

## Sustainable Agriculture through ICT innovation

**Scheduling Software Construction Utilizing the Sensor Network  
in Plant Factory**

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**ABSTRACT**

The sunlight-based plant factory supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF), which has a potential to achieve long-term stable tomato production under global climate change, is not yet able to produce tomatoes with the quality meeting the consumer's preference. Furthermore, even though the sunlight-based factories use less electricity than other factories, they still require a lot of energy to keep optimizing the growing environments. To solve these problems, we started creating a next-generation technology for plant factory system by utilizing the information and communication technology (ICT). The proposed system can manage the product quality demand as a dependent variable, make it possible to reduce electric power consumed to maintain the temperature, and make a stable production of a certain level of quality, which can be determined by counting the consumer's preference backward. We have successfully created the scheduling software used in the system.

**Keywords:** Agricultural and bio-systems, networked sensor system, process control, japan

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## 1. INTRODUCTION

In 2011, the Demonstration and Training Center for Greenhouse Agricultural Production equipped with the sunlight-based plant factory supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) has been developed in Central Mie. This center has been managed by Mie Prefectural Agricultural Research center. The plant factory was constructed to achieve the yearly-stable supply of the tomato cultivation with the productivity growth and quality improvement. In the present situation, however, the plant factory is not able to produce such tomatoes as possess the quality which meets the consumer's preference while it has a potential to allow long-term stable tomato production to be maintained under global climate change. Furthermore, even though the sunlight-based factories use less electricity than totally-controlled factories, they still require a lot of energy to keep optimizing the growing environment in coordination with many environmental control equipments. We then studied a next-generation scheduling software by utilizing the information and communication technology (ICT) in order to solve the above problems.

## 2. MATERIALS AND METHODS

The proposed system can manage the product quality demand as a dependent variable, make it possible to reduce electricity consumption, and make a stable production of a certain level of quality, which can be determined by counting the consumer's preference backward.

The next-generation technology has the following features.

- 1) Cultivation management system, which enables us to control the product quality.
- 2) Optimized growing scheduling system to raise efficiency and simultaneously pursue profitability.
- 3) Efficient production with a few resources such as space, energy and human resources based on the optimized schedule.

This new system could reduce everyday operating cost through resource saving and it is also expected to facilitate prompt dissemination of plant factory, utilizing the information obtained from the sensor network.

## 3. RESULTS & DISCUSSION

### 3.1 The result in the 2012 Fiscal Year

In this research, we established a prototype of the scheduling method. To achieve it, we constructed a prototype of the forecasting model of the growing period only based on thermal time. At the same time, a miniature size wireless sensor for temperature, humidity and light intensity was developed for measuring canopy photosynthesis. The

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allocation of miniature sensors in the factory is also completed and the development of the scheduling software is also completed.

### 3.2 Forecasting Model of the Growing Period

For the forecasting model, we used the method referred in Kanagawa Agricultural Technology Center, 2010. It is known that the growth speed can be practically decided by temperature(Phenology). In this view, we calculated the accumulated temperatures necessary for tomato to reach the main developing stages. These temperatures are calculated for each season and time, and we use them to design the sowing plan for the growing system, which uses the cultivation methods, low node-order pinching and high density planting. Based on the manual(Kanagawa Agricultural Technology Center, 2010) and the cultivation data of a plant factory Mie base(Figure 1), the accumulated temperature(°C) at the start of Transplanting for tray, the start of Picking, and the end of Picking is corrected to 476, 1900, and 2650, respectively. Based on these, we built the “Forecasting Model of the Growing Period” used for a sowing plan.

