WSN Implementation in the Greenhouse Environment Using Mobile Measuring Station

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Abstract *– Continuous advancements in wireless technology and miniaturization have made the deployment of sensor networks to monitor various aspects of the environment increasingly flexible. The function of a greenhouse is to create the optimal growing conditions for the full life of the plants. Using autonomous measuring systems helps to monitor all the necessary parameters for creating the optimal environment in the greenhouse. The robot equipped with sensors is capable of driving to the end and back along crop rows inside the greenhouse. This paper deals with the implementation of mobile measuring station in greenhouse environment. It introduces a wireless sensor network that was used for the purpose of measuring and controlling the greenhouse application.*

Keywords *– WSN, Sun SPOT, embedded system, PIC, mobile robot, greenhouse*

1. INTRODUCTION

Mobile robotics is a young field of research. Its roots include many engineering and science disciplines, from mechanical, electrical and electronics engineering to computer, cognitive and social sciences. The Board Of Education is a complete, low-cost development platform equipped with the needed sensors for humidity, temperature, light, etc. As shown in Figure 1, the Boe-Bot is a great tool with which to get started with robotics.

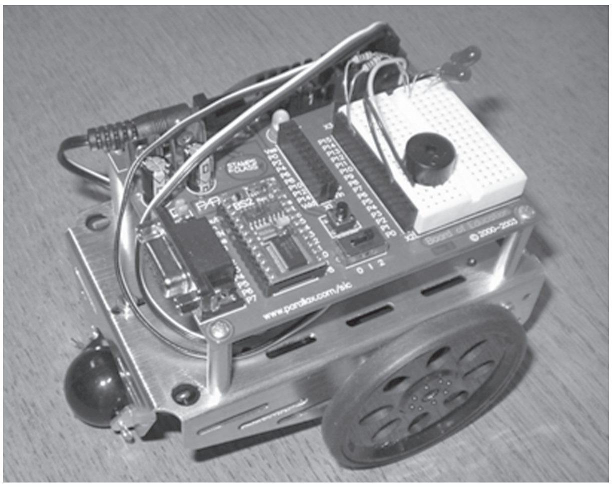

Fig. 1. Assembled Boe-Bot

The SunSPOT WSN module makes it possible for the Boe-Bot robot's BASIC Stamp 2 microcontroller brain to communicate wirelessly with a web based user interface running on a nearby PC. The BASIC Stamp microcontroller runs a small PBASIC program that controls the Boe-Bot robot's servos and optionally monitors sensors while it communicates wirelessly with the web server.

2. CONTROL SCHEME FOR MOBILE ROBOTS

A mobile robot needs locomotion mechanisms that enable it to move throughout its known or unknown environment. But there are a large variety of possible ways to move, and so the selection of a robot's approach to locomotion is an important aspect of mobile robot design. Figure 2, presents the control scheme for mobile robot systems. In the laboratory, there are research robots that can walk, jump, run, slide, skate, swim, fly, and, of course, roll. Any of these activities has its own control algorithm [16].

Locomotion is the complement of manipulation. In manipulation, the robot arm is fixed but moves objects in the workspace by imparting force to them. In locomotion, the environment is fixed and the robot moves by imparting force to the environment. In both cases, the scientific basis is the study of actuators that generate interaction forces, and mechanisms that implement desired kinematical and dynamic properties. The wheel has been by far the most popular mechanism in mobile robotics and in man-made vehicles in general. It can achieve very good efficiencies, and does so with a relatively simple mechanical implementation. In Figure 3, the kinematics of the mobile robot is depicted. In addition, balance is not usually a research problem in wheeled robot designs, because wheeled robots are almost always designed so that all wheels are in ground contact at all times [15].

