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http://www.isarc2008.vgtu.lt/

The 25th International Symposium on Automation and Robotics in Construction

June 26–29, 2008

ISARC-2008

A GATE SENSOR FOR CONSTRUCTION LOGISTICS

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ABSTRACT
Construction logistics plays an important role to complete construction projects successfully. It is necessary to monitor incoming and outgoing resources by time phase. And it is very significant to notify immediately where the incoming material or equipment should go at especially large construction site according to site advantages of RFID, Zigbee, and CDMA technologies to communicate with incoming and outgoing equipments such as trucks, construction equipments in addition to worker's checking in and out at the construction site. The prototype system of Gate Sensor was developed and tested successfully at out laboratory. This paper will describe 1) the architecture of Gate Sensor, 2) the technological set up for the equipments to be recognized by GateSensor, 3) the laboratory tests process and results, and 4) expected potentials for further applications.

KEYWORDS

Site Logistics, Material management, RFID, Wireless Radio Communication Technology

1. INTRODUCTION

Construction logistics is one of the crucial parts for project success. To manage the logistics successfully, the materials should be delivered to the right place at the right time, and the inventory information and the on-site delivery status should be monitored in real-time. Currently, such information is collected manually, which is susceptible to inaccuracy and error in the collected data. Automated data acquisition for the monitoring the delivery information is therefore necessary to avoid the problem.

There have been more than a few past researches which attempt to utilize the RFID technology for monitoring the on-site material delivery activities. Most of them are constrained to some specific material types, rather than all the types needed in the site. Song [1] used RFID-equipped gates to capture the delivery information of incoming pipe spools. That system however used active-type radio tags, which turned out to be less feasible in terms of cost [2].

In this research, the authors developed a Gate Sensor System (GSR), which uses the passive-type RFID tags (to overcome the drawbacks of the active-type sensors) and the Wireless Sensor Network (WSN) technology based on Zigbee and digital wireless telephony and data network (i.e. the CDMA network). Pilot tests and on-site field tests were conducted for evaluating technical feasibility of our system.

2. THE VISION OF CONSTRUCTION SUPPLY CHAIN MANAGEMENT OF NEXT GENERATION

In the construction industry, various managerial theories, such as Just In Time (JIT) and Supply Chain Management (SCM) to name a few, have been introduced for managing logistics. Also, emerging technologies [3, 4] such as RFID have been explored for the logistics management, albeit their roles are rather limited.

The authors intend here to build an intelligent logistics management system based on RFID and WSN, which will bring the current practices of the construction logistics management to the next level in terms of efficiency.

As illustrated in Figure 1, our system collects delivery information from multiple locations using various sensor-equipped devices, such as pallets, trailers, hoists, etc. The collected data is then transmitted wirelessly via the gate sensor in real-time, allowing for uninterrupted data communication between the construction site and the materials warehouse.

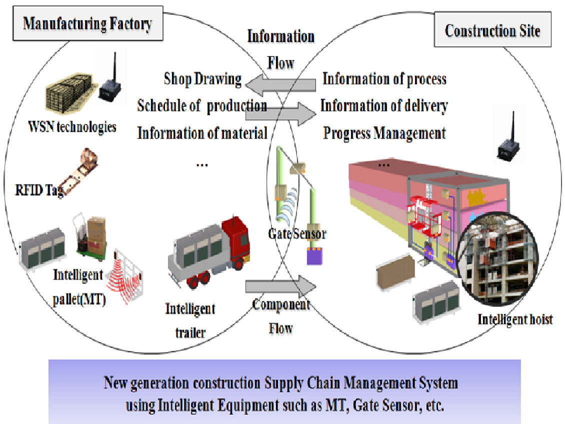

Figure 1. New generation Construction Supply Chain Management System

3. GATESENSOR PROTOTYPE SYSTEM

As previously mentioned, we have developed the gate sensor for real-time delivery status monitoring. When it captures RFID signals from the incoming materials (and their vehicles), it then sends the captured data to the logistics management server over the wireless sensor network, allowing data sharing between the project participants.

For feasibility study, we initially constructed a miniature model of the system. A full-scale system was then made later. The latter were tested for real-world applicability of the system using a real truck.

The gate sensor is composed of an RFID module (which is also composed of a reader and an antenna), a WSN equipment (for sending the collected tag data to the server), a crossing gate with an electric sign panel(for controlling the vehicle’s entry), a warning light (for wrong vehicles that are not allowed to enter), and a controller module for the sensor. Figure 2 shows the nomenclature of the sensor. Each equipment mounted on the sensor frame performs various functions such as identification, display, data transmission, etc., when the vehicle is approached to it. The detailed descriptions of those equipments are listed in Table 1.

The process of the sensor operation is as follows, which is also illustrated in Figure 3.