Process		Sowing seed	Transplanting for tray	Planting	Training	Flowering (1st truss)	Flowering (2nd truss)	Flowering (3rd truss)	Pinching	Start of picking time	End of picking time
Model		Plant model				Plant community model					
Critical Control Point			○	○		○		○			
Sample of Schedule (Summer)	Date	7/4	7/25	8/2		8/15	8/23	9/1	9/9	9/16	10/24
	The growth days	0	21	29	36-39	42	50	59	67	74	112
Sample of Schedule (Winter)	Date	10/3	10/25	11/4		11/18	12/5	12/20		1/23	3/26
	The growth days	0	22	32	36-39	46	63	78		112	174
Investigation item	Temperature	○	○	○	○	○	○	○		○	○
	Electrical conductivity (dS/m)	1.8	1.1~1.4		1.1~1.3						
	Quantity of the supply	-	-	○	○	○	○	○		-	-
	EC of drained nutrient solution	-	-	○	○	-	-	-		-	-
	Stem diameter	-	-	-	-	○	○	○		-	-
Work	Sowing	○									
	Transplanting for tray		○								
	Planting			○							
	lateral disbudding				○						
	Training				○	○	○	○	○	○	
	hormone's spray					○	○	○			
	Fruit thinning							○	○		
	Pinching								○		
	Picking									○	○
	Fruit grading									○	○

Figure 1 Cultivation Process for Mie prefectural Agricultural Research center

### 3.3 Miniature Size Wireless Sensor

We developed a small and low-power consumption radio sensor, in which temperature, humidity, and illumination functions are integrated. It also carries a 920 MHz band transceiver and can realize the stable data communications in an available light type

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plant factory. Moreover, it is waterproofed and can be installed in plant community without any loss of stability.

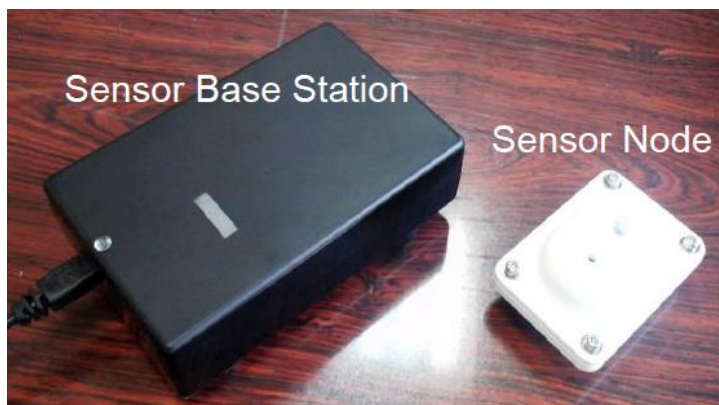


Figure 2 The picture of the sensor node and base station

## Wireless transmission method

- 1) ISM band (ARIB STD-T108) using 920MHz
- 2) Transmission speed 40kbps
- 3) Maximum transmission output -12dBm
- 4) Reception level -105dBm
- 5) Sensor sampling 5sec
- 6) Communication report space 5min. (the mean of 60 times of samplings)
- 7) RF communication time 10ms
- 8) Consumption electric current 17mA mean at RF movement
- 9) Prospect outreach around 200m



Figure 3 Whole view of the plant factory

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Figure 3 is a whole picture of the plant factory in Mie Prefecture. We located the wireless temperature-humidity, the illumination sensor which we developed this time in a tomato plant factory. Figure 4 shows the placement of 14 wireless sensors installed in the plant factory.

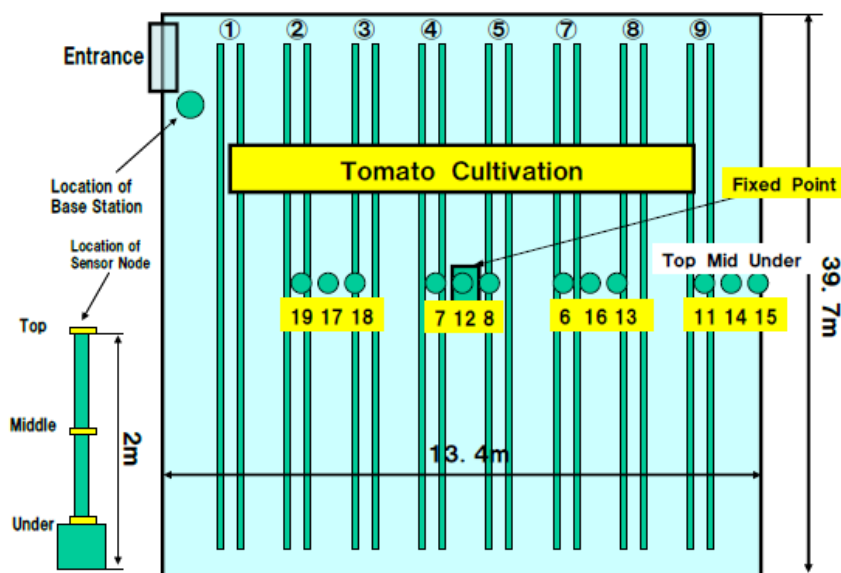


Figure 4 Locating 14 places in a figure of placement of wireless temperature-humidity, the illumination sensor in a plant factory