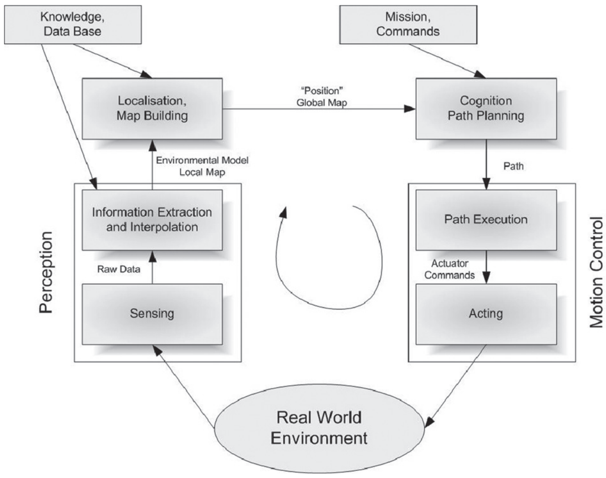

Fig. 2. Reference control scheme for mobile robot systems

Thus, three wheels are sufficient to guarantee stable balance, although, as we shall see below, two-wheeled robots can also be stable [12]. When more than three wheels are used, a suspension system is required to allow all wheels to maintain ground contact when the robot encounters uneven terrain. Motion control might not be an easy task for this kind of systems. However, it has been studied by various research groups, and some adequate solutions for motion control of a mobile robot system are available [16].

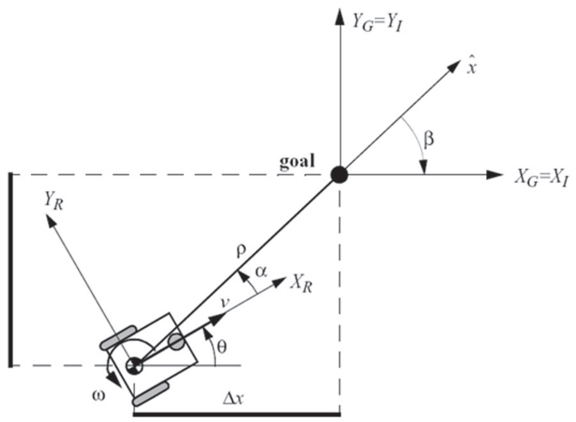

Fig. 3. Robot kinematics and its frames of interests

3. WSN AND EVENT-BASED SYSTEM FOR GREENHOUSE CLIMATE CONTROL

A wireless sensor network (WSN) is a computer network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations [1]. The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. Figure 4, presents the sensor node architecture. However, wireless sensor networks are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation, and traffic control.

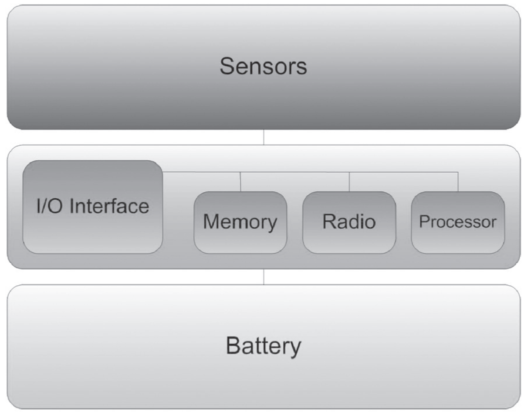

Fig. 4. Sensor Node Architecture

In addition to one or more sensors, each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. Figure 5 shows the typical wireless sensor network.

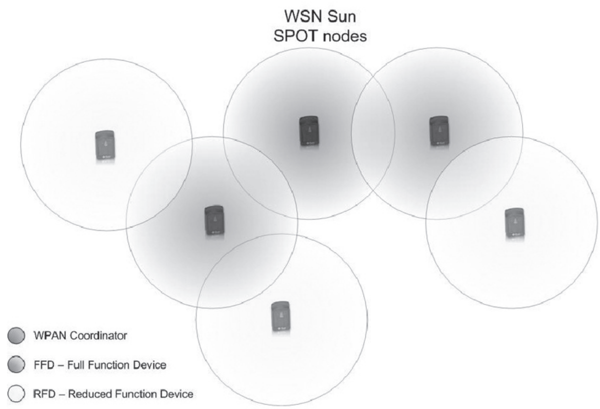

Fig. 5. Typical wireless sensor network (WSN)

