An Integrated WSN and Mobile Robot System for Agriculture and Environment Applications

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Abstract. Agriculture and environment issues are becoming increasingly important and are facing some new challenges. It is believed that wireless Sensor Networks (WSNs) and machine automation are among the key enabling technologies to address these challenging issues. Although extensive research has been conducted on individual technologies, their seamless integration to solve complex environmental problems has not been done before. This paper provides a design concept and some preliminary results for an integrated autonomous monitoring system. The integrated system will provide a powerful and cost-efficient tool for optimal, profitable, and sustainable management of environment and agriculture and thus bring significant social and economic benefits.

Keywords: Wireless sensor networks · Robot localization · Air quality · Environment monitoring · Animal welfare

1 Introduction

Agricultural and environmental issues, such as water shortage, food safety, air quality, climate change, and rising food prices have caused serious global economic and political concerns. Humanity depends on the environment and agriculture for survival. The optimal, profitable, and sustainable management of land, water and air quality is critical. These requirements can be better addressed through using the integrated and established technologies such as Wireless Sensor Networks (WSNs).

WSN has been regarded a disruptive technology by many technology and business analysts. The MIT Technology Review called WSNs one of the ten emerging technologies that will change the world. The Business Week Magazine labeled WSNs one of the 21 most important technologies for the 21st century. If we consider the Internet as connecting human beings through computers, the wireless sensor networks will connect human beings with the physical world. With the advances of microelectronics,

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the intelligent low-cost low-power small sensor nodes can be developed to sense almost anything of human's interest. A sensor network consists of a large of number of sensor nodes which are densely deployed and connected through wireless links in a self-configured and self-organised manner [1, 6]. Such sensor networks would enable numerous new and exciting applications and bring another technology evolutionary wave to penetrate every aspect of our lives (e.g. home, health, environment, military, agriculture, transport, manufactory, entertainment).

Environment, animal and farm monitoring and control are natural applications for WSN. Cheap, smart devices networked through wireless links and connected intimately with the physical environment can enable detailed and localised data collection at scales and resolutions that are difficult or impossible to obtain through traditional instrumentation. Many networked systems have been successful developed for such applications. For example, a ZigBee WSN was designed for the cattle localization in grazing areas [5] and WSN systems were deployed in a wheat field to monitor the soil property, such as soil water-holding capacity, moisture content, bulk density, temperature and salinity [6]. The WSNs have great potential in agriculture as their cost and improved performance compares favourably with traditional wired networks.

This study took air quality monitoring at poultry buildings as a practical example. Environmental quality within livestock buildings can potentially affect the health and welfare of the animals and also the stockmen working in these buildings [2, 3]. The main factors influencing environmental conditions inside livestock buildings include air temperature (AT), relative humidity (RH), ammonia (NH_3), carbon dioxide (CO_2) and airborne dust [11]. Dust concentrations in poultry buildings are usually quite high especially when compared to average dust concentrations measured in pig and cattle buildings [8]. High temperatures in the piggery buildings might affect the appetite and fertility of pigs that can lead to reduction in production efficiency [4]. Therefore, it is very important to control the temperature and relative humidity levels as well as minimise dust concentrations inside livestock buildings to maintain optimal environmental quality.

This paper describes the design and implementation of an integrated system with WSN to address the above environmental and agricultural problem. The system aims to achieve autonomous monitoring of livestock movement, welfare and environmental impact. The system will provide not only a solid base for the development and delivery of air quality control system at large poultry buildings but also a general solution for the domain of applications in environment and farm management. The cost-effective solution that addresses the important agriculture issue will bring significant social and commercial benefits.

2 The System Design and Implementation

A measurement system was designed to utilise a combination of WSN technology and a mobile robot. The system deployed a number of wireless sensor nodes which was evenly distributed in a laboratory building. These sensor nodes continuous collected the environmental data such as temperature and humidity at the interval suitable for the task. A mobile robot/vehicle is deployed to carry the more expensive sensors (such as NH_3 and Co_2) and a wireless gateway. The mobile robot regularly walks through the defined path in the building at a certain interval. The data at the fixed sensor nodes will be uploaded to the mobile gateway when the robot approaches to the closest point to the individual sensors. The fixed sensor nodes not only help collect certain environmental data but also assist the robot to identify its location through the signal strengths during the communications.

