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Design and Implementation of Context Aware Sensor Tags for Distribution Measurement of Farm Products

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Abstract

This paper discusses the design and implementation of context-aware sensor tags that can be attached to various containers. The tags are designed to be utilizable in non-standardized fruit boxes, and can identify whether fruit has been loaded in a box because they are attached inside the box. After recognizing normal load status, data are sent only when there is content. The tags were designed and implemented to measure distribution by detecting the movement of the fruit box, and sending data through a context-aware function that determines whether fruit is loaded, and a data-transmission event; the tags also send data periodically, even when the fruit box is not moved

Keywords: *context aware, sensor tags, distribution measurement*

1. Introduction

Because of the advancement of information technology, progress has been made in the technology of many other fields. In addition, the importance of fusion technology and industry in different fields is increasing gradually. This trend is also found in the agriculture, fisheries, and livestock (AFL) industries, and when applied to the AFL industries, many fusion technologies have greatly influenced the advancement of primary industries, and increased productivity. For many years, studies related to AFL industries have been performed in diverse fields and manners, and particularly, studies for original technologies, such as seed improvement related to AFL products, have been the majority of the studies performed. This research trend continues today, and various attempts are being made to apply fusion technologies and gain synergy effects through this.[1-3]

Studies on distribution measurement in the agriculture field have also been performed in various ways for many years, and this indicates an importance of distribution measurement for agricultural products. Distribution measurement of agricultural products has been performed as a way of accomplishing various goals, such as production estimation of agriculture products, price trend forecast, and securing farm incomes.[4-6, 12, 13] This study is concerned with the implementation of context-aware sensor tags for achieving a goal of production estimation for agricultural products. In other words, it is a study on sensor technology as a fusion technology that can be used in the AFL industries.

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Sensor technology is applied in various fields for various purposes, and it is producing many positive results. The purpose of this paper is to design and implement a sensor with an embedded context-aware function in order to use it in the production estimation of agriculture products in the agriculture field. The sensor was designed to be usable in various non-standardized fruit containers, and it can identify whether fruit is loaded without causing inconvenience when loading fruit boxes because the sensor is attached inside the fruit box. Furthermore, after recognizing the normal load status of fruit, data are sent only when there is content under the normal load status. In addition, as a method for using the movement of fruit boxes for determining data transmission timing, a context-aware function from the sensor tags that determines whether fruit is loaded, detects movement and sends data; and even when the fruit box is not moved, the sensor is designed to transmit data periodically several times a day. As a result, the distribution measurement data that can occur from the movement of empty boxes are excluded. Based on the obtained data, fruit-loaded boxes are extracted, and based on this, not only is the production of fruit estimated, but also basic data are obtained to estimate agriculture product inventory and farm production capability.

2. Proposed System

2.1. Design and Object Recognition

The importance of designing sensor tags that can be attached to various containers used as the means for loading, storing, and moving agriculture products is recognized in many areas, such as user management convenience and function. In this study, a hard tag method is applied for attachment to non-standardized containers. The hard tag method has the following characteristics: arbitrary attaching/detaching is impossible because the tag is attached with a steel pin, and it can be used in containers of various materials, such as plastic fruit boxes, paper boxes, vinyl, and cloth. Furthermore, a sensor tag can be detached by a manager with a hard tag remover only, and it can be attached easily by inserting a hard tag pin.

