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Development of a Decision Support System for Precision Agriculture

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***Abstract*— The advancement of technology has changed the way industries operate. Traditional agriculture industry heavily relies on man-power. With current advancement of computer and communication technology, the agriculture industry has been reformed. To support the ever-growing world population with limited farm land, researchers investigate the implementation of precision agriculture. Precision agriculture focuses on management in respect to crop science, environmental protection, and economics. It targets at real-time acquiring crop condition information and precisely taking action, such as irrigation, fertilization, and pest control. To achieve this goal, decision support system and mobile based information communication technology are to be adopted. Both techniques are popular in urban areas, but the huge market has not been realized by users on the farm. This article focuses on a United State Department of Agriculture sponsored project for smart irrigation. Field sensors collect temperature, humidity information, and transmit them through wireless sensor network. Mobile devices, such as iPhone and iPad applications are developed for farmers to help them make decisions. Furthermore, a data cloud expands the system by providing data storage space. The data cloud is enabled by a National Science Foundation sponsored IBM high performance cluster which has mass storage capability.**

This research work will give farmers the capability to observe farm data in real-time and consequently provide them the convenience to make immediate appropriate decisions.

Keywords*— *Precision Agriculture; Wireless Sensor Network; Data Cloud

I. INTRODUCTION

Agriculture is the practice of land cultivation, crop planting and animal raising for the conversion of raw materials into consumable goods [1]. Agriculture produces our food, clothing, and materials, which are important in our daily lives. Recent statistic data showed that in 2010, $115 billion worth of American agricultural products were exported around the world. The United States sells more food and fiber to world markets than we import, creating a positive agricultural trade balance [2]. While the agricultural land is diminishing due to the construction of more roads and buildings for modern lives, it becomes very crucial to find a way to sustain the world's ever-growing population with limited land available. To answer this call, Precision Agriculture (PA) is proposed and becomes one of the most electrifying forms of technology that is in the world today. Precision agriculture is used throughout the world in many countries including the United States, Germany, Japan, and Canada. PA, also known as precision farming or satellite farming, is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops [3]. PA uses advance technology to collect real time data from the field. The data are utilized to make intelligent decisions on irrigation, fertilization, and so on. It also uses advanced technology like remote sensing that can direct the farmers' efforts toward crop zones in need of water, nutrients, or other attention [4]. It makes life easier so that farmers do not have to experience dangerous condition that occurs on farms.

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II. BACKGROUND

In 2011, 570 agricultural workers died from work-related injuries [5]. The fatality rate for agricultural workers was 7 times higher than the fatality rate for all workers in private industry; agricultural workers had a fatality rate of 24.9 deaths per 100,000, while the fatality rate for all workers was 3.5 [6]. In order to bring this fatal rate down, proper agricultural machines and systems need to be developed. This research is one of them, which explores a smart irrigation system. The system was created so that agricultural workers can collect data without going to the field to avoid being injured.

A. Precision Agriculture

PA uses advanced technologies like Information and Communication Technology (ICT) and Decision Support System (DSS), which enhance and control the farmer's tools on the farm from anywhere in the world. The United States use of PA goes back nearly thirty years ago. The practice of yield sensors established from innovative technologies, shared by the beginning of GPS receivers, has been increasing ever since. PA today has machines that cover many thousands acres of farm land in the United States. Those machine are called Drones, also known as Unmanned aerial vehicle (UAV). They are used to help collect weather data in the United States.

Another leading country utilizing PA is Japan where the procedure is referred as mechanization. Mechanization in Japan has been developed based on a small-scale farming in rice cultivation because of the limited size of paddy field in addition to the social needs and importance of increasing the production as the staple food after the end of World War II [7]. During the last half of past century, Japan's agricultural instrument has been remarkably transformed from human-powered, to animal-powered, and then mechanically powered. Variety of Japanese agricultural equipment has also been reformed from the one which the user has to push to the one which the user can ride or even remotely controlled. Mechanization carried the rise of yield in each unit region.

B. Decision Support System

There is a considerable amount of experimental data that human natural knowledge and decision making is often a struggle and far from the best. Human knowledge usually begins to decline with complexity and stress. Since in numerous circumstances the value of decisions is crucial; assisting the human knowledge and decision making has been a main attention of science throughout the past years. The world is now using an information system called Decision Support System (DSS). DSS is a computer-based information system that supports business or organizational decision-making activities [8]. The theory of DSS is tremendously large, and its definitions differ, depending on the resource. DSS helps people make decision based on the information that is collected. DSS also takes information and solves problems. DSS provides data storage and retrieval but enhance the traditional information access and retrieval functions with support from model building and model-based reasoning [9]. DSS is used for assistances, management, and planning in many discipline areas. Some of the discipline areas includes business, medicine, military, and engineering. Those discipline areas use DSS to establish countless approaches for making intelligent choices. Additionally in recent years; these approaches are frequently improved by a mixture of methods coming from information science, cognitive psychology, and artificial intelligence. DSS have been carried out in the method of computer software package or as a joined computerized surroundings for difficult decision making. DSS offers several industries a reasonable benefit over their challengers; letting DSS to make the finest choices for technological developments. DSS can be categorized into communication-driven, knowledge-driven, data-driven, model-driven, and documentation-driven.

