval) * 10) + humBase;

end
```

```
    rowData(sampCtr,1) = cellstr(num2str(tempVal(sampCtr),'%.2f'));
    rowData(sampCtr,2) = cellstr(num2str(presVal(sampCtr),'%.2f'));
    rowData(sampCtr,3) = cellstr(num2str(humiVal(sampCtr),'%.2f'));

    if sampCtr < sampTotal

        sampCtr = sampCtr + 1;

    else

%compute Kalman Predictions

        [sRW,sCL] = size(PredT);
        aVar = PredT(sRW);
        pVar = lastPT;
        PredT = zeros(1);

        for i = 1 : 10

            kVar = pVar / (pVar + sDevT);
            aVar = aVar + (kVar * (tempVal(i) - aVar));
            pVar = (1 - kVar) * pVar;
            PredT(i) = aVar;
            rowData(i,4) = cellstr(num2str(aVar,'%.2f'));

        end

        lastPT = pVar;

        [sRW,sCL] = size(PredP);
        aVar = PredP(sRW);
        pVar = lastPP;
        PredP = zeros(1);

        for i = 1 : 10

            kVar = pVar / (pVar + sDevT);
            aVar = aVar + (kVar * (presVal(i) - aVar));
            pVar = (1 - kVar) * pVar;
            PredP(i) = aVar;
            rowData(i,5) = cellstr(num2str(aVar,'%.2f'));
        end

        lastPP = pVar;
```

```
[sRW,sCL] = size(PredH);
aVar = PredH(sRW);
pVar = lastPH;
PredH = zeros(10);

for i = 1 : 10

    kVar = pVar / (pVar + sDevT);
    aVar = aVar + (kVar * (humiVal(i) - aVar));
    pVar = (1 - kVar) * pVar;
    PredH(i) = aVar;
    rowData(i,6) = cellstr(num2str(aVar,'%.2f'));
end

lastPH = pVar;

%get Heat Index

for i = 1 : 10

    tRounded = round(PredT(i));
    hRounded = round(PredH(i));

    if tRounded == 27

        if hRounded == 40

            rowData(i,7) = cellstr(sprintf('CAUTION (27)'));

        elseif hRounded == 45

            rowData(i,7) = cellstr(sprintf('CAUTION (27)'));

        elseif hRounded == 50

            rowData(i,7) = cellstr(sprintf('CAUTION (27)'));

        elseif hRounded == 55

            rowData(i,7) = cellstr(sprintf('CAUTION (28)'));

        elseif hRounded == 60
```

```
        rowData(i,7) = cellstr(sprintf('CAUTION (28)'));
    elseif hRounded == 65
        rowData(i,7) = cellstr(sprintf('CAUTION (28)'));
    elseif hRounded == 70
        rowData(i,7) = cellstr(sprintf('CAUTION (29)'));
    elseif hRounded == 75
        rowData(i,7) = cellstr(sprintf('CAUTION (29)'));
    elseif hRounded == 80
        rowData(i,7) = cellstr(sprintf('CAUTION (30)'));
    elseif hRounded == 85
        rowData(i,7) = cellstr(sprintf('CAUTION (30)'));
    elseif hRounded == 90
        rowData(i,7) = cellstr(sprintf('CAUTION (31)'));
    elseif hRounded == 95
        rowData(i,7) = cellstr(sprintf('CAUTION (31)'));
    elseif hRounded == 100
        rowData(i,7) = cellstr(sprintf('CAUTION (32)'));
    end
elseif tRounded == 28
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('CAUTION (28)'));
    elseif hRounded == 45
```

```
    rowData(i,7) = cellstr(sprintf('CAUTION (28)'));
elseif hRounded == 50
    rowData(i,7) = cellstr(sprintf('CAUTION (28)'));
elseif hRounded == 55
    rowData(i,7) = cellstr(sprintf('CAUTION (29)'));
elseif hRounded == 60
    rowData(i,7) = cellstr(sprintf('CAUTION (29)'));
elseif hRounded == 65
    rowData(i,7) = cellstr(sprintf('CAUTION (30)'));
elseif hRounded == 70
    rowData(i,7) = cellstr(sprintf('CAUTION (31)'));
elseif hRounded == 75
    rowData(i,7) = cellstr(sprintf('CAUTION (31)'));
elseif hRounded == 80
    rowData(i,7) = cellstr(sprintf('CAUTION (32)'));
elseif hRounded == 85
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (33)'));
elseif hRounded == 90
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (34)'));
elseif hRounded == 95
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (35)'));
elseif hRounded == 100
```

