Cultivation of Plants Harnessing an Ontology-Based Expert System and A Wireless Sensor Network

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***Abstract*—In this research an expert system was developed for taking adequate care of plants through the use of Android smart phones based on ontology for data collection and analysis. A Wireless Sensor Network has been applied to collect and transmit environmental data such as soil moisture, soil pH, and sunlight. The Expert System was developed to control the watering of plants, which consists of three parts: 1) data acquisition: Provided by the Thai Meteorological Department, the data were used according to the rules from the Plant Ontology; 2) watering control system: The self-activating system controls the watering of the plants using the expert system and an automated dispensing mechanism; and 3) decision making process: The Expert System applies the data and suggests a particular way to adequately provide the requirements of each plant, amount of water, and amount and type of fertilizer. The system has the ability to notify users by sending messages to their smart phones in a sufficient and timely way to ensure optimum cultivation activities and efficient and effective plant husbandry.**

***Index Terms*—Automatic Watering; Expert System; Smart Phone; Plant Ontology; Wireless Sensor Network, Plant Husbandry, Plant Cultivation Systems.**

I. Introduction

The successful cultivation of plants and trees requires an appropriate level of knowledge and understanding that most people, in the domestic situation, do not have, but is essential for those whose business and livelihood depend on the products obtained from the plants and trees under cultivation. Successful cultivation means achieving a useful result by way of flower production, fruit production, or wood production. The ability to have, perhaps two or even three harvests per year usually depends on the proper approach to the planting, watering and fertilizing of the crop. In some cases, over-watering (or less-watering) the crop, be it trees, vegetables of flowers, will lead to less than optimum outcomes, and possibly even a total loss of the crop. Such mismanagement of the cultivation requirements creates variations in the micronutrient content of the soil, and soil conditions perhaps even inappropriate to the species of plant, or just to the proper conditions required by the plants. Large domestic gardens pose a particular problem for the owner/gardener due to the impracticality and inconvenience, and physical and time consuming requirements of watering the plants, especially trees. In the more general sense, there may be a significant unnecessary waste of water. The availability of horticultural and ‘gardening’ advice in a myriad of books does not guarantee the necessary expertise in taking adequate care of the garden. Also, information gained from these books and other information sources may not be appropriate to the current situation.

In [1], the development of a computer program to predict the effects of tree watering was discussed. The system used information transmitted from sensors to achieve more successful flowering or fruiting. The sensor system used various parameters such as temperature, soil moisture content and sunlight levels. The results of the study showed that controlling water supply based on the sensor data produced better outcomes, when compared to the usual watering approach which can best be described as an indiscriminate broad casting watering approach. The assumptions from these results are that each tree in its particular location and situation needs different soil moisture levels and watering times.

A similar approach was described in [2] with the design and development of an irrigation system using Wireless Sensor Network in measuring temperature, moisture, and sunlight. This system was a Web based application for the automatic control of plants and also to control the operation of the system. The system reduced the time to water the plants. However, a drawback to this system was that it is triggered by low moisture levels in the soil [3] and does not consider the real moisture requirements of the particular tree, thereby failing to cater for the correct water requirements for each tree. A similar system was described in [4] which also uses a Wireless Sensor Network in watering system that works on soil moisture and temperature. This system was appropriate to large areas of cultivation or broad acre cultivation and where the crop may be remote or at a distance from the grower. However, this system, as with the other systems, lacked weather forecasting information and overall soil conditions: Information more necessary in this broad acre situation than the domestic garden or small horticultural situation.

Selecting fertilizers and meeting appropriate plant nutrition requirements were discussed in [5], in which a decision support system was created that selects organic fertilizer for trees according to the age of the tree. It is known that trees at different age stages require different nutrients.

All of the systems referred to were based on the similar requirement of providing proper and correct watering and fertilizing requirements for crops. However, each had shortcomings and drawbacks. This present study sought to overcome these drawbacks by developing a more sophisticated expert system based on a detailed Plant Ontology able to cater more precisely to the individual needs of each particular tree. The data requirements have been extended to encompass most, if not all of the appropriate characteristics and requirements of the plants and the environmental factors of importance. This system also uses a Wireless Sensor Network, but includes the added feature of providing real-time information to the grower via mobile telephone network and SMSs. This is to determine the capacity of the network system to transmit factors that affect the growth of trees such as soil moisture, soil pH, water, sunlight, and other relevant information. These various parameters will be used in watering the trees through an automated system. The system also sends notifications for fertilizing via smart phone. In the following sections, we layout the methodologies of this research including the system architecture, the testing process, the results and finally, the conclusions and future works.