The size a single sensor node can vary from shoebox-sized nodes down to devices the size of grain of dust [2]. The cost of sensor nodes is similarly variable, ranging from hundreds of dollars to a few cents, depending on the size of the sensor network and the complexity required of individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth. In computer science, wireless sensor networks are an active research area with numerous workshops and conferences arranged each year [4].

As commented above, this paper is devoted to analyzing diurnal and nocturnal temperature control with natural ventilation and heating systems, and humidity control as a secondary control objective. Under diurnal conditions, the controlled variable is the inside temperature and the control signal is the vent opening. The use of natural ventilation produces an exchange between the inside and outside air, usually provoking a decrease in the inside temperature of the greenhouse. The controller must calculate the necessary vent opening to reach the desired setpoint. The commonest controller used is a gain scheduling PI scheme where the controller parameters are changed based on some disturbances: outside temperature and wind speed. In the case of nocturnal temperature control, forced-air heaters are used to increase the inside temperature and an on/off control with dead/zone was selected as heating controller.

Nowadays, commercial systems present more flexibility in the implementation of control algorithms and sampling techniques, especially WSN, where each node of the network can be programmed with a different sampling algorithm or local control algorithm with the main goal of optimizing the overall performance.

4. SOLUTION

Building and programming a robot is a combination of mechanics, electronics, and problem solving. What you're about to learn while doing the activities and projects in this text will be relevant to "real world" applications that use robotic control, the only difference being the size and sophistication. Robotics has come a long way, especially for mobile robots. In the past, mobile robots were controlled by heavy, large, and expensive computer systems that could not be carried and had to be linked via cable or wireless devices. As shown in Figure 8, the mobile measuring station is navigating inside the greenhouse. Today, however, we can build small mobile robots with numerous actuators and sensors that are controlled by inexpensive, small, and light embedded computer systems that are carried on-board the robot.