```
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (36)'));
    end
elseif tRounded == 29
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('CAUTION (29)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('CAUTION (29)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('CAUTION (30)'));
    elseif hRounded == 55
        rowData(i,7) = cellstr(sprintf('CAUTION (30)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('CAUTION (31)'));
    elseif hRounded == 65
        rowData(i,7) = cellstr(sprintf('CAUTION (32)'));
    elseif hRounded == 70
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (33)'));
    elseif hRounded == 75
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (34)'));
    elseif hRounded == 80
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (35)'));
    elseif hRounded == 85
```

```
            rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (36)'));
        elseif hRounded == 90
            rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (37)'));
        elseif hRounded == 95
            rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (38)'));
        elseif hRounded == 100
            rowData(i,7) = cellstr(sprintf('DANGER (40)'));
        end
    elseif tRounded == 30
        if hRounded == 40
            rowData(i,7) = cellstr(sprintf('CAUTION (30)'));
        elseif hRounded == 45
            rowData(i,7) = cellstr(sprintf('CAUTION (30)'));
        elseif hRounded == 50
            rowData(i,7) = cellstr(sprintf('CAUTION (31)'));
        elseif hRounded == 55
            rowData(i,7) = cellstr(sprintf('CAUTION (32)'));
        elseif hRounded == 60
            rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (33)'));
        elseif hRounded == 65
            rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (34)'));
        elseif hRounded == 70
```

```
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (35)'));
    elseif hRounded == 75
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (36)'));
    elseif hRounded == 80
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (38)'));
    elseif hRounded == 85
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (39)'));
    elseif hRounded == 90
        rowData(i,7) = cellstr(sprintf('DANGER (41)'));
    elseif hRounded == 95
        rowData(i,7) = cellstr(sprintf('DANGER (42)'));
    elseif hRounded == 100
        rowData(i,7) = cellstr(sprintf('DANGER (44)'));
    end
elseif tRounded == 31
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('CAUTION (31)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('CAUTION (32)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (33)'));
    elseif hRounded == 55
```

```
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (34)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (35)'));
    elseif hRounded == 65
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (36)'));
    elseif hRounded == 70
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (38)'));
    elseif hRounded == 75
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (39)'));
    elseif hRounded == 80
        rowData(i,7) = cellstr(sprintf('DANGER (41)'));
    elseif hRounded == 85
        rowData(i,7) = cellstr(sprintf('DANGER (43)'));
    elseif hRounded == 90
        rowData(i,7) = cellstr(sprintf('DANGER (45)'));
    elseif hRounded == 95
        rowData(i,7) = cellstr(sprintf('DANGER (47)'));
    elseif hRounded == 100
        rowData(i,7) = cellstr(sprintf('DANGER (49)'));
    end
elseif tRounded == 32
    if hRounded == 40
```

```
    rowData(i,7) = cellstr(sprintf('CAUTION (32)'));
elseif hRounded == 45
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (33)'));
elseif hRounded == 50
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (34)'));
elseif hRounded == 55
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (36)'));
elseif hRounded == 60
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (37)'));
elseif hRounded == 65
    rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (39)'));
elseif hRounded == 70
    rowData(i,7) = cellstr(sprintf('DANGER (40)'));
elseif hRounded == 75
    rowData(i,7) = cellstr(sprintf('DANGER (42)'));
elseif hRounded == 80
    rowData(i,7) = cellstr(sprintf('DANGER (44)'));
elseif hRounded == 85
    rowData(i,7) = cellstr(sprintf('DANGER (47)'));
elseif hRounded == 90
    rowData(i,7) = cellstr(sprintf('DANGER (49)'));
elseif hRounded == 95
```

```
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (51)'));
    elseif hRounded == 100
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (54)'));
    end
elseif tRounded == 33
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (34)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (35)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (36)'));
    elseif hRounded == 55
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (38)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('DANGER (40)'));
    elseif hRounded == 65
        rowData(i,7) = cellstr(sprintf('DANGER (41)'));
    elseif hRounded == 70
        rowData(i,7) = cellstr(sprintf('DANGER (43)'));
    elseif hRounded == 75
        rowData(i,7) = cellstr(sprintf('DANGER (46)'));
    elseif hRounded == 80
```