The time interval for the fixed sensor nodes deployed in the field can be set at an arbitrary interval (e.g. every 1 h). However, the optimal time interval can be chosen by balancing the need of adequate capture of the environment changes and the energy consumption saving of the sensors. For much less frequent interval based on the requirements (e.g. every 24 h), the mobile vehicle travels along the path around the field to collect the data. When the vehicle is near to one of the nodes, the GW communicates with the node and collects the node's data. These field nodes' data include the environmental AT & RH situation of the building within a 24 h period. The sensors on the mobile vehicle itself also collect the environmental AT & RH data and dust concentration data while the vehicle moves along the given path.

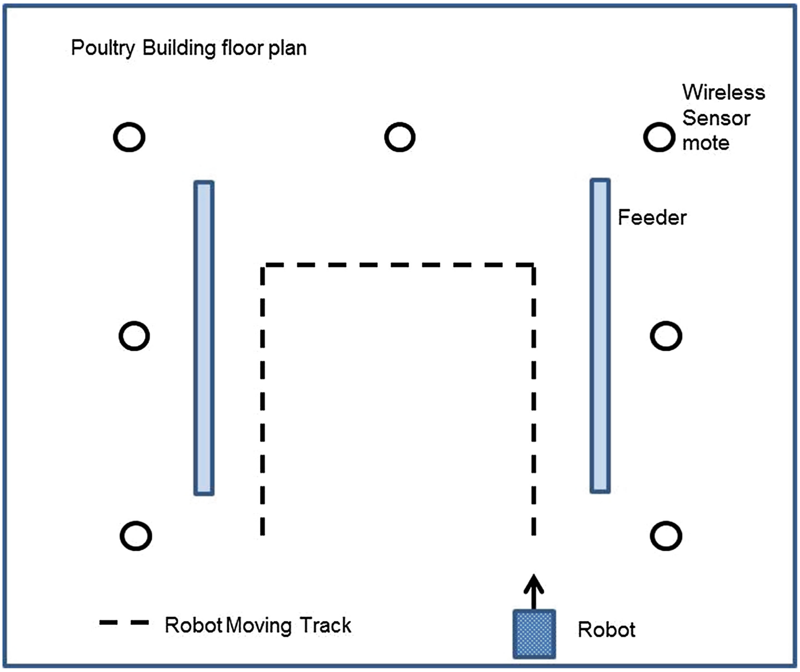

Fig. 1. The system deployment plan

One example of the system is illustrated in Fig. 1. The combined temperature and relative humidity sensors (SHT1X; Manufactured by OFROBOT) and a dust sensor (GP2Y1010AU0F COM-09689, Little Bird company Pty Ltd.) are fixed on the vehicle together with a Crossbow gateway. The fixed sensor motes (Crossbow MPR2400 Motes) included temperature and relative humidity sensors. The gateway (Crossbow, MIB520CA) was connected to a computer via a USB interface board. The vehicle measurement system structure is shown in Fig. 2.

The system prototype was implemented and experiments were carried out at our labs at Faculty of Engineering at USQ, i.e. Z, Z2, and P12. The same system and experiment methods were used at three different experimental fields to test the instrumentation's accuracy and reliability.