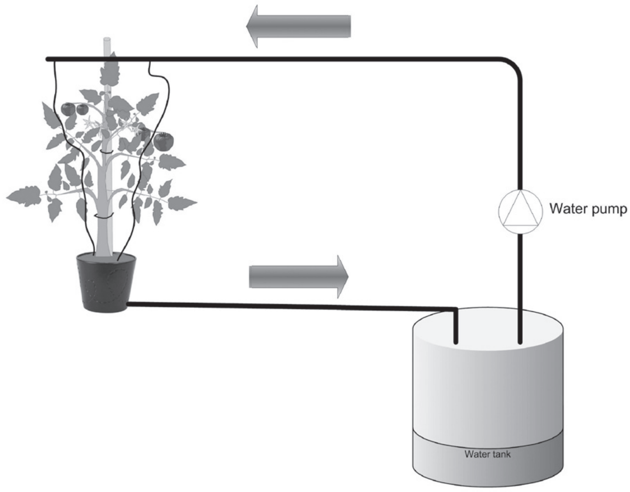

Fig. 6. Humidity control

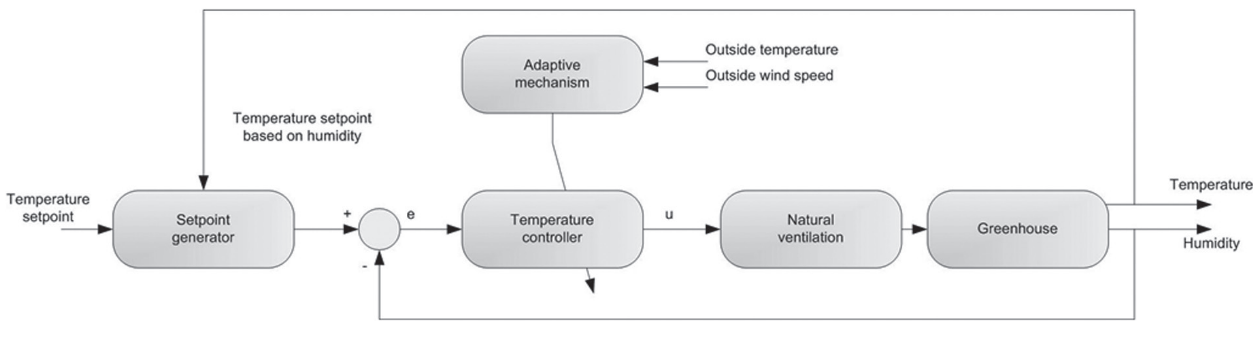

Fig. 7. Temperature controller

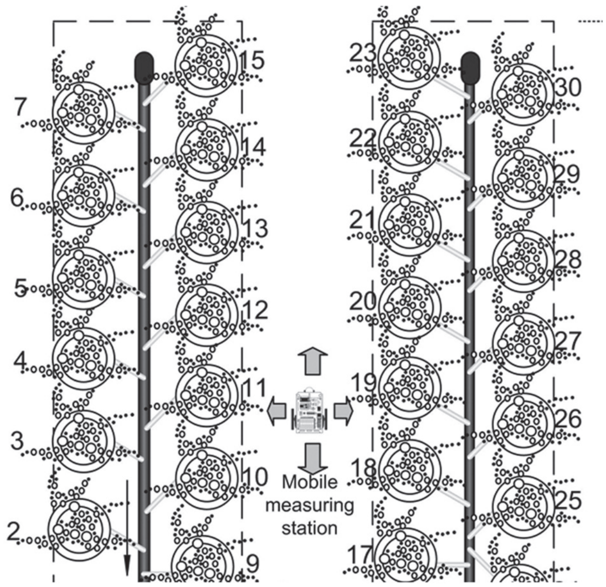

Fig. 8. Greenhouse top view with the mobile measuring station

The mechanical principles, example program listings, and circuits you will use are very similar to, and sometimes the same as, industrial applications developed by engineers. In this project we have used SunSPOT-s to achieve remote control over a Boe-Bot. For this project we have used 2 SunSPOT-s from the kit (free range and base station module) as depicted in Figure 9. SunSPOT's wireless protocol is Zigbee based protocol [6].

The Hardware basically centers around Sun SPOT and DC Motors controlled by Basic Stamp. The Sun SPOT base station will send data to Sun SPOT on the mobile measuring station which will drive the Basic Stamp controller to DC IO pins [7]. The microcontroller will drive the Motors which will run the measuring station. Figure 10 shows the testing phase of the mobile measuring station.