II. Methodology

A. Plant Ontology

In this research, the researchers designed a Plant Ontology for garden and lawn care based on Protégé 5.0. This work was divided into three classes: 1) Flower Class, which consists of Flowering Herbs, Flowering Shrubs, Flowering Climbers, Flowering Trees, Leafy Plants, Floating Plants, and Bamboos; 2) Fruit Class, which comprises both edible and inedible fruits, according to their biological designation; and 3) Herb class, which composes of medicinal herbs and aromatic herbs. As seen on Figure 1, each class has the data properties of water requirements, sunlight, soil moisture, soil pH, and nutrients with appropriate time and quantity according to each day or week and for different ages of trees. This is a comprehensive set of data, the collection and use of which is enabled by the use of the ontology and expert system, which are computer-based.

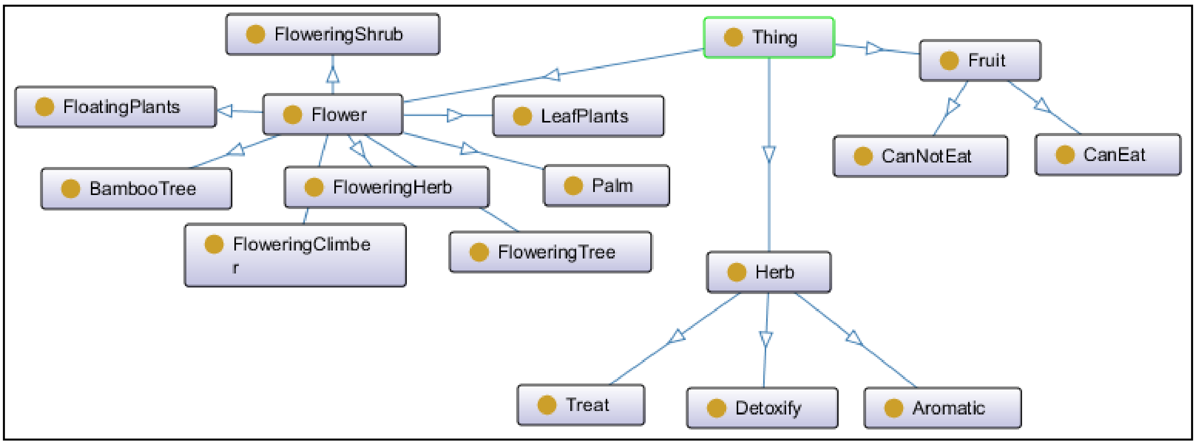

Figure 1: Plant Ontology

B. Wireless Sensor Network

The 'Internet of things' is a recently coined term for the Internet-based technology enabling the connection and sensing of any type of electronically controlled or accessible device. A Wireless Sensor Network is one kind of technology which enables the Internet of things, allowing human-to-human, human-to-computer, or computer-to-computer connectivity. Data transmission and device control are two major aspects of this technology [6]. Currently, this network capability is used in a wide array of industrial applications and industries including agriculture, plantation management, fishery, irrigation control, surveillance assets, to name but a few [7].

In this work, the Zigbee Wireless Network was employed to collect data on soil moisture levels, soil pH, and sunlight of individual trees. Zigbee is based on IEEE 802.15.4 standard and has beneficial factors such as being cheap to purchase and easy to install and operate. The hardware is water and sun resistant and the system is energy efficient, [4,8]. Three kinds of sensors were used for data collection:

1. Moisture Sensors.
2. Light Sensors.
3. Soil Sensors.

The number of sensors in the system varies according to the number of trees being sensed. Our testing included seven trees only, but the total number of trees that could be monitored is large, making the system useful and useable in large scale plantations. Each type of sensor sets the initial value for humidity, sunlight, and soil pH following the rules from the Plant Ontology. Each tree has the three sensors closely located. Data collected by the sensors were transmitted as data packets over the wireless network. Being wireless, of course, means that there is no network infrastructure required linking the trees to the server.

III. System Architecture

In this research, a system architecture has been designed for taking adequate care of plants with the help of Android smart phones, which can divided into three parts: water supply, advisory component for watering, and advisory component for growing plants.

1. The water supply component consists of the following:
   - Weather information can be received from RSS file provided by the Meteorological Department in XML format. The information contains temperature data, relative humidity, and wind speed of users' locations.
   - Sensor data is collected from Soil Moisture Sensor, Soil Sensor, and Light Sensor. All sensors are settled in the indicated place for each plant. Data from each sensor is transmitted via wireless

network to data center to be used by the expert system.