C. Wireless Sensor Network

Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing to collected data at a central location [10]. WSNs are a significant technology for huge scale monitoring, allowing sensor dimension sat high temporal and spatial resolution. The straightforward process is typical and direct where data are communicated to a base station, nonetheless WSNs can also achieve in-network sort out operations such as aggregation, event detection, or actuation. The first WSN document a decade ago clearly articulated the promise of the technology for a diverse range of monitoring applications including forests, waterways, buildings, security, and the battlefield, and how it would transform the way we live [11]. Some of the earliest use of WSN technology started back with military. WSN is a mature technique in the field of electrical engineering. It is also widely used in the agriculture field.

Usually in WSN there are several nodes communicating to each other; while in order to efficiently organize the structure of transmission, the network topology needs to be studied. The topology is designed so that nodes can be able to transmit large amount of data and reach a wider area to other nodes. The topology plays an important role in reducing several constraints such as limited energy, latency, computational resource crisis, and quality of communication [12]. Topology plays an important role in different tasks such as choosing between a routing paths or deciding to use a broadcast or unicast. There are peer to peer, star, tree, and mesh topologies.

C. High Performance Computing and Data Cloud

High-Performance Computing (HPC) refers to the use of supercomputers or clusters of computers to solve difficult computational problems that typically arise through scientific inquiry [13]. Computer operators go to HPC when a task is too tough to solve on an original laptop or desktop computer because it involves considerable amount of memory or computational power. In addition, regular laptops or desktop runs much slower than a high performance computer and won't be able to do the tasks that high performance computing can do. In some circumstances, the word HPC may also be useful to calculate structures used by businesses for data warehousing and examination.

Another very popular utilization of HPC technique in academic and industry comes with its massive storage capability. It is called data cloud. Data cloud or cloud storage is a representation of data storage where the digital data is kept in logical groups, the physical storage spread numerous servers (sometimes in many setting), and the physical surroundings is normally held and operated by a hosting company. Every year technology is improving; cloud storage is one of the reasons that those technologies will improve and be used a lot in the world today. Cloud Storage suppliers are accountable for keeping the data obtainable and usable. Data Cloud also keeps the physical atmosphere secure and operating. Private business owners and companies purchase or rent out storage space from the cloud storage supplier to make sure that the private business owners or companies can store data or information from its customers. Cloud storage supplier has server farm that can help with storing data. Server farms have hundreds or even thousands of supercomputer or clusters to store data on. Some cloud storage suppliers are Google, Facebook, and Dropboxs.

II. SYSTEM DESIGN

The smart irrigation system that was created at Prairie View A&M University allows users to read real time data such as temperature and humidity from sensors in the field. The information then will be transmitted through WSN and finally be displayed on a computer screen or mobile devices. The system also contains an alert mechanism to help decision making. It will email or send text message to the users if there is a problem in the field. For example, user can set the threshold of temperature and humidity at a certain range for a specific crop. The system will notify the user by email or text message if any of the data obtained from the sensors goes beyond the threshold. The smart irrigation system also allows user to watch the node's battery level from a computer or mobile devices since the WSN can only be accurate when the nodes are supported by sufficient battery power. Figure 1 gives the diagram of this smart irrigation system.

In the system, sensors are connected to WSN nodes, which are installed in the farm. They communicate wirelessly with WSN gateway which is connected to a computer (workstation). The National Instruments (NI) WSN technique operates on IEEE 802.15.4 standards and supports a distance of 300 meters between node and gateway. The National Instruments node and gateway are listed in Figure 2 (a) and (b) respectively.