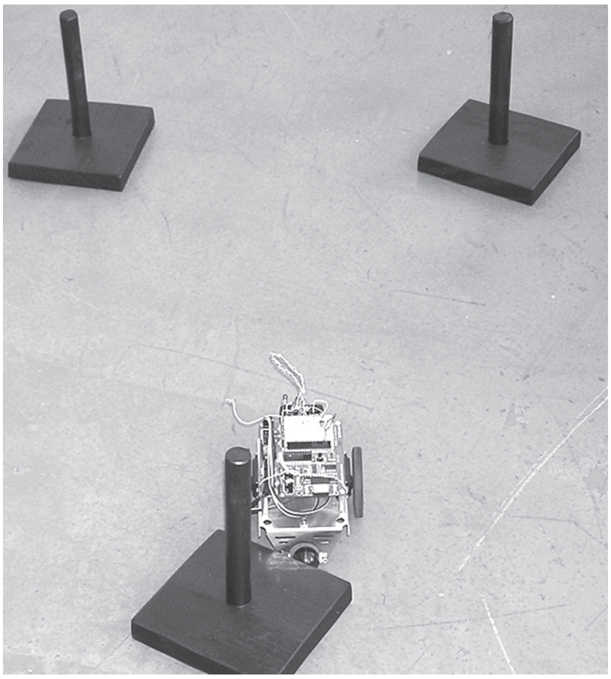

Fig. 10. Boe-bot with SunSPOT mounted

5. EXPERIMENTAL RESULTS

The applications for WSNs are many and varied. They are used in commercial and industrial applications to monitor data that would be difficult or expensive to monitor using wired sensors. They could be deployed in wilderness areas, where they would remain for many years (monitoring some environmental variable) without the need to recharge/replace their power supplies. They could form a perimeter about a property and monitor the progression of intruders (passing information from one node to the next). There are a many uses for WSNs [8].

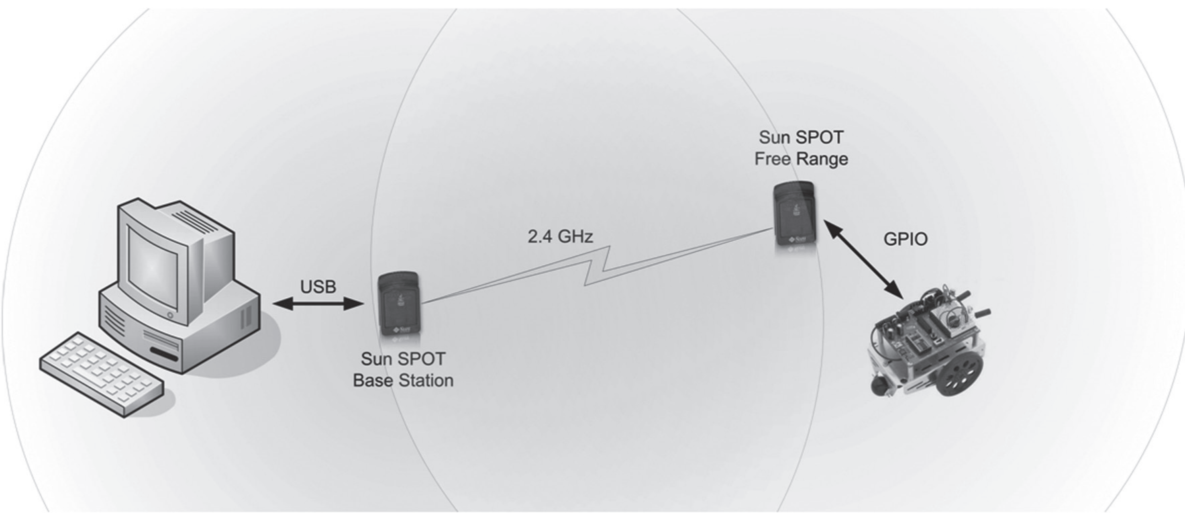

Fig. 9. Connection of the system

Fig. 11. Crops in greenhouse

Typical applications of WSNs include monitoring, tracking, and controlling. Some of the specific applications are habitat monitoring, object tracking, nuclear reactor controlling, fire detection, traffic monitoring, etc. In a typical application, a WSN is scattered in a region where it is meant to collect data through its sensor node. Figure 12 shows the complete control system of the greenhouse. The WSN-based controller has allowed a considerable decrease in the number of changes in the control action and made possible a study of the compromise between quantity of transmission and control performance.

The limit of the level crossing sampling has presented a great influence on the event based control performance where, for the greenhouse climate control problem, the system has provided promising results.