Figure 5 The miniature size wireless sensors located in the upper, center and bottom part of the tomato plant community

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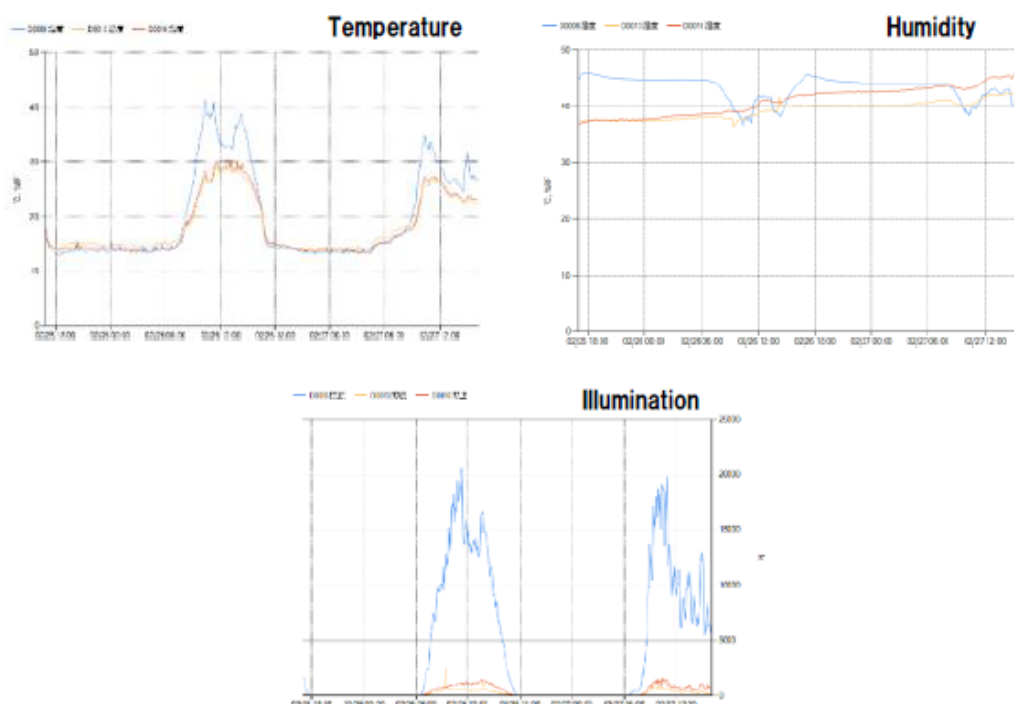


Figure 6 2-day acquisition data

Figure 5 shows the sensors located in the upper, center, and bottom part of the tomato plant community. The data which we acquired are sent to the base station by 920MHz wireless transmission. The data which we acquired every five seconds are sent to the sensor base station as mean data of five minutes (60 times of total). Figure 6 shows 2-day acquisition data, showing the changes of temperature, humidity and illumination well. It also shows that the light hardly arrives at the sensors located in the bottom.

### 3.4 Scheduling Software

The scheduling software displays the schedule and the environment information from sensors (See Figure 7). This software consists of two models, the forecasting model of the growing period and the scheduling model.

The scheduling model is designed to minimize the distribution of the yield for each season. The model handles planting dates as variables and the followings as constraints.

- 1) The total yield more than fixed
- 2) Prohibit the concurrent use of the same equipment
- 3) Prohibit the overlap of growing periods
- 4) Prohibit a void period in one cycle.
- 5) Prohibit the harvest in a specified period

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We adopted the multi-start greedy method in consideration of the future constraints extension and computation time. From now on, we will perform gap comparison with the exact solution and, if needed, change a technique.