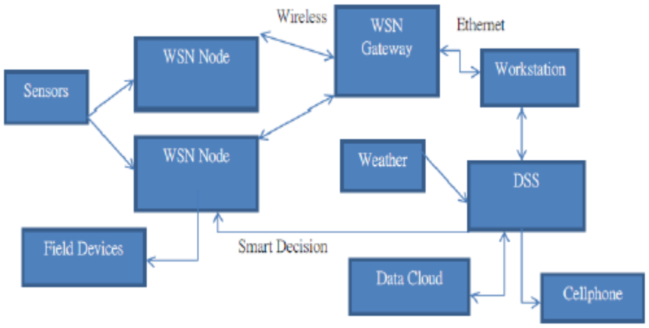

Figure 1 Smart Irrigation System Diagram

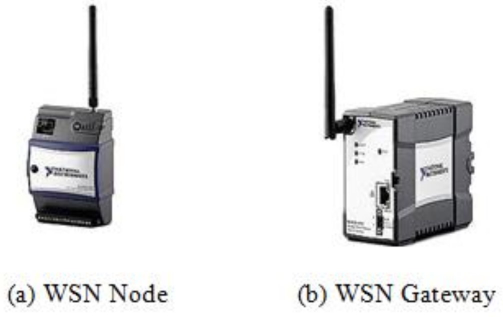

Figure 2 National Instruments WSN nodes and gateway

A. Range Extension

As mentioned earlier, NI WSN node has a functioning distance of 300 meters from the gateway. In the real field application, farmland usually covers a wider range. Thus there must be a method to extend the nodes working distance instead of insert more gateways and workstations. After the study of WSN topology, a node extension scheme is implemented based on the tree topology (a combination of star topology and peer to peer topology), which is more power effective. In order to achieve the goal, some nodes are set to be router nodes as illustrated in Figure 3. Router nodes are placed between gateway and end nodes. They can receive as well as send information, while end nodes are set to have only sending capability. In order to test the efficiency of the nodes extended system, an experiment was conducted as shown in Figure 4. The gateway and workstation are located inside Electrical and Computer Engineering building of Prairie View A&M University. The yellow star marks the router node position, so the two end nodes can be placed further than 300 meters away from gateway. It is proved that with the router node, signal strength is enhanced and the range covered by the system is successfully extended. This new system can support four router nodes from the gateway, each router node can connect to up to 8 end nodes as illustrated in Figure 3. So all together the system can use total of 36 group of sensors at 36 different locations to observe the field situation.

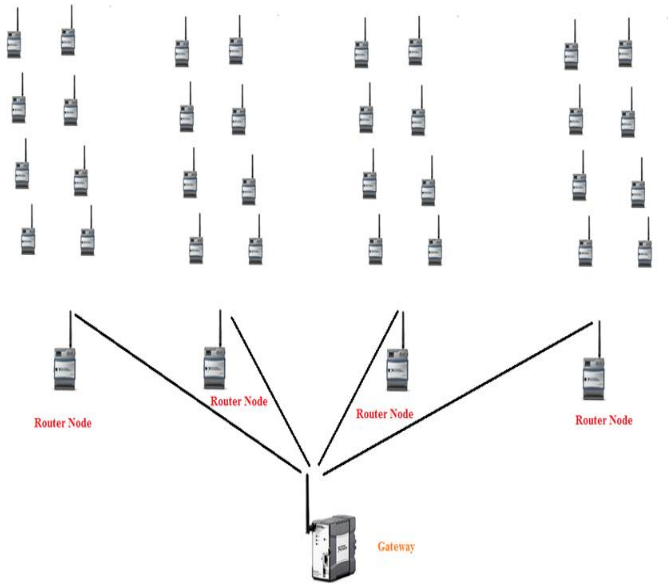

Figure 3 Nodes Extension with Tree Topology

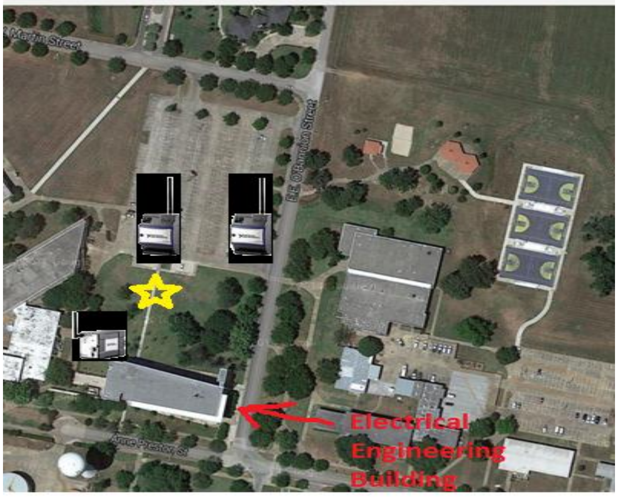

Figure 4 Nodes Extension Testing

B. Data Cloud

Since the Smart System is obtaining and updating data in on hourly bases, and it has the ability to use 36 different sets of sensors, the growing data is stored on a local data cloud at Prairie View A&M University. Data cloud is when data is being stored on a server at an outside location. In our case the data from the smart irrigation system is being sent to Prairie View A&M University's IBM High Performance Computing (HPC) cluster. Figure 5 shows the cluster which is funded by National Science Foundation. The smart irrigation system uses File Transfer Protocol (FTP) to send data to the Data Cloud (IBM HPC Cluster).