Fig. 11. Capsicum

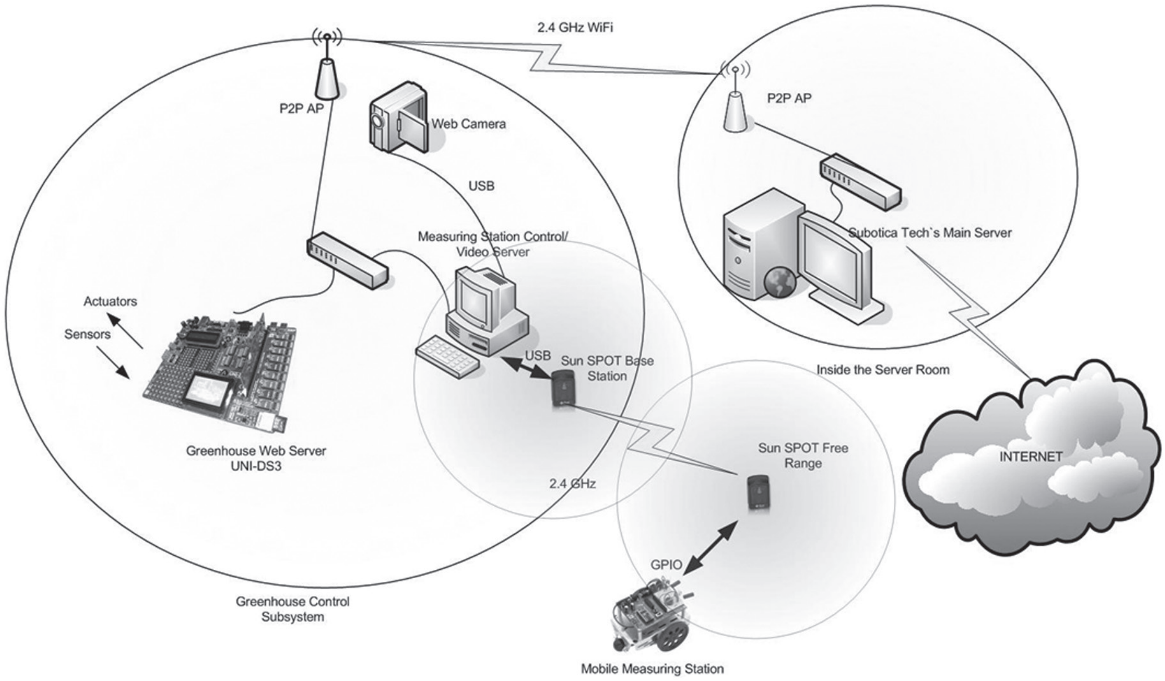

Fig. 12. Greenhouse control system

Motion control of mobile robots is a very important research field today, because mobile robots are a very interesting subject both in scientific research and practical applications. In this paper the object of the remote control is the Boe-Bot. The vehicle has two driving wheels and the angular velocities of the two wheels are independently controlled [9]. When the vehicle is moving towards the target and the sensors detect an obstacle, an avoiding strategy is necessary. The host system connects to the mobile robot with the SunSPOT module. A remote control program has been implemented as shown in Figure 14.