- The rule-based Plant Ontology provides information on how to take care of the plants. Useful information includes water, sunlight, humidity, and nutrient using the age of each tree and their corresponding time frame for example, the number of times to water the trees for each day or week.
- All data, e.g. water and fertilizers, is stored in the database for comparison in order to make the software mechanism run faster. The data is also used to learn about tree watering and growing rate.

2. The advisory process of the water supplying system to trees.
    - The rule-based expert system takes data from 1 to be created as a rule based decision making to supply water for each tree.
    - The watering mechanism automatically supplies sufficient water for trees using time to determine the amount of water (Figure 3)
3. Advising system for taking adequate care of trees.
    - The water recommendation system quantifies amount of water to each tree.
    - The fertilizer recommendation system offers nutrient and amount of minerals to each tree. The system will notify users by messaging to users' smart phone e.g. aggregate of organic fertilizer and shoveling. Because of complications of this system, this part will not be automated.

Figure 3 shows the mechanism of operation to turn on/off the water supply for each tree. The system starts the timer for the water supply system (n = start_time). The system then compares the volume of water supply to the soil moisture. The system works until the volume from water supply is greater than or equal to the moisture content of the soil. The system then turns off the water valve and set the total time used to variable (end_time – n). Finally, the system stores the total time used value and amount of water into the database.

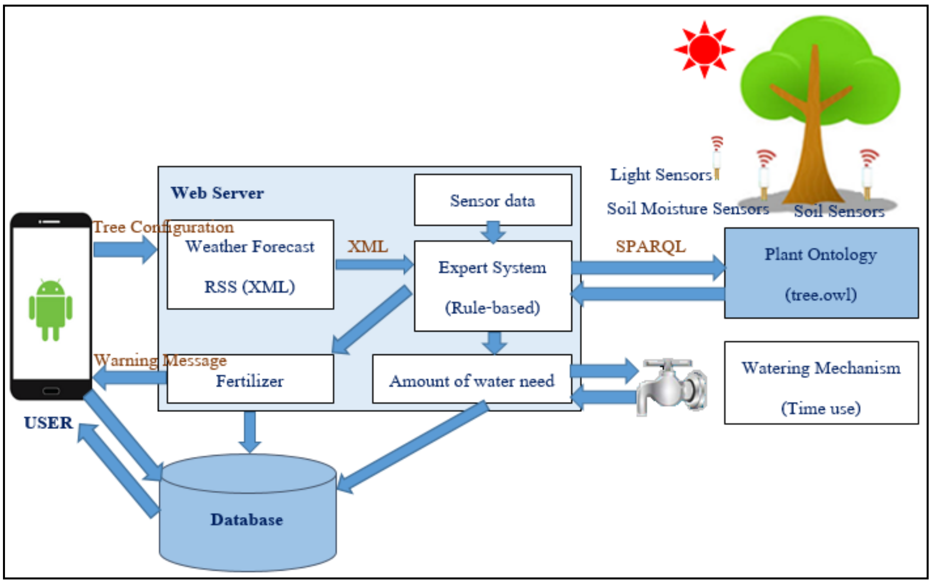

Figure 2: System Architecture

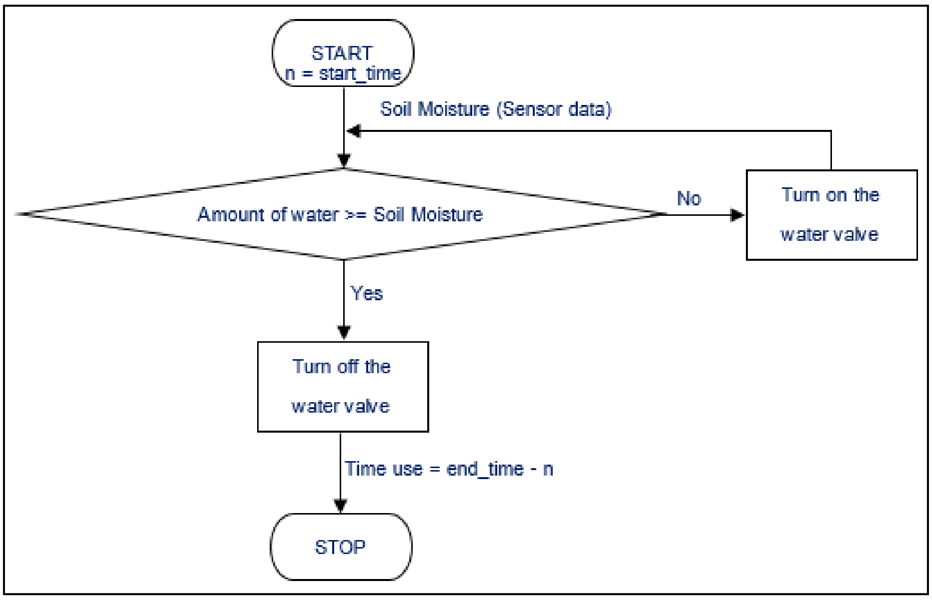

Figure 3: Watering Mechanism

IV. TESTING AND RESULTS

Figure 4 and Figure 5 show the Interface of the cultivation of plants harnessing an ontology-based expert system for taking adequate care of plants on Android smart phones.