IV. EXPERIMENTAL RESULTS

The smart irrigation system is successfully designed and implemented with sensors collecting data real-timely from the field. Mobile devices are able to observe the field condition. Smart decisions can be made based on the information collected. Furthermore, a data cloud is connected to support the data storage in the smart system.

Figure 5 Prairie View A&M University IBM HPC cluster

Figure 6 gives the Labview front panel of the smart irrigation system if the user was viewing the data on the computer screen. In Figure 6, the green light indicates that an email or text message has been sent out to notify the user. Figure 6 demonstrates when there are two nodes in the system and each node has one sensor connected to it. The Smart System also has the ability to watch the node's battery level from a computer or mobile devices. In case the batteries are too low to function, a warning message is going to be sent out to the user since the information received will not be precise. So changing of batteries is recommended. Labview is a graphical programming platform that helps engineers scale from design to test and from small to large systems. Labview offers unprecedented integration with existing legacy software, IP, and hardware while capitalizing on the latest computing technologies [14].

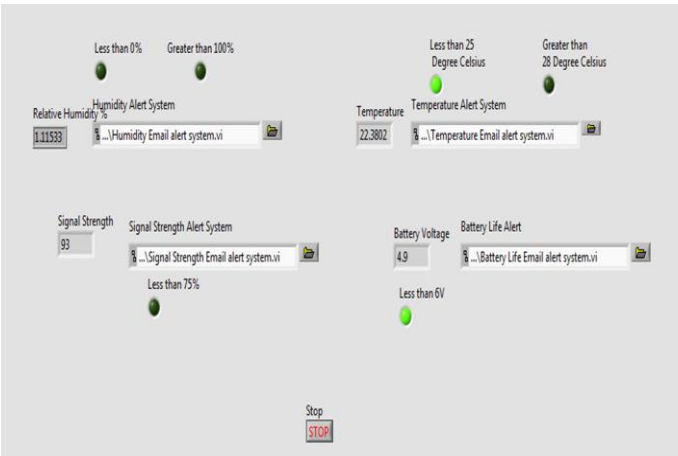

Figure 6 Front Panel of smart irrigation system in Labview

Figure 7 was created in Labview, and it illustrates a small portion of the smart irrigation system schematics. In Figure 7, the red circle indicates a block that gives users the ability to access their data on a mobile device. It is called a shared variable. The shared variable will observe the data that is being sent to the computer and it also share the data to the computer's network. Figure 7 also shows what occurs in the block diagram when the email or text message is being sent out to the user. In Figure 7, there are two blocks: one block says "True" and the other says "False". The block that says false means the field sensed data meets the user needs and no email or text message will be sent out to the users. The false block diagram can also switch to true. If the false block switches to true, it will then trigger the email or text message function.

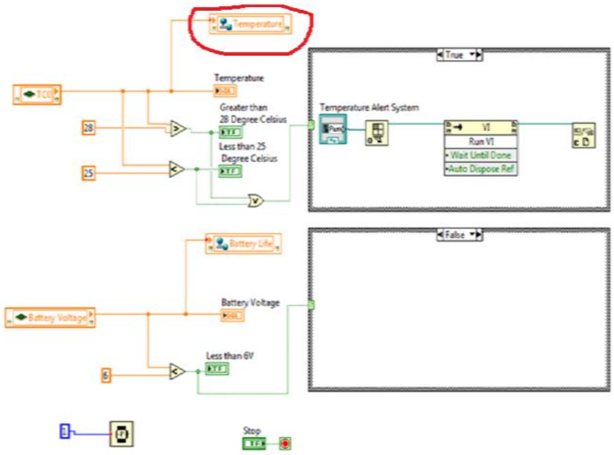

Figure 7 A small portion of the Smart System schematics

A. *Real Time Data Collection and Observation through Mobile Devices*

Figure 8 shows the mobile device interface that allows the user to view data in real time. Having the data to show on a mobile device is one of the main objectives of the smart irrigation system. The ability of having the system to be viewed on a mobile device gives the farmer the ability to remotely receive information and make decisions while away from the field. For example, the farmer can view data in severely hot or extreme cold conditions without leaving their conformable homes.

