A Control System in an Intelligent Farming by using Arduino Technology

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Abstract—**"Internet of Things" (IoT) is a technology that allows things to communicate and connect with each other. This will change the patterns and processes in both industry and agriculture towards higher efficiency. Particularly, agriculture is an important foundation of Thai economy. Consequently, we propose an intelligent farming system (IF) to improve the production process in planting. IF composes of two main parts which are a sensor system and a control system. In this paper, we focus on the control part which are watering and roofing systems of an outdoor farm based on the statistical data sensed from the sensor systems (including temperature, humidity, moisture and light intensity sensors) Since the sensed data would not be always accurate due to noises, we apply Kalman filtering to smooth the data before using as an input in our decision making process. For the decision making process, we do not consider only the sensed data, but also the weather information. A decision tree model is generated to predict the weather condition. Then, a set of decision rules based on both the sensed data and the predicted weather condition is developed to automatically make a decision on whether watering and roofing system should be on or off. Moreover, we also provide functions for users to manually control the watering and roofing systems via our mobile application.**

Keywords— Intelligent Farming; Smart Farming; Internet of Things; Wireless Sensor Network;

I. INTRODUCTION

Agriculture is one of the important businesses that mainly affects the mankind life. From the ancient to the agricultural revolution in Great Britain England, farming is the way that human used to harvest plants and consumed them in their daily life. Farming has been improved by many technologies supporting cropping system. In addition to the technologies in the agricultural revolution era, there have been many technologies that have impacts on agriculture such as harvest machine, seed drill machine, reaper machine, and the others that can reduce manpower and wasting time.

Recently, Internet has involved in people's daily activities. Internet has been widely used to connect people together, people with devices, or devices with devices. In an electronics device, it is embedded by software and sensors for using to commutate and to exchange data with other devices and people. When millions of devices are connected together through the Internet, this is called Internet of Things (IoT). IoT encompasses many new intelligent concepts for using in the near future such as smart home, smart city, smart transportation, and smart farming.

Recently, there are few research works on smart farming [1][2][3]. In [1], a wireless sensor network is used in potato fields in Egypt. The proposed system is used to monitor the potato fields such as looking for diseases and harmful fungi and record useful information for improving future planting and managing resources such as water and soil. In Thailand, agriculture is also massively important for Thailand's economy. Particularly, the agriculture section has contributed 8.4 percent to Thailand's GDP. Then, to increase the crop yield, the smart farming technology would help.

In this paper, we have proposed an intelligent farming (IF) system. IF is the technology that uses the concepts of IoT and smart farming to help farmers to monitor and sense useful information from their farms in order to help in the quality improvement and product quantity. Our Intelligent farming system consists of two main parts. The first one is a sensor system, including temperature sensor, humidity sensor, moisture sensor and light intensity sensor. The second part is a control system. In this paper, we focus on the control system. Our control system has two main subsystems which are watering and roofing subsystems. The system uses the statistical data collected from the sensor system and the weather information to make a decision to control the farm environment. Particularly, the statistical data is collected from sensors. We then apply Kalman filtering theory to make the data more

978-1-5090-1125-4/16/$31.00 ©2016 IEEE

accurate since there can be noise collected from the sensors (errors sensed by sensors).

To support outdoor farming, not only the sensed data but also weather information from an external source is also considered. Weather information records in a planting area are retrieved from a weather forecast repository. Then we generate a decision tree model to predict the weather condition (either "no rain", "rain", or "storm") by using historical weather data (including temperature, humidity, pressure at sea level and wind speed). Finally, our proposed decision rules are set up based on the smooth sensed data and predicted weather condition. Our watering and roofing subsystems can be automatically turn on or off based on the decision made by the rules. However, it is possible to let users manually control the watering and roofing subsystems via a mobile application.

II. SYSTEM ARCHITECTURE AND FUNCTIONS

Fig. 1 shows our proposed IF. In IF, the sensor subsystem is a set of tools and sensors that are connected to a microcontroller board called Arduino board. Sensors are used to measure essential values of the planting process including temperature, humidity, moisture and light intensity. The sensed values are then uploaded to the server by using a Wi-Fi module integrated on the same Arduino board. On another part, the control subsystem is a set of devices used to control the roofing subsystem and watering subsystem. The roofing and watering subsystems can be automatically open or close according to the decision from our proposed decision tree model (described in Section III). Also, the roofing and watering subsystems can be manually controlled by a user via our mobile application. Moreover, there is a notification system used to provide the user the current farming status and also ask for the response from the user to an important event such as when the plants need water and the temperature is tending to high. If the user does not have any response within a limited time. The system will work automatically.

