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A Case Study on the Estimation of the Amount of Harvested Agricultural Products through a Sensor Network

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Abstract

This study examined the predictability of harvested amounts of agricultural products by using the technology of a sensor network. For the prediction of harvested amounts of agricultural products in a fruit farm, the containers made for exclusive transportation of agricultural products were equipped with context aware sensor tags and a context aware communication module was implemented. The implemented system was installed on-site at the fruit farm to examine the data of the amount of harvested agricultural products carried by the containers from the farm to each storage location to provide the methods to predict the harvested amount of agricultural products. Results obtained from the empirical experiment showed the recognition of contents in each container. Reliability of communication between sensors and communication unit were essential for the prediction of harvested amount of agricultural products.

Keywords: *sensor network, agricultural products, prediction, containers*

1. Introduction

On the wave trending towards globalization requiring endless competition among countries, various policy measures and many research investments are being committed in order to secure the competitiveness of domestic industries in all countries. Also, importance of the agricultural, fishing, and livestock industries are being emphasized. Thus all countries of the world are taking such industries as national resources to raise and secure respective national competitiveness. [1]

Studies delved into subjects of agricultural, fishing, and livestock breeding industries have been diversified and promoted the advancement of the primary industries. In addition they are still forging a way to secure respective competitiveness. [2-12] In particular, due to the rapid change and fluctuation in the production amount of these industries caused by the global climate change, diverse measures have been established and implemented by each government. However, they are still remaining far away from fundamental solutions.

This study intended to explore and develop the technology to predict the production amount in primary industries. In doing so the primary industries could exert its potential by deriving synergy effects, comprising the establishment, implementing agricultural policies, and securing stable price competitiveness. [4-12]

In this study, the algorithm designed to employ exclusive containers used for the transportation of agricultural products at each local site is presented to predict the production amount of agricultural products in harmony with technologies developed through diverse studies for the prediction of the production amount in primary industries.[4]-[12] That is, the algorithm was designed to enable users to monitor every container moved with its contents to calculate the total amount of agricultural products contained therein.

To enable the real time monitoring of each container carrying agricultural products on site, the sensor network technology was applied [13-20]. Above all, each container of agricultural products was equipped with sensor tags. The sensor tags to be attached on each container were furnished with the function of context aware sensing that could enable the recognition of the move and volume of contents in each container.[19, 20] A container made

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of PVC was selected in this study because it has been mostly used among diverse types of containers in actual agricultural sites. The presented method will comprise the calculation of the amount of contents in each container and the number of containers moved for the prediction of production amount of agricultural products at each site.

2. Method and Technology

Studies explored the predictability of agricultural products in each field have been conducted actively and have rendered many applications currently used in agricultural, fishing, and livestock breeding industries. [1-12]

For the case of the livestock breeding industry, the sensor network technology using the forage containers with piezoelectric sensors was employed together with an automated system to calculate the amount of forage production. [2-3] The precision technology for agricultural products cultivated in greenhouses, remote sensing technologies to monitor growth of crops to predict production amount or to estimate acreage under cultivation, or the system regularly monitoring changes of organic carbon in soils have been commercialized.

Containers used for storage, distribution, or for sales of agricultural products have diversified specifications. Thus, making standardized types of container would be quite difficult.

In fields of agricultural products produced in factories, the standardization has been on its way depending on types of facilities introduced.[2] Currently, only the IT technology employed as a secondary application to the field have demonstrated tangible standardization.

Companies placed in the middle of supply chains of such products have been making efforts to normalize or standardize the processes of storage or distribution of such products and completed achievements. However, the industry-wide standardization for products of the primary industry has been reported that it would be impossible.

Thus in this study, the application of the system developed in this study by employing the sensor network technology to predict the production amount of agricultural products was limited to the case of application of PVC containers used for the storage and transportation of agricultural product in fruit farms.

Figure 1. Applied Sensor Tags & Communication Units

The hardware infrastructure employed in this study is as follows. The context aware sensor tags suggested in the reference [19] was used. Also, the systems of communication unit [20] and monitoring [14] employed in this study were all those suggested in existing references.

As illustrated in Figure 1, the PVC containers to be used in fruit farms and in storages were equipped with the context aware sensor tags. Communication units were installed in both the storages and farming sites. The information of distribution of agricultural products to be generated by 2 systems was designed to be integrated into the control system.

3. Empirical Experiments

For the empirical experiment conducted in this study, the developed systems were applied to both production sites (on open field) and low temperature storages of agricultural products. Figure 1 illustrates the overall diagram of the conducted empirical experiment.

A total of 4 on-site experiments on distribution of harvested peaches (once) and apples (3 times) were carried out with respective numbers of 100, 200, 300, and 400 of the containers for the transportation of fruits during the period of harvest and storage.

In order to ensure the stability of the application system, an internal operational experiment (laboratory test) process was completed in advance. In the test of sensor tags to be applied in the counting of the amount of distribution, 3 sensors were detected to be defective (1.5% of defective ratio) among the whole lot of 200 sensor tags tested.