The system supports both Thai and English languages, and its interface is divided into three parts (Figure 4 and 5):

1. The weather information (upper-left corner of the screen) consisting of the place where the trees were planted, was at Ampure Muang, Nakhon Sawan province. The query data from Thai Meteorological Department on August 22, 2015 showed 36°C for the temperature, 67% for the relative humidity, 40% of chance to rain, and cloudy sky. These useful data were used for advisory section in part three.

2. Sensor data from each tree (upper-right corner of the screen) comprises Tree Name, Soil Moisture, Sunlight, and Soil pH. These data were measured twice a day, morning and evening. The system needs to collect data from the tree to look for the suitable time to water them because different types of trees need water at different times. For example, data from August 22, 2015 morning showed that the Tembusa Tree had 30% soil moisture, 80% sunlight, and 6.5 soil pH, whereas, data for the Cordia Tree showed 30% soil moisture, 100% sunlight, and 6.5 soil pH.

3. Advisory section in taking care of each type of tree (at the bottom part of the screen) contains amount of water, amount of fertilizer, type of nutrient, and soil improvement. For example, Yellow Elder needed 5 minutes for watering and had 8.0 soil pH. This refers to the acid soil condition (data comes from sensor as shown in Figure 4 upper-right corner). The system made notification and recommendation to users to maintain the acid soil condition by fertilizing them with 700 grams of compost or by putting lime and shoveling the soil. For Pride of Barbados tree, the system performed the watering for three minutes and sent the message to users to fertilize with 300 grams of compost and shoveling the soil.

Users can access the record of water used per day as shown in Figure 6. For example, watering system spent 27 minutes and 243 liters of water on August 22, 2015. For the time setup section, it allows users to schedule watering because different types of plants need water at different times. Notification area warned users to fertilizer with type and amount and the way to enrich the soil.

