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STRUCTURE OF SENSING SYSTEMS FOR AUTONOMOUS GREENHOUSES USING EMBEDDED COMPUTER

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Abstract. *The autonomous greenhouse is aiming small-scale regional plant factory at low cost system. Normally, initial costs of plant factories automatically controlled by computer system are very expensive, because plant factories grow plants using hydroponic culture inside a building under controlled environment. The autonomous greenhouse consists of attaching several components to a normal (original) greenhouse; in order to realize low cost model, the normal (original) greenhouse grows plants under natural environment. Main components of the autonomous greenhouse are the normal (original) greenhouse, sensors, solar panels, a battery, and an embedded computer system. Thus, autonomous greenhouse does not intend to realize a full automation greenhouse. We are researching the intelligent autonomous greenhouse which is controlled by an embedded computer such as Raspberry Pi. The embedded computer system controls air-conditioning systems, water pumps in the greenhouse, and monitoring of plants growing, since the system supports the day-to-day farm work.*
Keywords: Embedded computer, Sensors system, Autonomous greenhouse, Greenhouses, Hydroponic culture

1. **Introduction.** Nowadays, plant factory such as indoor hydroponics is becoming mainstream for producing high-quality vegetables [1]. These plant factories have various labor saving equipment such as air conditioning managements and automatic water feed devices. So these plant factories are automatically controlled by a computer system. In addition to this, the plant factory has various merits such as growing all season, tolerance of bad weather, and space saving. However, the cost of these plant factory is very expensive. In addition to this, these plant factories require much equipment such as air-temperature control systems, fertilizer scattering systems, and LED lighting equipment. Thus, plant factory has various merits and demerits. Plant factories are especially large-scale facility operated by enterprise, and initial installation cost is very expensive. For these reasons, it is difficult for individual level such as regional agriculture to introduce systems of plant factory. Plant factory is unsuitable for regional agriculture. For the regional activation, scale of agriculture is very important. However, large scale farming is inappropriate for regional agriculture.

Therefore, in this study, we were researching whether it can be realized or not for a low cost model of a plant factory by using an embedded computer and sensor systems [2]. For this reason, a full automation plant factory does not match cost, so it is difficult for individuals to introduce into regional agriculture. Thus, we are researching the intelligent autonomous greenhouse which is controlled by an embedded computer at low cost; target

cost is a few hundred dollars. Greenhouse producing various vegetables, needs control of equipment, air conditioning management and water pump. The system controls air conditioning and water pumps in the greenhouse. The system is based on stand-alone solar power, so the system can work without commercial power supply.

In this paper, we introduce sensing systems using embedded processor for the autonomous greenhouse.

2. **Autonomous Greenhouse.** Greenhouse is a building with glass or plastic transparent walls and roof, and it glows plants under controlled conditions. Figure 1 shows a typical greenhouse. Therefore, we think that greenhouse has some merits. In addition to this, greenhouse is an alternative facility to plant factory, and it is capable of using at the individual level. In this study, we use a hydroponic culture method instead of a soil culture method. A plant factory which is using hydroponic culture is a high cost system, and it needs expensive equipment such as air condition control, and LED lighting equipment. However, we think that using a hydroponic culture in a greenhouse does not require more expensive equipment. The reason for this is that farming in a normal (original) greenhouse uses natural environment like sunlight, rain, and wind. Thus, farming in the normal greenhouses does not require expensive equipment. Figure 2 shows hydroponic culture unit which we are using [3].

The autonomous greenhouse is aiming small-scale regional plant factory at low cost system. Main components of the autonomous greenhouse are sensors, solar panels, battery, and an embedded computer system. Therefore, the autonomous greenhouses are able to construct by attaching these devices to the normal greenhouse; the autonomous greenhouse uses sensing system by an embedded computer. In order to realize a low cost system, the autonomous greenhouses use Raspberry Pi [4] as an embedded computer system. Raspberry Pi has many advantages by comparison with any other board. These advantages are low power consumption, interfaces of communication function, and extension ability of sensors by I/O pin. In addition to this, Raspberry Pi is a low cost embedded