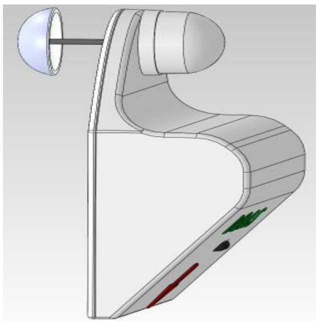

Figure 1. Tags

Furthermore, to avoid inconvenience when loading boxes from the management perspective, the sensor tag was designed to be attached inside a box in order to minimize damage or conflict between boxes when the boxes are loaded into storage; on the outside of the box, only a sensor tag attachment pin is present, thus minimizing conflict between boxes. The context-aware sensor tag was designed to have directivity to detect normal box load status. This refers to the case where a box is positioned in parallel; when a box is stacked or positioned in a different shape, it is determined to be an abnormal status. To detect such status, the sensor tag is positioned in such a way that the infrared projection is directed toward the bottom side in a standing state, as shown in Figure 2. To face the lower side, the sensor is attached as close as possible to the bottom of the box so that it does not rotate with the hard tag pin. To identify the existence of content inside the box (*i.e.*, to determine whether the box is loaded), an infrared detection sensor is embedded in the sensor tag. The detection range for the detection sensor is 5 cm, and it determines whether there is content by analyzing an infrared ray that is reflected when there is fruit or other content within the detection range.

Figure 2. Content Detection

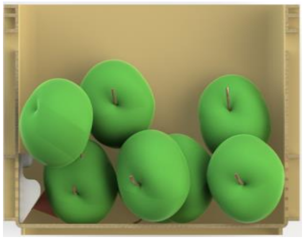

Figure 3. Normal Content Detection

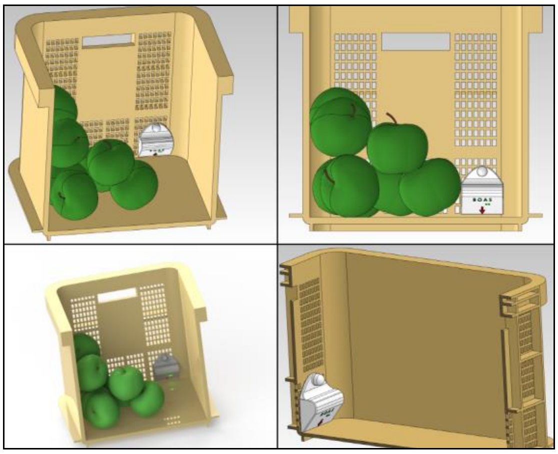

Figure 4. Examples of Applying the Sensor Tag

To adopt a low power operation method that reduces unnecessary data transmission in order to minimize the power consumption of the sensor tag, this study determines the status of the fruit box using the sensor tag. The status factors of the fruit box are its load status, existence/absence of content, and moving/stored status. The reason for determining the fruit box load status and the existence/absence of content is to transmit data by selecting normal fruit boxes that contain fruit; moreover, the reason for determining the box moving/stored status is to transmit data in short intervals when box is moving so that power consumption can be minimized by having minimal communication when the box is in the stored state. The movement detection method prevents unnecessary data transmission by determining whether a fruit box with a sensor tag attached is being moved, loaded, or stored after loading. With regard to the method for detecting the fruit box moving status, a movement detection method applied to the sensor tag is used. The detection method uses a high-sensitivity impact sensor embedded in the sensor tag, which becomes activated and determines movement when it is moved at constant speed in an up/down/left/right direction, or when there is an impact. The box status detection method prevents unnecessary data transmission by determining whether a fruit box with a sensor tag attached is in the normal load status. With regard to the method for detecting the normal load status, a tilting status detection method applied to the sensor tag is used. The tilting status detection method determines whether the infrared projection direction of the sensor tag faces the ground surface; if so, the fruit box is determined to be in the normal load or loading-waiting status.

The content detection method determines the existence/absence of content using the infrared detection sensor and analyzing the signals of the reflected infrared ray. The infrared sensor detection range applied to the sensor tag is 5 cm, and it can be adjusted as necessary.

2.2. Hardware Design

The design of the SRD RF, which is a wireless communication method, was performed using a 424 MHz narrow band frequency. For the block diagram, a CC1020 RF transceiver IC-applied module was used, as shown in Figure 5. The RF block diagram and basic specification are as follows.(Table 1) [7-11].