```
        rowData(i,7) = cellstr(sprintf('DANGER (48)'));
    elseif hRounded == 85
        rowData(i,7) = cellstr(sprintf('DANGER (51)'));
    elseif hRounded == 90
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (54)'));
    elseif hRounded == 95
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (57)'));
    elseif hRounded == 100
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    end
elseif tRounded == 34
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (35)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (37)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (38)'));
    elseif hRounded == 55
        rowData(i,7) = cellstr(sprintf('DANGER (40)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('DANGER (42)'));
    elseif hRounded == 65
```

```
        rowData(i,7) = cellstr(sprintf('DANGER (44)'));
    elseif hRounded == 70
        rowData(i,7) = cellstr(sprintf('DANGER (47)'));
    elseif hRounded == 75
        rowData(i,7) = cellstr(sprintf('DANGER (49)'));
    elseif hRounded == 80
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (52)'));
    elseif hRounded == 85
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (55)'));
    elseif hRounded == 90
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    elseif hRounded == 95
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    elseif hRounded == 100
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (54)'));
    end
elseif tRounded == 35
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (37)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (39)'));
    elseif hRounded == 50
```

```
        rowData(i,7) = cellstr(sprintf('DANGER (41)'));
    elseif hRounded == 55
        rowData(i,7) = cellstr(sprintf('DANGER (43)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('DANGER (45)'));
    elseif hRounded == 65
        rowData(i,7) = cellstr(sprintf('DANGER (48)'));
    elseif hRounded == 70
        rowData(i,7) = cellstr(sprintf('DANGER (50)'));
    elseif hRounded == 75
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (53)'));
    elseif hRounded == 80
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (57)'));
    else
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    end
elseif tRounded == 36
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('EXTREME CAUTION (39)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('DANGER (41)'));
    elseif hRounded == 50
```

```
            rowData(i,7) = cellstr(sprintf('DANGER (43)'));
        elseif hRounded == 55
            rowData(i,7) = cellstr(sprintf('DANGER (46)'));
        elseif hRounded == 60
            rowData(i,7) = cellstr(sprintf('DANGER (48)'));
        elseif hRounded == 65
            rowData(i,7) = cellstr(sprintf('DANGER (51)'));
        elseif hRounded == 70
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (54)'));
        elseif hRounded == 75
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (58)'));
        else
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
        end
    elseif tRounded == 37
        if hRounded == 40
            rowData(i,7) = cellstr(sprintf('DANGER (41)'));
        elseif hRounded == 45
            rowData(i,7) = cellstr(sprintf('DANGER (43)'));
        elseif hRounded == 50
            rowData(i,7) = cellstr(sprintf('DANGER (46)'));
        elseif hRounded == 55
```

```
        rowData(i,7) = cellstr(sprintf('DANGER (48)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('DANGER (51)'));
    elseif hRounded == 65
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (55)'));
    elseif hRounded == 70
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (58)'));
    else
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    end
elseif tRounded == 38
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('DANGER (43)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('DANGER (46)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('DANGER (49)'));
    elseif hRounded == 55
        rowData(i,7) = cellstr(sprintf('DANGER (52)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (55)'));
    elseif hRounded == 65
```

```
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (59)'));

    else
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    end
elseif tRounded == 39
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('DANGER (46)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('DANGER (49)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('DANGER (52)'));
    elseif hRounded == 55
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (55)'));
    elseif hRounded == 60
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (59)'));

    else
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    end
elseif tRounded == 40
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('DANGER (48)'));
```

```
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('DANGER (51)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (55)'));
    elseif hRounded == 55
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (59)'));

    else
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    end
elseif tRounded == 41
    if hRounded == 40
        rowData(i,7) = cellstr(sprintf('DANGER (51)'));
    elseif hRounded == 45
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (54)'));
    elseif hRounded == 50
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (58)'));

    else
        rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
    end
elseif tRounded == 42
    if hRounded == 40
```

```
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (54)'));
        elseif hRounded == 45
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (57)'));

        else
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
        end
    elseif tRounded == 43
        if hRounded == 40
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (57)'));

        else
            rowData(i,7) = cellstr(sprintf('EXTREME DANGER (-)'));
        end
    else
        rowData(i,7) = cellstr(sprintf('UNDEFINED'));
    end

end

switch grpFlag
    case 1
        subplot(1,1,1);
        cla;
        plot(tempVal,'b');
        plot(PredT,'r');
```