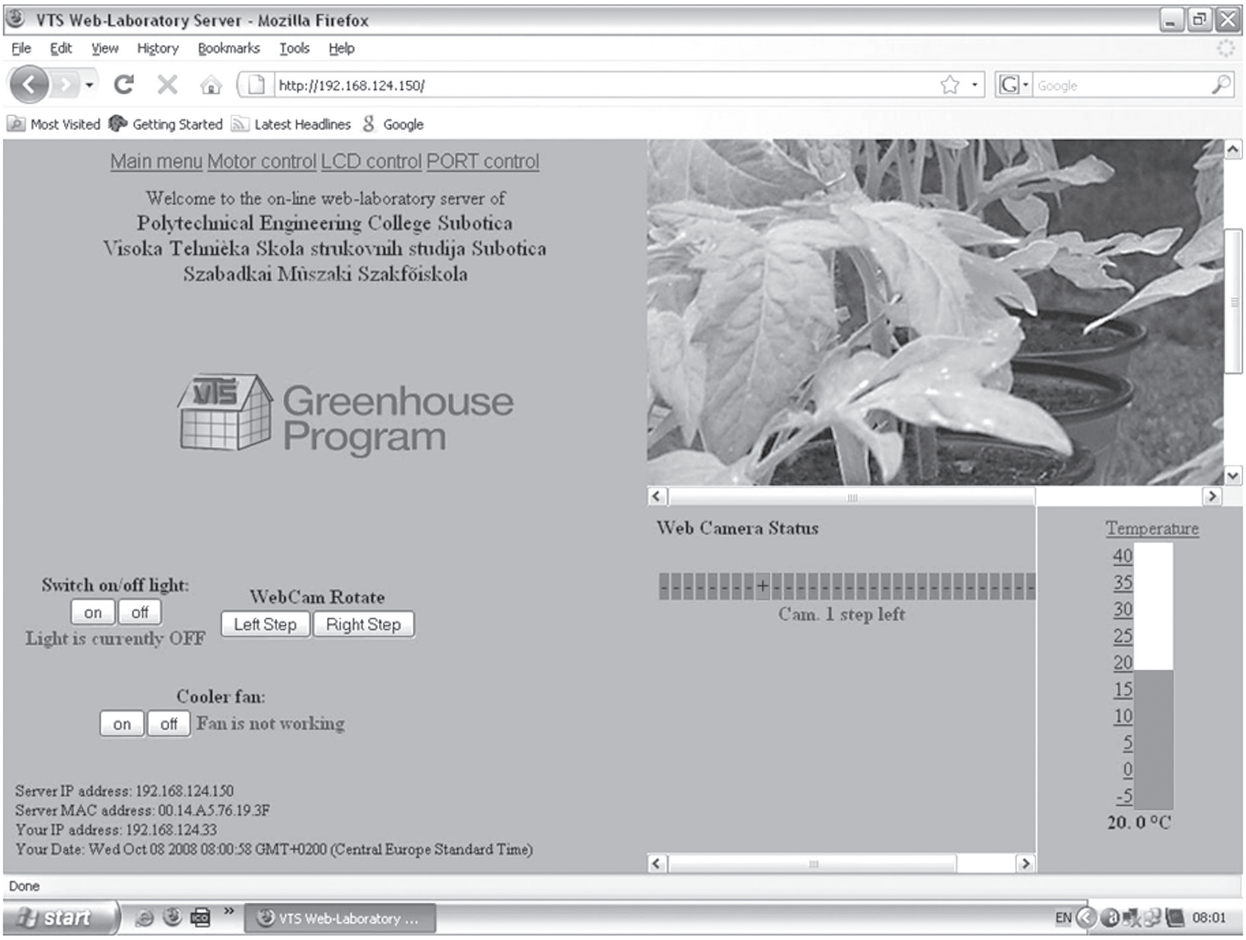

Fig. 14. Screenshot of the system

The code snippet below gives an example of testing the communication devices in broadcast mode as we can see in Figure 15. It is written in Java and runs on SunSPOT modules. Each SPOT is assigned its own adress and can broadcast or unicast to the other SPOTs. This code is implemented for testing purposes only.