Figure 2. Sensor Tags Prepared for the Test of Internal Operation

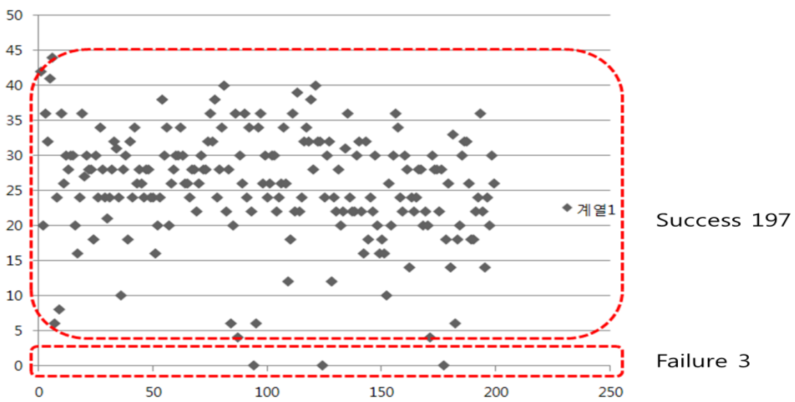

Figure 3. Results of Internal Operation Test of Sensor Tags

Figures 2 and 3 represent the results obtained from the laboratory test. Using the paper box, on which all subject sensor tags were attached to, acquired information of movement and operation of each sensor tag were tested. Figure 3 represents the results obtained from the test of operation of sensor tags. The vertical axis represents statuses of temperature and movement of sensor tags while the horizontal axis denotes the IDs of each sensor tag.

The First Site Experiment

The first site experiment was carried out at the Maehyeon-ri, Chungju city with 100 sensor tags attached on each distribution container of harvested peaches. The triangular sensor tag (of the type of hard-tag) was used for the experiment. However, the employed sensor tags have generated sensing errors attributable to each case of the sensor tags. Thus the sensor tags employed for the successive site experiments (after the secondary site experiment) were replaced with sensor tags taken from improved cases.

Figure 4 shows the data collector installed in the production sites and storages. Figure 5 shows the PVC container box equipped with the context aware sensor tags.

Figure 4. Data Collector Installed for the First Experiment

Figure 5. Sensor Tags Employed for the First Experiment

The Second to fourth Site Experiments

A total of 4 data collectors along with more than 600 sensor tags were employed in the second to fourth site experiments conducted in the harvest period of apples in the farm placed in Chungju city. Figure 6 shows the data collectors installed at the farm, and Figure 7 shows the PVC container with improved context aware sensor tags that fixed the flaws found in the first site experiment. Figure 8 shows the process of transporting harvested fruits to the storage through vehicles.

Table 1 summarizes the overall results obtained from all empirical site experiments, including the IDs of each container and statuses of received information. In case of the container of ID 4, the IDs represented through statuses of its storage and reception of information were unmatched. Thus, this was judged to be the case of an error.

In the second experiment with sensor tags counting the amount of distribution, more than 85% of the amount of distribution was identified. From the third and fourth experiments, the sensor tags attached on each box were placed un-inverted for a long time marking the sensing ratio over 93%. With a long duration of each box placed inverted, some of the attached sensor tags tended to stop respective operations. Thus, the improved sensor tags were employed in the fourth experiment.

Figure 6. Data Collectors Installed in the Farm

Figure 7. Sensor Tags Installed On Containers Used at the Fruit Farm

Figure 8. Agricultural Products Placed in Storage

4. Conclusions

In this study, the algorithm to calculate the production amounts of agricultural products, to be carried in PVC containers equipped with context aware sensor tags, were developed and tested by employing a sensor network technology.

The prediction model embedded the algorithm developed in this study revealed approx. 15% of the error rate attributable to errors in sensing of sensor tags together with errors of approx. 3~5% of deviated weights of products randomly loaded into each container.

With the results obtained from empirical experiments, it was estimated that the monitoring of agricultural products contained in each container could enable the prediction of the amount produced agricultural products. It was also estimated that, by minimizing the error rate through improving the function of sensor tags, the developed prediction model could be employed into practical applications.

Table 1. Results Obtained from Site Experiments Conducted to Count the Amounts of Harvested Agricultural Products

Box No.	October 28, 2013 Maehyeon-ri		October 29, 2013 Maehyeon-ri		Evening (29^{th})	Remarks
	Number of Box in Storage	Received box number	Number of Box in Storage	Received box number	Received box number	
1	1	1			1	
2						For tests
3	1	1			1	
4	1					
5	1	1			1	
6	1	1			1	
7	1	1			1	
8					1	
9					1	
10			1			
11	1	1			1	
12	1	1			1	
13			1	1	1	
14	1	1			1	
15			1	1	1	
16			1	1	1	
17					1	
18			1	1	1	
19	1	1			1	
20			1	1	1	
21	1	1			1	
22			1	1	1	
23	1	1			1	
24	1					
25	1	1			1	
26					1	
27			1	1	1	
28					1	
29					1	
30			1	1	1	

Box No.	October 28, 2013 Maehyeon-ri		October 29, 2013 Maehyeon-ri		Evening (29^{th})	Remarks
	Number of Box in Storage	Received box number	Number of Box in Storage	Received box number	Received box number	
101	1	1			1	
102	1	1			1	
103	1	1			1	
104	1	1			1	
105	1	1			1	
106			1	1	1	
107			1	1	1	
108						
109			1	1	1	
110						
111			1	1	1	
112						
113	1					
114			1			
115			1	1	1	
116					1	
117	1	1			1	
118						No products are left.
119						
120	1	1			1	
121						
122					1	
123	1					
124	1	1			1	
125	1	1			1	
126						
127	1	1			1	
128	1	1			1	
129			1	1	1	
130	1	1			1	

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