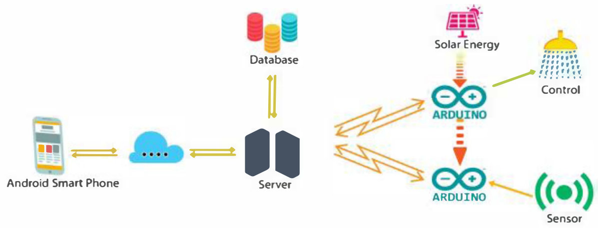

Fig. 1 A system architecture of the system

III. A PROCESS FRAMEWORK FOR OUR CONTROL SYSTEM IN IF

In Fig. 2, there are five steps for our process framework of our control system in IF. The details of each step are as follows:

A. *Acquiring data from sensors*

This stage is to sense raw data from sensors. The raw data from the sensors ranges between 0 and 1023. Each sensor has its own method to convert the raw data to be a voltage value However, the main problem in this stage is that the sensor node would not be always precise due to noises from the sensors. To remove the noises, we apply Kalman filtering to filter out the noises and smooth the sensed data as described in Section III-B.

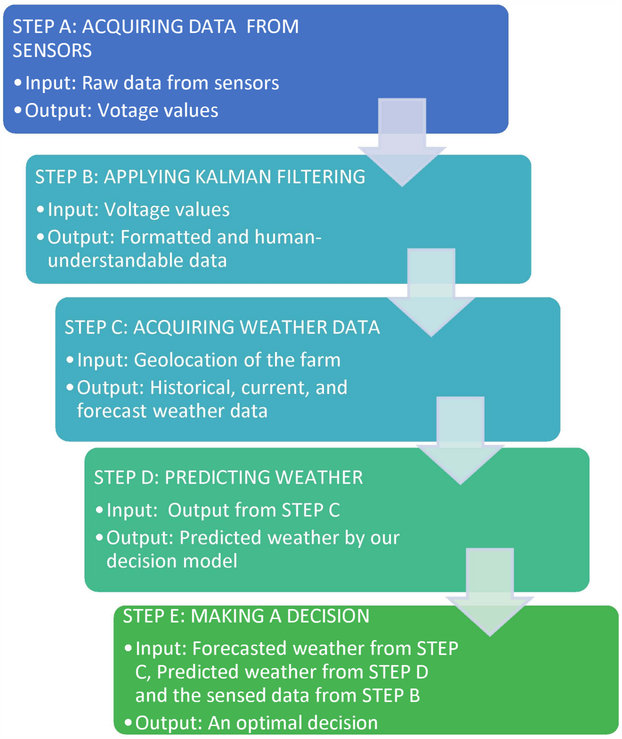

Fig. 2 A process framework of the control system in IF

B. *Applying Kalman Filtering*

In this stage, Kalman filtering [4] is used to estimate real values interfered by noise generated from the imperfect sensors or/and inaccurate sensor's measurement. From Fig. 3, the main process of Kalman filtering is a recursive process which uses a previous state and current estimated state to get the more precise state of the dynamic system. The algorithm works in a two-step process as follows:

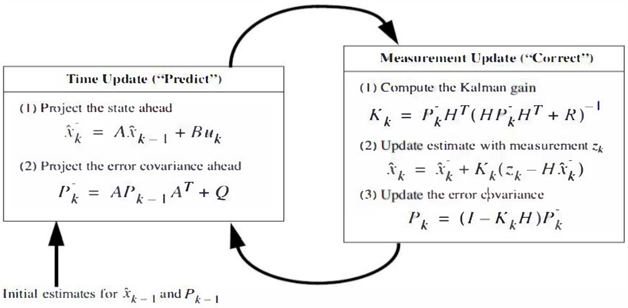

Fig. 3 A complete picture of the operation of the Kalman filtering

1) Prediction step: In this step, first the Kalman filtering addresses the general problem of estimating the state by the linear stochastic difference and with covariance Q to the time k. From our experiment, we have found that the proper value of the process noise is 10^{-8}. Then, we will estimate the current value and the error covariance matrix at time k which is given by:

$$\boldsymbol{\hat{x}_k^-} = \boldsymbol{A}\boldsymbol{\hat{x}_{k-1}^-} \tag{1}$$

and

$$\boldsymbol{P}_k^- = \boldsymbol{A}\boldsymbol{P}_{k-1}\boldsymbol{A}^T + \boldsymbol{Q} \qquad (2)$$

where $\boldsymbol{P}_k^-$ represents the error covariance of prediction which is used to estimate how much we can trust the values of the current estimated state. In this case, we assume that the first error covariance L is set to be one which is a large number for representing the error covariance.

Correction step*:* When the sensor sends data to the system, the measurement z_k will be used to compute the observed value of the measurement which is given by:

$$\boldsymbol{z}_k = \boldsymbol{H}x_k + \boldsymbol{v}_k \qquad (3)$$

The noise of the measurement v_k has to be Gaussian distributed. Our value of the measurement noise is derived from using "standard deviation" of the observed value during the calibration. The diagonal values of the matrix $\boldsymbol{R}_k$ (as the covariance) are 0.3377159, 0.0050016, 0.0098983, and 0.0005383 which are the covariance of humidity, light intensity, temperature, and moisture, respectively. Then, the system will compute the difference between the measurement z_k and the priori state $\hat{x}_k^-$. This is also called the innovation $\tilde{y}_k$:

$$\tilde{\boldsymbol{y}}_k = \boldsymbol{z}_k - \boldsymbol{H}\hat{\boldsymbol{x}}_k^- \qquad (4)$$

and the innovation covariance $\boldsymbol{S}_K$ is shown below.

$$\boldsymbol{S}_K = \boldsymbol{H}\boldsymbol{P}_k^-\boldsymbol{H}^T + \boldsymbol{R} \qquad (5)$$

The next step is to calculate the Kalman gain $\boldsymbol{K}_K$. The Kalman gain is used to indicate how much we can trust the innovation which can be computed by the following equation.

$$\boldsymbol{K}_K = \boldsymbol{P}_k^-\boldsymbol{H}^T\boldsymbol{S}_k^{-1} \qquad (6)$$

Now we have to update the posteriori estimate of the current state:

$$\boldsymbol{P}_k = (\boldsymbol{I} - \boldsymbol{K}_k\boldsymbol{H})\boldsymbol{P}_k^- \qquad (7)$$

The final output $\hat{\boldsymbol{x}}_k$ is the estimated value of the sensor data which is more precise and accurate. Then the value will be transferred to the database as a smooth values of the sensed data.

C. Acquiring Weather Data

Our control system also acquires the weather data, including historical, current, and forecasted weather, from Openweathermap.com to use as the conditions for making a decision. A user can see the weather information via the mobile application where we inquiry the next 3-day weather forecast to be shown.

D. Predicting Weather

The historical weather data is now used to model a decision tree [5] for predicting the weather condition as "no rain", "rain or storm". The decision tree model is generated by using a machine learning library for node.js [6]. Fig. 4 shows our decision tree to predict the weather condition.

E. Making a Decision

In this step, the predicted whether condition obtained from STEP D and the smooth sensed data obtained from STEP B are used to make a set of decision rules that the farmer should do as shown in the TABLE I.