```
            legend('Actual Data','Predicted Data');
            xlabel('Samples');
            ylabel('Temperature (c)');

        case 2

            subplot(1,1,1);
            cla;
            plot(presVal,'b');
            plot(PredP,'r');
            legend('Actual Data','Predicted Data');
            xlabel('Samples');
            ylabel('Pressure (kPa)');


        case 3

            subplot(1,1,1);
            cla;
            plot(humiVal,'b');
            plot(PredH,'r');
            legend('Actual Data','Predicted Data');
            xlabel('Samples');
            ylabel('Humidity (%)');



    end

    grid on;
    drawnow;
    set(handles.btnSendData,'Enable','on');
    btString =
sprintf('DATA_%08.2f_%08.2f_%08.2f\n',PredT(10),PredP(10),PredH(10));
    fprintf(s2,btString);
    colNames = {'Temperature','Pressure','Humidity','Predicted T','Predicted P',
'Predicted H','Heat Index'};
    %colData = {tempVal(:,20);presVal(:,20);humiVal(:,20)};
    colData = {rowData(:,:)};
    set(handles.tblDataLogs,'data',rowData,'ColumnName',colNames);
    tempVal = zeros(1);
    presVal = zeros(1);
    humiVal = zeros(1);
    sampCtr = 1;
```

```
        end

      end

   else

      tempVal = zeros(1);
      presVal = zeros(1);
      humiVal = zeros(1);
      subplot(1,1,1);
      cla;

      colNames = {'Temperature','Pressure','Humidity','Predicted T','Predicted
P','Predicted H','Heat Index'};
      colData = [0,0,0,0,0,0,0];
      set(handles.tblDataLogs,'data',colData,'ColumnName',colNames);

   end

   axes(h);


end
%DataAcq Block-----------------------------------------------------------


function varargout = WWM_OutputFcn(hObject, eventdata, handles)
varargout{1} = handles.output;
function btnGetData_Callback(hObject, eventdata, handles)
global AcqFlag;

if AcqFlag == 0
  AcqFlag = 1;
  set(handles.btnGetData,'String','Stop Data Acquisition');
else
  AcqFlag = 0;
  set(handles.btnGetData,'String','Start Data Acquisition');
end

function lstMode_Callback(hObject, eventdata, handles)
global grpFlag;

contents = cellstr(get(handles.lstMode,'String'));
```

```
selected = contents{get(handles.lstMode,'Value')};


if strcmp(selected,'Temperature') == 1

    grpFlag = 1;

elseif strcmp(selected,'Pressure') == 1

    grpFlag = 2;

elseif strcmp(selected,'Humidity') == 1

    grpFlag = 3;

end

message = sprintf('%s - %d', selected, grpFlag);

set(handles.pnlGrapher,'Title',message);


function lstMode_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function btnSendData_Callback(hObject, eventdata, handles)
global sendDataF;

if sendDataF == 0
   sendDataF = 1;

end

function pnlGrapher_ResizeFcn(hsObject, eventdata, handles)
```

ANDROID

Main Activity

```
#Region Module Attributes
	#FullScreen: False
	#IncludeTitle: True
	#ApplicationLabel: Kalman
	#VersionCode: 1
	#VersionName:
	#SupportedOrientations: unspecified
	#CanInstallToExternalStorage: False
#End Region

'Activity module
Sub Process_Globals

    Dim admin As BluetoothAdmin
	Dim serial1 As Serial
	Dim foundDevices As List
	Type NameAndMac (Name As String, Mac As String)
	Dim connectedDevice As NameAndMac
	Dim strBuffer As String
	Dim tempData() As String
	Dim i As Int
	Dim preTemp As String
	Dim prePress As String
	Dim preHumid As String
	Dim Timer1 As Timer

End Sub

Sub Globals

    Dim sf As StringFunctions
    sf.Initialize
	Dim Panel1 As Panel
	Dim Label1 As Label
	Dim Label2 As Label
	Dim Label4 As Label
	Dim Label6 As Label
	Dim lblDateTime As Label
	Dim lblHumidity As Label
	Dim lblPressure As Label
```

```
        Dim lblTemperature As Label

End Sub

Sub Activity_Create(FirstTime As Boolean)


        Activity.Title ="kalman"
        Activity.LoadLayout("kalman")


        If FirstTime Then

          serial1.Initialize("serial1")
          admin.Initialize("admin")

        End If

        Timer1.Initialize("Timer1",1000)
        Timer1.Enabled =True


        Activity.AddMenuItem("Connect","ConnectBT")
        'Activity.AddMenuItem("Test Data","TestData")
        Activity.AddMenuItem("Quit","QuitApp")