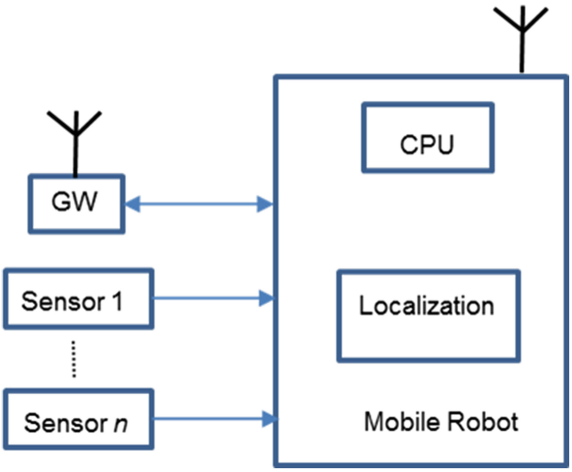

Fig. 2. Mobile robot measurement system

3 Mobile Robot Localisation

Besides the function of measuring the environmental data, the fixed sensor nodes were used in our design to track the movement of the mobile sensor nodes and accurately identify the location of automatic mobile robot. RSSI (Received Signal Strength Indicator) parameter was measured in our experiments to determine the relative distance between the mobile robot and the fixed sensor motes. The conceptual idea behind this is illustrated in Fig. 3.

In the design, it is assumed that the robot moved in a straight line and at a constant speed. The *RSSI(t)* value increased when the robot moved towards the fixed sensor nodes, and the value decreased when the robot moved away from the fixed sensor node. When the RSSI value reaches a minimum point, the environmental data was transmitted to the robot. *RSSI(t)* value is directly related to the distance between the moving robot and fixed nodes. The wireless signal and RSSI may also be affected by the building structure and hardware around the area. However, the distance can be accurately calculated based on some tests during the initial set up at a specific farm and for a specific node. The RSSI value can be recorded and analysed by the localisation function in the microprocessor embedded in the robot.

The experiments with several sensor nodes involved were carried out at level 4 of an office building Z. We collected the data over a period of time with sensors displayed at different distances from the gateway. The average data collected is presented in Table 1. From the results, we observed that the RSSI value decreased as the distance between the fixed sensor nodes and the gateway. However, the RSSI value is not simply the linear function of the distance. As the end node was further away from the gateway, the drops slowed down (Fig. 4).

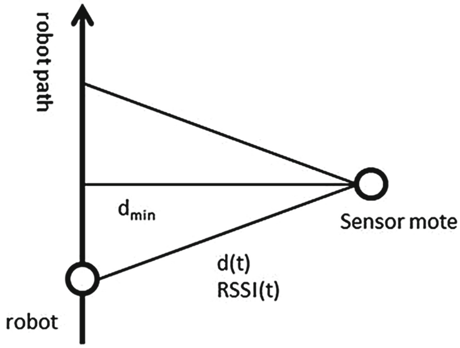

Fig. 3. Localisation of mobile robot

Table 1. Mean RSSI vs. distance

Distance (m)	1 m	5 m	10 m	15 m
RSSI (dbm)	78.6	60.1	49.3	46.6

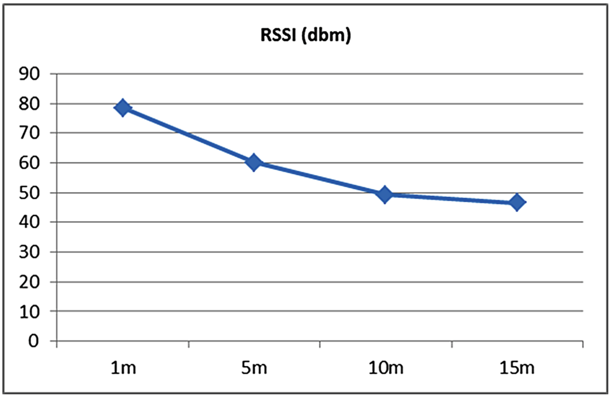

Fig. 4. RSSI value vs. distance between the end node and coordinator

4 Conclusions

In this research, we designed and developed a new environment measurement system for agriculture and environment management applications. The system uses both fixed and mobile wireless sensor motes to automatically monitor the environment. The system can automatically collect the environmental data with high accuracy, flexibility, and reliability. The number of sensors deployed to cover the building and the energy consumption by the sensors can be minimised in our design. In future research, we plan to use a wireless gateway to collect the data from the mobile vehicle to a central workstation and carry out the experiments over larger building areas. Another area of research is to enhance the mobile vehicle localisation function based on the signal from different fixed sensor motes.

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