FIGURE 1. Greenhouse

FIGURE 2. Hydroponic culture unit

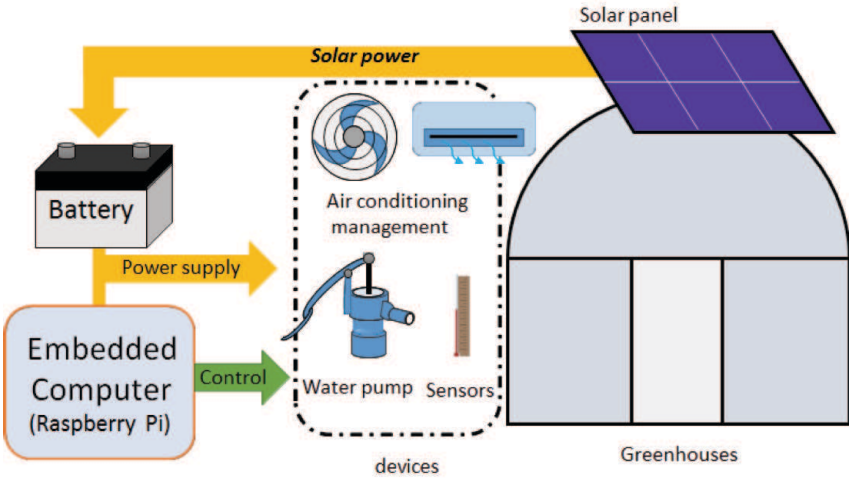

FIGURE 3. Autonomous greenhouse model

computer system. Thus, the autonomous greenhouse will be able to construct by adding some cost to the normal greenhouses. Figure 3 shows the autonomous greenhouse model.

Control model of the autonomous greenhouse using the embedded computer is as below.

- The system works with solar power and battery without commercial power supply.
- The system monitors utilization status of power by the embedded computer (Raspberry Pi), and controls solar power generation.

The reason why the system works with solar power and battery is that target area of the system assumes to have no commercial power supply. Therefore, the system is able to work with solar power and battery without commercial power supply. Thus, the system monitors utilization status of power by the embedded computer (Raspberry Pi), and the system shuts down devices of the autonomous greenhouse, if charging amount of battery becomes insufficient. The embedded computer controls sensors and several components of the autonomous greenhouse.

3. **Hardware Selection.** We select Raspberry Pi as an embedded computer because Raspberry Pi has many I/O pins, network interface and low power ability. In addition to this, Raspberry Pi is a low cost board, and it is easy to use as the embedded computer. Figure 4 shows Raspberry Pi.

FIGURE 4. Raspberry Pi board

Raspberry Pi is a credit card-sized embedded computer board, which is developed by the Raspberry Pi Foundation. Raspberry Pi has ARM processor, network, memory and GPIO ports on the board. Raspberry Pi contains an ARM processor, so it realizes low power consumption at 3.5 W. It is a low-cost single processor board since it is priced at US $35, which makes it easy to get. In addition to this, Raspberry Pi is able to use Linux ARM version, and has many software components as programming languages and software interfaces. Table 1 shows spec of Raspberry Pi board.

TABLE 1. Spec of Raspberry Pi board (Model B)

Type	*Raspberry Pi 1 (Model B)*	*Raspberry Pi 2 (Model B)*
CPU	ARM11 single core (700 MHz)	ARM Cortex-A7 quad core (900 MHz)
Memory	512 MB	1 GB
USB	USB2.0 × 2	USB2.0 × 4
Network	10/100 Mbit/s Ethernet	10/100 Mbit/s Ethernet
I/O	26 × GPIO	40 × GPIO
Power	3.5 W	4.0 W

4. **Sensor System.** In order to realize a low cost system, the autonomous greenhouse uses Raspberry Pi, battery, solar panel, voltage-current sensor, temperature sensor, and camera module. In the autonomous greenhouse system model, Raspberry Pi checks environment of the greenhouse by these sensors, and controls its environment. Therefore, we implemented Raspberry Pi with sensor systems, and tested these sensor systems.

- Water temperature sensor: DS18B20 [5]
  DS18B20 is a digital thermometer which provides Celsius temperature measurements.
- Voltage, current and power sensor: INA226 [6]
  INA 226 is a sensor, which is developed by Texas Instruments. It measures battery voltage and amount of electric power generation of solar panel. We used a sensor module including INA226.