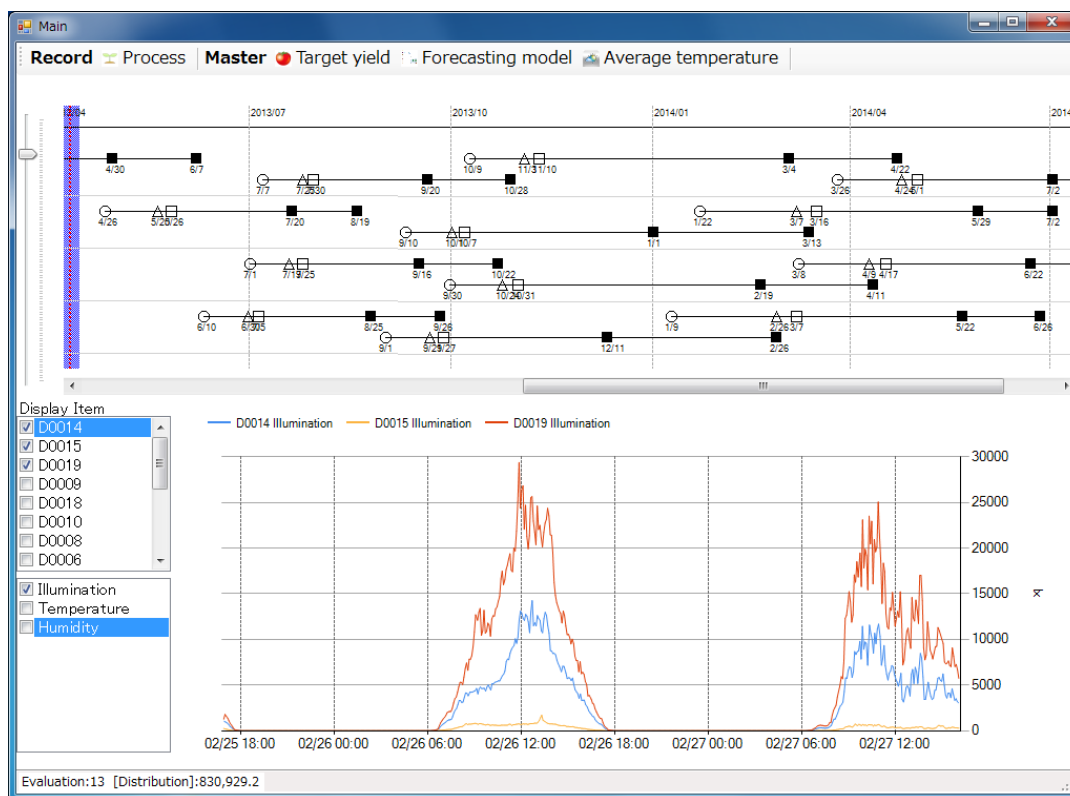


Figure 7 Scheduling system screen

In the present research, we try to upgrade a growth model, upgrade a scheduler and analyze the electric power of the plant factory facilities.

#### 4. ACKNOWLEDGEMENTS

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#### 5. REFERENCES

Takaharu Kameoka, Atsushi Hashimoto. 2013. A sensing approach to fruit-growing, "Wireless Sensor Networks and Ecological Monitoring, Series: Smart Sensors,

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## Sustainable Agriculture through ICT innovation

Measurement and Instrumentation, Vol. 3 Mukhopadhyay, Subhas C; Jiang, Joe-Air (Eds.), XII, 217-246, Springer 2013

Tomohiro Kawakita. 2013. Miniature size three modes wireless sensor development to link to management in a plant factory growth schedule: Organized Session in SICE 2013

Kanagawa Agricultural Technology Center. 2010. "The annual tomato multi-harvest manufacturing technique manual by the low stage and multi-stage combination cultivation", Japan Greenhouse Horticulture Association, March 2010

Youichi NONAKA, Attila Lengyel, Yuuichi SUGINISHI, Kouichi SUGIMOTO, Rieko AIZAWA, Natsuko YANO, Masaki KATO, Toshiya KAIHARA, Nobutada FUJII, Takako KURANO. 2010. "Maintenance Planning in Re-entrant Flow Shop (2nd Report) -Application of Multi-start Greedy Method and Verification Test-": Journal of the Japan Society for Precision Engineering, Vol76, No 12, 2010, Pages 1398-1405

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