The 424 MHz wireless IC applied to the sensor tag can be used in various narrow bands, and provides low power operation. A maximum 10 dBm transmission output is possible, and the operating voltage is 2.3 to 3.6 V. The communication between main CPUs uses a four-wire serial communication method, and wireless data are communicated with separate data input/output (DIO) and data clock (DCLK). Each register setting and operation uses four-wire communication.

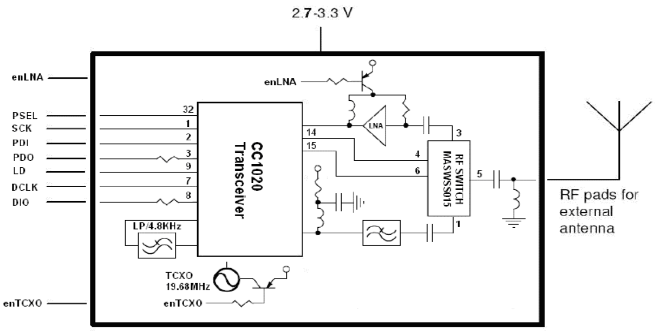

Figure 5. RF Block Diagram

Table 1. RF Specification

Parameter	Min	Max	Units
Supply voltage, VCC	- 0.3	3.6	V
Voltage on any pin	- 0.3	VCC+0.5 V	V
RF Input Power		10	dBm
Storage temperature	-50	125	℃
Operating temperature	- 30	85	℃
ESD(HBM EIA/JESD22-A114-A)		±3	kV , ANT terminal

The sensor tag circuit was designed considering power management efficiency with low power operation first, and sensor operation and wireless communication-related circuits were main design factors. The power source part was designed using 3.6 V primary battery, and a power source discharge alarm function was embedded to be able to predict the battery replacement time. The sensor detection circuit was designed to be able to compare measurement values of the infrared transceiver, and read the inclination values of the tilting sensors for pose awareness.

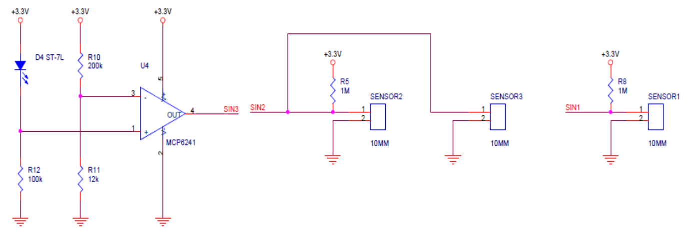

Figure 6. Sensor Detection Circuit

For wireless communication between external devices, a 424 MHz frequency band was used, and for minimal electrical current consumption, it was designed to communicate upon sensor detection completion, and at least once a day when sensor detection is not finished.

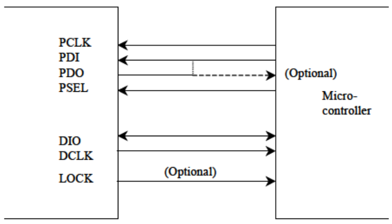

Figure 7. Communication between CPUs

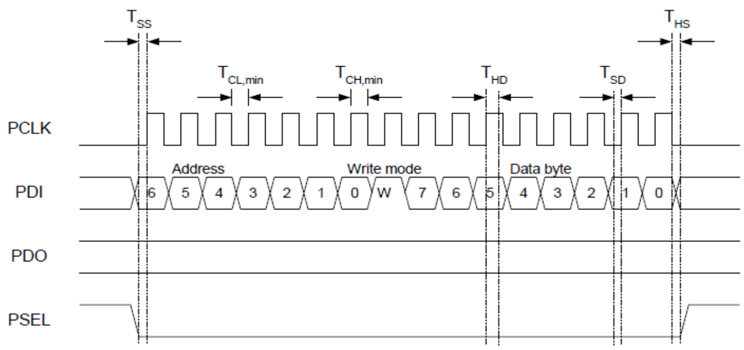

Figure 8. Register Setting

3. Implementation and Experiment

With respect to content and box status detection, it is confirmed that there are many causes for malfunctions. The material for the tested fruit box was plastic, and when a sensor tag was installed, misdetection of the box load status occurred because lateral movement of the sensor tag occurred. When the sensor tag moved to the left and right, movement that surpassed the reference angle was detected, and consequently, the sensor tag erroneously perceived the fruit box to be loaded while lying on the side.