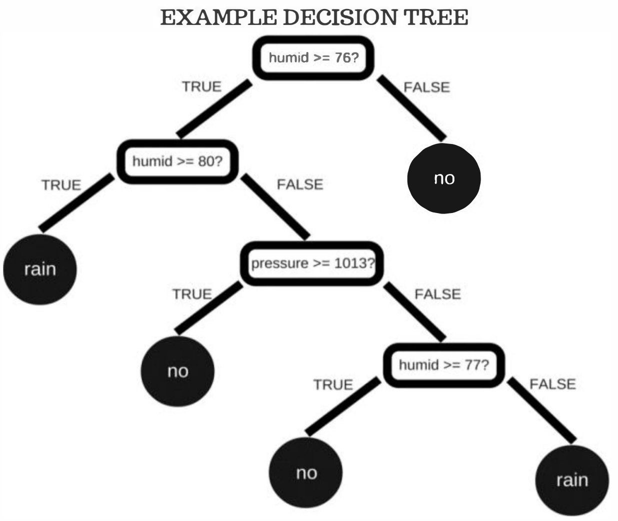

Fig. 4 Our decision tree for predicting the weather condition

TABLE I. DECISION RULES FOR DECISION MAKING PROCESS

Result from Decision tree	Smooth sensed data	Decision to do
"no rain"	Moisture ≥ 70%	"watering"
"no rain"	Moisture ≤ 70%, Light ≤ 2,000 lux || Temp ≤ 35 Celsius	"closing roof"
"rain "or "storm"	Moisture ≥ 70%	"wait for raining"
"rain "or "storm"	Moisture ≥ 70%	"opening roof"

Note that each condition in TABLE I derives from the optimal condition of cabbage [7]. Different plants will use different decision criteria based on the optimal condition for each kind of plants. For example, the moisture threshold of cabbage is about 70% so when the system detect that the moisture is below 70% and the predicted weather condition is no rain. The system will decide to watering the plants as the "Decision to do" in TABLE I.

IV. RESULTS

A plot prototype equipped with watering, roofing systems and sensors is shown in Fig. 5. The user can manually operate the watering and roofing systems via our developed mobile application and monitor the current status of the plot.

Fig. 5 A plant plot as a prototype installed with watering and roofing system and with sensors

Particularly, the mobile application has three main parts (in Fig. 6) as follows: i) a user can see historical sensed data from the plot, ii) a user can monitor plants status data and manually operate watering and roofing systems, and iii) a user can check the current and forecasted weather for the next three days.

Fig. 6 Mobile application for users to monitor and control the farm

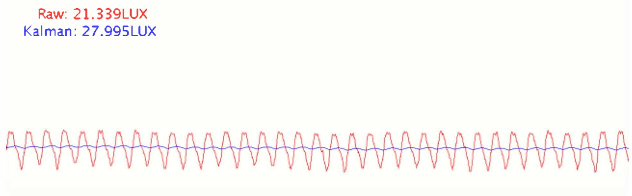

Fig. 7 A captured measurement from light intensity sensor test and the estimated values from the Kalman filtering

In Fig. 7, the sinusoidal line represents the measurement values of light intensity sensor which has the data in range between 10-40 lux due to the voltage noise. On the other hand, the almost straight line in the middle of the graph represents the estimated values from the Kalman filter which is 28 lux. Note that the real light intensity in the experiment is around 30 lux.

TABLE II shows an example of the predicted weather condition compared with the real condition. We can see that the results from our decision tree is accurate.

TABLE II. EXAMPLE DECISION VS REALITY

Date	Most Result from Decision tree	Reality	Input Conditions
2016-02-20	"no rain"	"no rain"	Temp = 29.35, Humid = 72.5%, Moist = 50.21%, Light = 1072.79 lux, Forecast == "Clear"
2016-04-14	"no rain"	"no rain"	Temp = 27.08, Humid = 40.84%, Moist = 86.96%, Light = 973.81 lux, Forecast == "Clear"
2016-04-18	"no rain"	"no rain"	Temp = 32.69, Humid = 59.69%, Moist = 74.91%, Light = 60.43 lux, Forecast == "Clouds"

V. CONCLUSION

We have proposed a control system for an intelligent farming for an outdoor farming, called IF. To make a decision, the model requires two important information pieces which are the sensed data from the sensors in the plot and the weather condition. To smooth the sensed data, we have applied Kalman filter to remove noises. Also, we have generated a decision tree model to predict the weather condition. Based on this information, we have set up rules for making a decision in our control system on whether watering and roofing system should be on or off. Moreover, we have also provided functions for users to manually control the watering and roofing systems via our mobile application.

ACKNOWLEDGEMENT

The work was supported by the Higher Education Research Promotion and National Research University Project of Thailand, Office of the Higher Education Commission (NRU59 Grant No.59000399) and National Electronics and Computer Technology Center (NECTEC) under the National Science and Technology Development Agency (NSTDA), Thailand.

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