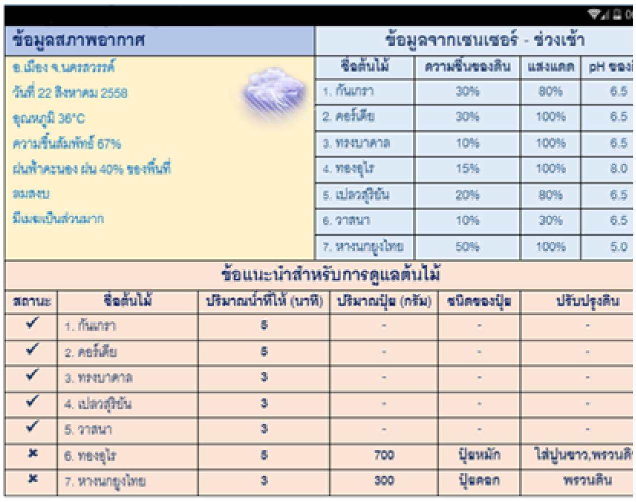

Figure 4: User Interface in Thai

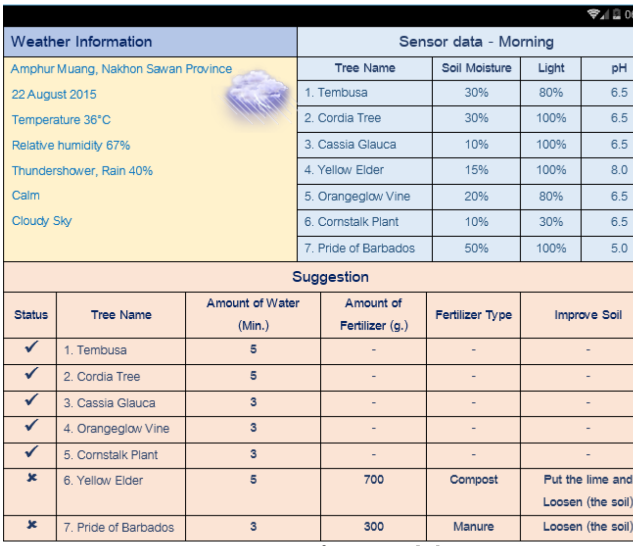

Figure 5: User Interface in English

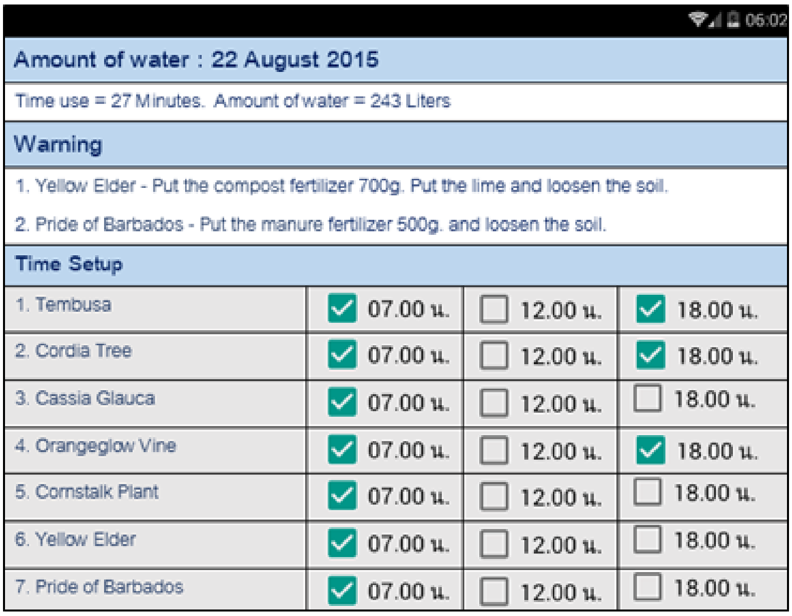

Figure 6: Watering schedule and amount of water used per day (English version)

V. Conclusion and Further Work

In this paper, we presented the cultivation of plants harnessing an ontology-based expert system and a wireless sensor network for taking adequate care of plants through the use of Android smart phones. Ontology has been utilized to store information on how to adequately take care of trees as well as the tree watering system. The watering system accumulated data from the collection over time in order to effectively perform watering arrangement, and automatic irrigation scheduling. In addition, the system could send notifications to users, so this system facilitates reduction of cost and time by taking care of trees. Users will no longer waste time searching for information on how to adequately take care of trees from several sources. It is also beneficial to users who lack knowledge and understanding of the nature of trees.

However, the full automation system of fertilization will be carried out in the future, since the fertilization process is yet to perform automatically.

References

[1] Wen-jin, Y., Ryo, K., Katsuhiko, K., Lian-hua, L., and Hirokazu, F. 2010. A Computer Program for Automatic Watering Based on Potential Evapotranspiration by Penman Method and Predicted Leaf Area in Miniature Pot Rose Production. *Agricultural Sciences in China*. 9(3): 370-377.

[2] Zhang, S. 2014. Design and implementation of flowers watering control system based on the ZigBee. *Journal of Chemical and Pharmaceutical Research*, 6(1): 459-464.

[3] Sumonphanand, E., and Boonroddit, S. 2013. Control of Watering Plants System with moisture Test Transmit Zigbee Protocol. *Proceedings of 51st Kasetsart University Annual Conference: Architecture and Engineering.* Bangkok, Thailand. 5-7 February 2013. 309-316.

[4] Patel, N., and Desai, N. 2015. Wi-Fi Module and Wireless Sensor Network Based Automated Irrigation System. *International Journal of Innovative and Emerging Research in Engineering*. 2(4): 70-76.

[5] Srichetta, P., Shuuttha, V., and Pholsi, T. 2014. Decision Support System for Selecting Crops and Organic Fertilizers Suitable for Each Other. *The Tenth National Conference on Computing and Information Technology*. Phuket, Thailand. 8-9 May 2014. 645-651.

[6] Peytun, B., Gojanur, A., and Mccarthy, K. 2007. *Investigation of Zigbee Sensor Network Platforms*. Department of Electrical & Electronic Engineering. University College Cork, Ireland.

[7] Khan, R., Suryani M.A., and Ahmad M. 2014. WSN's Based Noise Evading Decision Support System. *American-Eurasian Journal of Agricultural & Environmental Sciences*. 14(8): 793-799.

[8] Lee, J., and Huang, Y.C. 2006. ITRI ZBnode: A ZigBee/IEEE 802.15.4 Platform for Wireless Sensor Networks. IEEE Conference on Systems, Man, and Cybernetics. Taipei. 8-11 October 2006. 15-20.