The Sun SPOT is a Java programmable embedded device designed for flexibility. The basic unit includes accelerometer, temperature and light sensors, radio transmitter, eight multicolored LEDs, 2 push-button control switches, 5 digital I/O pins, 6 analog inputs, 4 digital outputs, and a rechargeable battery. Java imple-

```
    protected void startApp() throws MIDletStateChangeException {
        System.out.println(„Broadcast Counter MIDlet”);
        //showColor(color);
        //switches[0].addISwitchListener(this);
        //switches[1].addISwitchListener(this);
        try {
            tx = (RadiogramConnection)Connector.open(„radiogram://broadcast:123”);
            xdg = (Radiogram)tx.newDatagram(20); //transmitting the radiogram
            RadiogramConnection rx = (RadiogramConnection)Connector.
open(„radiogram://:123”);
            Radiogram rdg = (Radiogram)rx.newDatagram(20);
            //outs[0].setHigh();
            while (true) {
                try {
                    rx.receive(rdg);
```

```
                    int cmd = rdg.readInt();
                    //int newCount = rdg.readInt();
                  //int newColor = rdg.readInt();
                    /*if (cmd == CHANGE_COLOR) {
                        System.out.println(„Received packet from „ + rdg.getAddress());
                        //showColor(newColor);
                    } else {
                        //showCount(newCount, newColor);
                    }*/
                    switch (cmd){
                        case 0: outs[demo.H0].setLow(); outs[demo.H1].setLow(); leds[0].
setRGB(200, 0, 0); leds[0].setOn(); leds[1].setOff();leds[2].setOff();leds[3].setOff();
break;
                        case 4: outs[demo.H0].setHigh(); outs[demo.H1].setLow(); leds[1].
setRGB(200, 0, 0); leds[1].setOn(); leds[0].setOff();leds[2].setOff();leds[3].setOff();
break;
                        case 3: outs[demo.H0].setLow(); outs[demo.H1].setHigh(); leds[2].
setRGB(200, 0, 0); leds[2].setOn(); leds[1].setOff();leds[0].setOff();leds[3].setOff();
break;
                        case 1: outs[demo.H0].setHigh(); outs[demo.H1].setHigh(); leds[3].
setRGB(200, 0, 0); leds[3].setOn(); leds[1].setOff();leds[2].setOff();leds[0].setOff();
break;
//setting up the diagnostic leds
                        default: leds[4].setRGB(200, 0, 0); leds[4].setOn(); break;
                    }
                } catch (IOException ex) {
                    System.out.println(„Error receiving packet: „ + ex);
                    ex.printStackTrace(); // Error detection
                }
            }
        } catch (IOException ex) {
            System.out.println(„Error opening connections: „ + ex);
            ex.printStackTrace(); // Error detection
        }
    }
```

Fig. 15. Sending broadcast packets via WSN from base station

mentation and programming the Sun SPOT is surprisingly easy. Experimental testing has demonstrated the validity of our approach.

6. COMPARISON OF THE FRUIT PRODUCTION

Tomatoes are a warm season vegetable crop. They grow best under conditions of high light and warm temperatures. Low light in a fall or winter greenhouse, when it is less than 15% of summer light levels, greatly reduces fruit yield when heating costs are highest. For this reason, it is difficult to recommend that a greenhouse operator should grow and harvest fruit from December 15 to February 15. Based on few years of experience, tomato production is most successful in the spring. Excellent light, moderate heating costs and good prices annually demonstrate this is the best time for greenhouse tomato production. Tomato plants grow best when the night temperature is maintained at 16 - 18 °C. Temperatures below 16 °C will prevent normal pollination and fruit development. In warm or hot outdoor conditions, tomato greenhouses must be ventilated to keep temperatures below 35 °C. High temperatures not only affect the leaves and fruit, but increased soil temperatures also reduce root growth. Table 1 gives an overview of effectiveness of the control system.

Table 1. The average total weight and number of fruit harvested

Tested plants	Average weight of fruit (with WSN control)	Average weight of fruit (without WSN control)	Average number of fruit per plant (with WSN control)	Average number of fruit per plant (without WSN control)
Tomato	210 g	180 g	17	11
Capsicum	135 g	110 g	15	12
Cucumber	70 g	60 g	13	10

Success in greenhouse plants depends completely on fruit yield. Yields of 20 – 25 % gain per plant are very good for annual costs.

7. CONCLUSION

The system and its implementation have been successful; however there are still possibilities for further development. The first cycle of plant development has just passed, and it has provided numerous valuable data. For the next cycle better conditions will be provided, with more experienced staff. With further developments the application of professional industrial electronics will also have to be taken into consideration, which would significantly decrease possible problems.

ACKNOWLEDGEMENTS

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