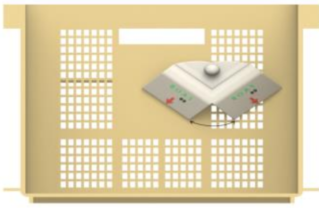

Figure 9. Sensor Tag Lateral Shaking

Furthermore, for the infrared detection part that identifies content, misdetection also occurred depending on the installed position of the sensor tag. When the attachment position of the sensor tag was at the bottom, there were cases where the sensor detected the bottom and determined there to be content. Such problem of content misdetection was determined to be caused by the protruding infrared sensor part of the sensor tag case that faces the downward direction.

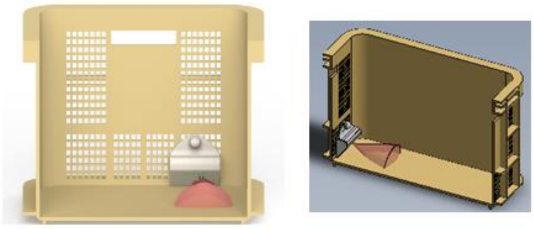

Figure 10. Content Misdetection

For the testing process, each function and program download were tested after finishing physical assembly. With regard to the program execution sequence, when the power source is impressed, firmware initialization is performed, and the input/output (I/O), universal asynchronous receiver/transmitter (UART), and timer designated to each port are initialized. In addition, a buffer allocated for the data storage memory is initialized. When the system becomes stabilized, each port is set up and data are read. When sensor data is input normally through the AD convertor in a stabilized range, the data are stored in the allocated buffer and transmitted through UART.

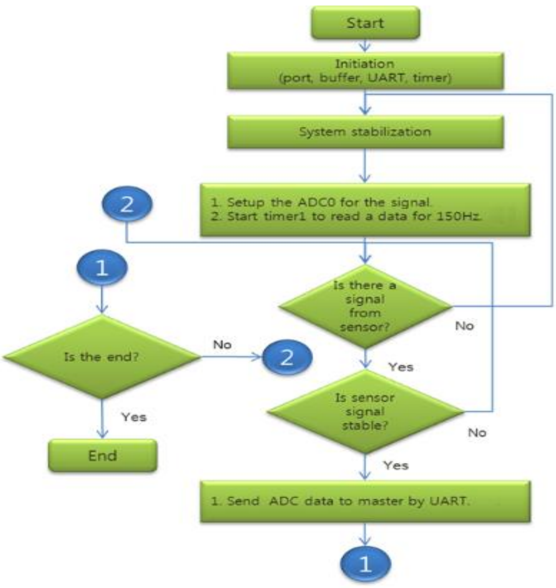

Figure 11. Firmware Flowchart for Sensor Tag

With regard to a method for testing the sensor tag where firmware is downloaded, joint test action group (JTAG) and UART were used. JTAG was connected to the sensor tag and the project was loaded. The implemented program was checked to determine whether it was operating normally, and when an error occurred, a debugging process for checking the respective I/O and register status was performed. While debugging occurred, the computer terminal checked whether the data sent from the device to UART was uploading normally.