5. **Evaluation.** We evaluated the implemented system by basic sensor systems measuring temperature and measuring battery voltage, because implementation of the embedded computer system for the autonomous greenhouse is not finished yet. We implemented a battery voltage control system, a temperature measure-control system, and a camera control system to Raspberry Pi 2 board. Figure 5 shows an implemented system diagram

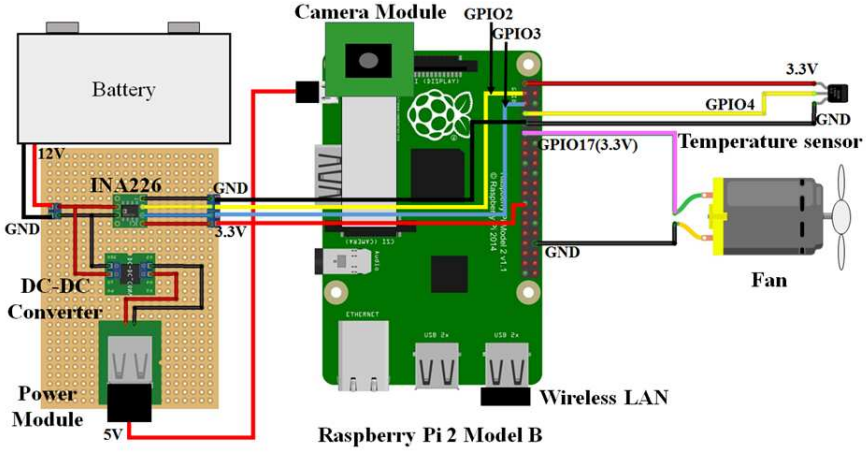

FIGURE 5. Evaluation of the embedded computer system diagram

using the embedded computer system. The battery voltage control system can get system's battery voltage, and manages its power supply control using battery or not. The temperature measure-control system can get temperature of a target, and have a function of its thermal management.

To evaluate these systems easily, we tested water temperature control by battery power supply. Figures 6 and 7 show evaluation result. The evaluate system measures water temperature, and controls cooling fan. If water temperature is higher than threshold, the system drives cooling fan. In this evaluation, we checked that the system is able to measure temperature. In addition to this, we measured temperature changing in the case of with cooling-fan or without cooling-fan. Thus, from this evaluation, we found that the system is able to measure temperature. In addition to this, we had evaluated that the system is checking its battery and it is able to manage its power supply control using battery or not.

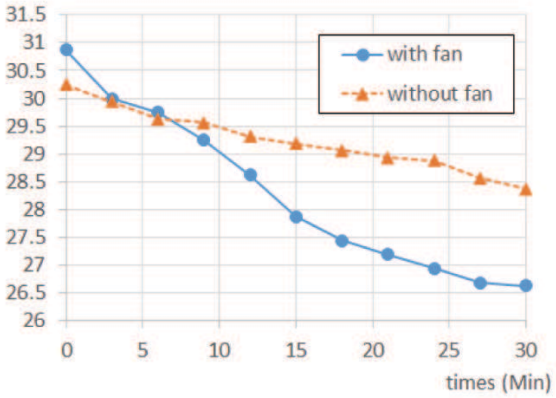

FIGURE 6. Measuring water temperature

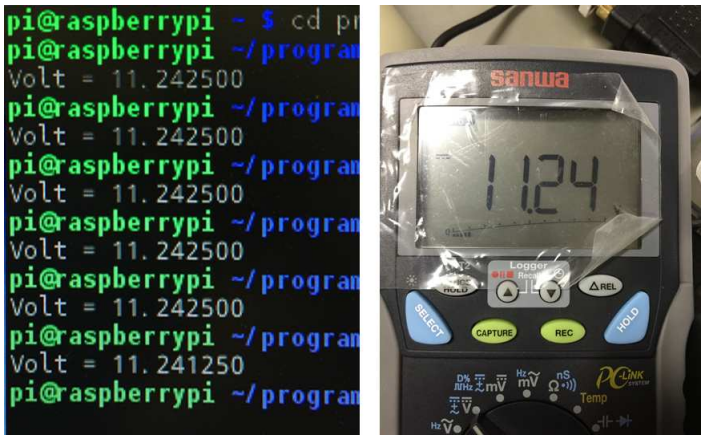

FIGURE 7. Checking for battery voltage

6. **Conclusions.** In this paper, we describe the sensing systems using the embedded processor for the autonomous greenhouse. The autonomous greenhouse is aiming a small-scale regional plant factory by low cost system, and it does not intend to realize a full automation greenhouse. Therefore, it is constructed by attaching sensors, solar panels, battery, and the embedded computer system to the normal (original) greenhouse.

We evaluated several of the system components. Thus, we confirmed that the system which is driven by battery is able to measure water temperature and control cooling fan.

Following tasks are implementing the sensing system, and evaluating the system using a greenhouse in our campus (Figure 8).

FIGURE 8. Greenhouse in our campus

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