Figure 8 Mobile Device Interface

The smart irrigation system's capability of emailing or text messaging, serves as an alert system for the user. Figure 9 shows a sample email that the user can get if the temperature is not within the desired range. Figure 10 shows an example of a text message that a user can get if the humidity reading is not in the desired range.

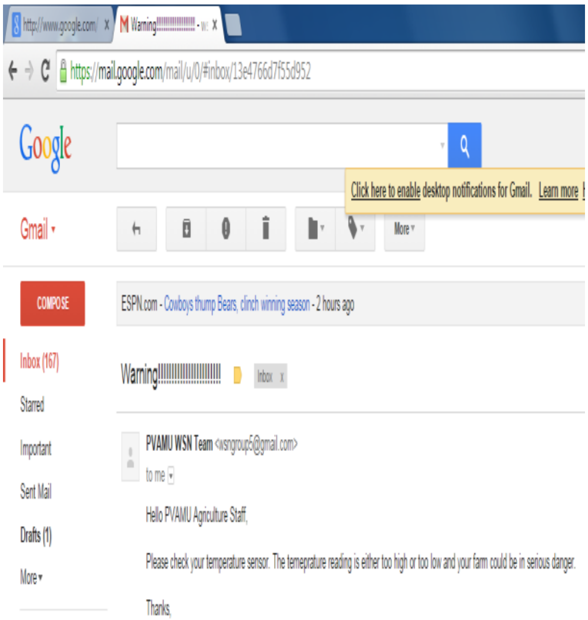

Figure 9 Sample email alert

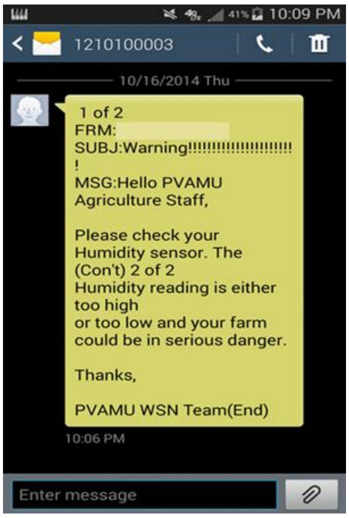

Figure 10 Sample text message

B. Data Cloud in Smart Irrigation System

The smart irrigation system is successfully designed and implemented with sensors collecting data real-timely from the field. Mobile devices are able to observe the field condition. Smart decisions can be made based on the information collected. Furthermore, a Data Cloud is connected to support the observation in the smart system. When the sensors collect and transmit data to the workstation, the data is automatically stored on the Data Cloud through Labview programming. Access to a remote Data Cloud not only backs up the smart system with data loss tolerant features, but also enables future big data analysis. Figure 11 shows how data is being stored on our data cloud (IBM Cluster). User can view the data that is coming from the field anywhere by going to Prairie View A&M University data cloud website.

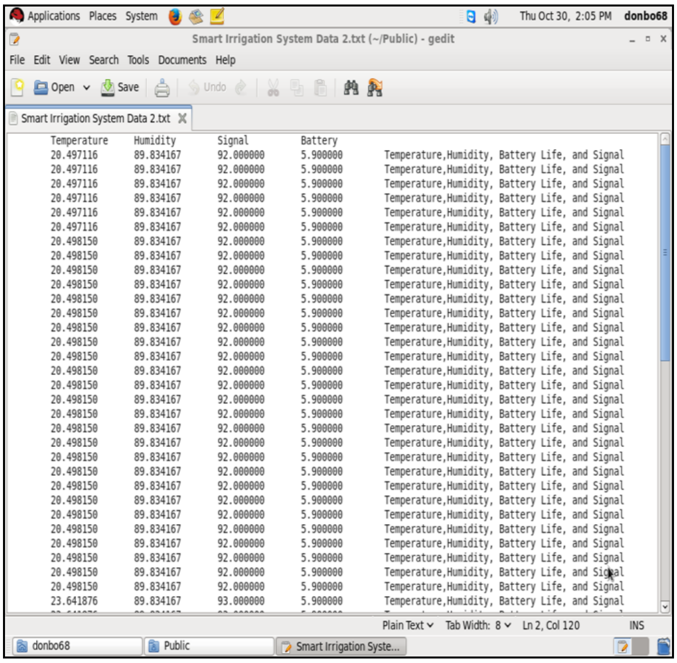

Figure 11 Data on the Data Cloud

V. CONCLUSION AND FUTURE WORK

The design of a smart irrigation system was a success. The system can observed data, such as temperature and humidity, from a computer and from mobile devices. The system can assist farmers to make irrigation decision and it is able to email or text the user. In the future, the system will include more decision making aspects such as weather condition and field location.

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