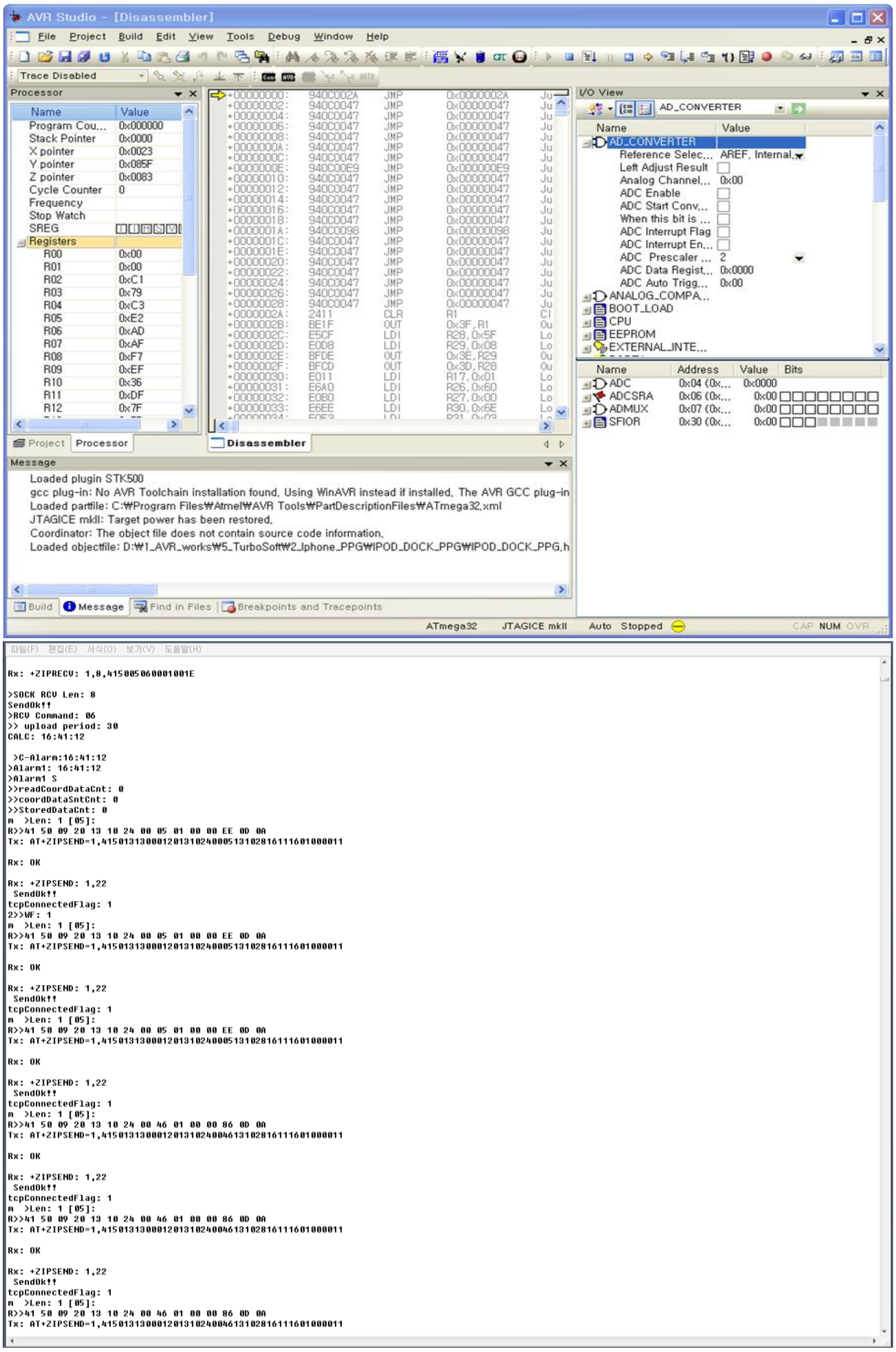

Figure 12. Debugging Screen

4. Conclusion

This paper discussed the design and implementation of a context-aware sensor tag for distribution calculation of agriculture products. By applying the proposed sensor tag to boxes loaded with agriculture products, the loaded/unloaded status of the agriculture products can be determined in producing areas, and the number of boxes loaded with agriculture products can be identified. Based on this, the distribution and production of agriculture products can be estimated. Through a field test of implemented sensor tags, we acquired 85% accuracy, and determined that higher accuracy can be obtained if a system enhancement process is performed. Furthermore, if many years of reference data are acquired, it should be possible to estimate the agricultural production of given farms.

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