        DateTime.TimeFormat  ="hh:mm:ss"


End Sub

Sub Activity_Resume

If admin.IsEnabled = False Then

                If admin.Enable = False Then

                        ToastMessageShow("Error enabling Bluetooth adapter.", True)

                Else

                        ToastMessageShow("Enabling Bluetooth adapter...", False)
                        'the StateChanged event will be soon raised
```

```
        End If

    Else

        Admin_StateChanged(admin.STATE_ON, 0)

    End If

End Sub

Sub Activity_Pause (UserClosed As Boolean)

End Sub
Sub Admin_StateChanged (NewState As Int, OldState As Int)

    'btnConnectBT.Enabled = (NewState = admin.STATE_ON)
    'btnAllowConnection.Enabled = btnSearchForDevices.Enabled
    Log(NewState)

End Sub
Sub Serial1_Connected (Success As Boolean)

    ProgressDialogHide
    Log("connected: " & Success)

    If Success = False Then

        Log(LastException.Message)
        ToastMessageShow("Error connecting: " & LastException.Message, True)

    Else

        StartService(BTService)

    End If


End Sub
Sub Admin_DeviceFound (Name As String, MacAddress As String)

    Log(Name & ":" & MacAddress)
    Dim nm As NameAndMac
    nm.Name = Name
    nm.Mac = MacAddress
```

```
        foundDevices.Add(nm)
        ProgressDialogShow("Searching for devices (~ device found)...".Replace("~",
foundDevices.Size))
        'ProgressDialogShow("Connecting device wait...")

End Sub
Sub Admin_DiscoveryFinished

        ProgressDialogHide
        If foundDevices.Size = 0 Then


                ToastMessageShow("No device found.", True)

        Else

                Dim l As List
                l.Initialize
                For i = 0 To foundDevices.Size - 1
                        Dim nm As NameAndMac
                        nm = foundDevices.Get(i)
                        l.Add(nm.Name)
                Next
                Dim res As Int
                res = InputList(l, "Choose device to connect", -1)
                If res <> DialogResponse.CANCEL Then
                        connectedDevice = foundDevices.Get(res)
                        ProgressDialogShow("Trying to connect to: " &
connectedDevice.Name & " (" & connectedDevice.Mac & ")")
                        serial1.Connect(connectedDevice.Mac)
                End If

                'connectedDevice.Mac="00:12:07:12:47:31"
                'serial1.Connect(connectedDevice.Mac)

        End If

End Sub
Sub ConnectBT_Click()

foundDevices.Initialize
        If admin.StartDiscovery     = False Then
                ToastMessageShow("Error starting discovery process.", True)
        Else
```

```
            ProgressDialogShow("Searching for devices...")
        End If

End Sub
Sub QuitApp_Click()
ExitApplication
End Sub
Sub NewMsgFromServiceAStream

  'The received message comes from the global variable MsgReceived from
ServiceAStream

   strBuffer=strBuffer & BTService.MsgReceived

        If strBuffer.Contains("DATA") AND strBuffer.StartsWith("DATA")=False  Then
'prepare prefix data

       strBuffer="DATA_"
                BTService.MsgReceived =""
                Log(strBuffer)

        Else If strBuffer.Contains("DATA_") AND strBuffer.StartsWith("DATA_") = True
Then 'Get Complete Data

                If strBuffer.Contains("DATA_") AND strBuffer.EndsWith(Chr(13)) = True
Then

                        Log(strBuffer)
                    ParseData
                        strBuffer=""

           End If

        End If

End Sub
'Sub TestData_Click()
'
'DummyTest
'
'End Sub
Sub DummyTest

preTemp=Rnd(1,1000)
```

```
prePress=Rnd(1,1000)

preHumid=Rnd(1,1000)

strBuffer="DATA_" & preTemp & "_" & prePress & "_" & preHumid & "_" & Chr(13)

ParseData

End Sub
Sub ParseData

tempData=Regex.Split("_",strBuffer)

preTemp=tempData(1)
prePress=tempData(2)
preHumid=tempData(3)

lblTemperature.Text=preTemp
lblPressure.Text =prePress
lblHumidity.Text=preHumid

strBuffer=""


End Sub
Sub Timer1_Tick()

lblDateTime.Text="Date/Time:" & DateTime.Date(DateTime.Now)  & "/" &
DateTime.Time(DateTime.Now)

End Sub
```