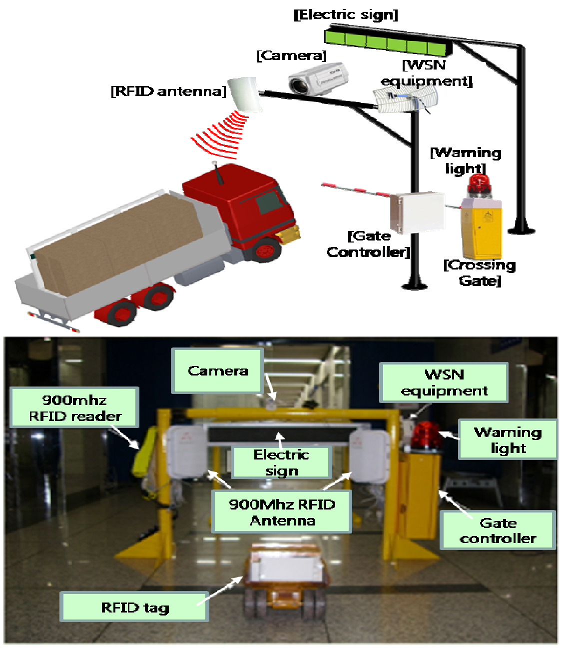

Figure 2. Prototype of GateSensor

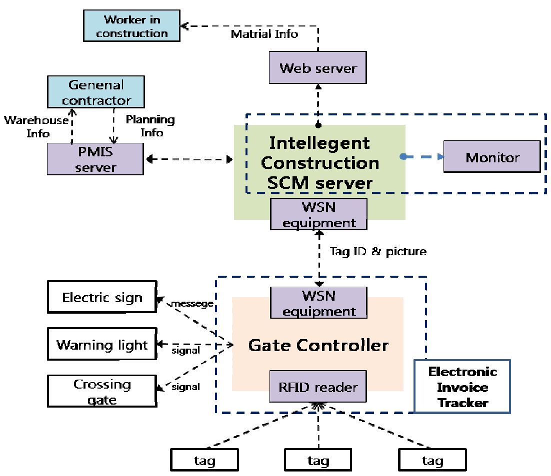

Figure 3. Data Forwarding Architecture

Table 1. Funtion of equipment

Gatecontroller	900Mhz RFID reader
	
Function : Store, processing, communication, control and display of data	Function : Information collected from Tag transmits to middleware
RFID antenna	camera
	
Function : Tag recognition of vehicle When Vehicle into Gate	Function : capturing a license number plate and materials loading state of vehicle into gate
Warning light	Electric sign panel
	
Function : warning Operation when Unplanned Vehicle is entry into a place	Function : display vehicle information and direction of vehicle
WSN equipment	RFID tag
	
Function : Gate Controller and intelligent construc-tion supply chain server communication equipment	Function : ID and data holding

1) When a trailer enters the gate sensor, it detects the electronic tag that is attached to the vehicle via the RFID antenna and receives data from it. The tag data contains the delivery information from the supplier.

2) The received data is temporarily stored in the gate controller until it is transmitted to the intelligent logistics server via WSN. The latency between data receipt and its WSN transmission is so short that the overall procedure is considered real-time.

3) At the logistics management server, the delivery data is compared with the planned delivery schedule stored in a separate project management information server(PMIS).

4) If there is no problem with the received data, the logistics management server sends appropriate orders (such as raising the gate bar and displaying the unload location) back to the gate controller

5) If the received data is wrong, the gate controller alarms the driver by flashing the warning lamp. The sign panel will display the 'do not enter' message.

6) The delivery information is available to the PMIS in real-time, which is accessible by various client terminals. For example, a general contractor may check the delivery status using her web browser. Also, a field engineer may use her wireless PDA or a cell phone to access the server as well.

4. PILOT & FIELD TEST

4.1. Pilot Test

A miniature model of the gate sensor was assembled to evaluate its technical feasibility such as (1) its RF sensor performance and maximum range, (2) feasibility of the vehicle entry control components, such as the warning lamp and the electronic sign board.

4.1.1. Test 1: sensor performance

Test 1 was conducted to evaluate the performance of the sensor's RF module.

4.1.2. Test procedure and the result

1) The miniature gate-sensor system was laid out as shown in Figure 4. A remote-controlled miniature test vehicle with eight sensors onboard was driven to the gate, and monitored the sensor to see whether it is able to pick up all of the eight tag signals.

2) Next, move the test vehicle from a distant location (enough for the gate sensor to lose the tag signals) toward the RFID antenna, to measure the maximum range of the tag signals (Figure 5).

Figure 4. GateSensor Installation and Recognition Test

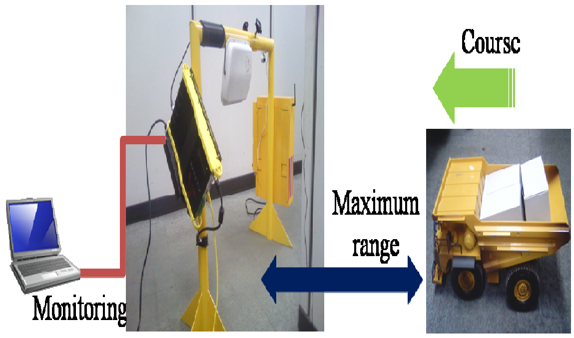

Figure 5. Maximum range test

As a result, the sensor was able to pick up one of the tags from 7 meters; within 4 meters, All of them are picked up stably.

4.1.3. Test 2: Control Equipment Test

Test 2 is to verify the function of equipment such as warning lights and electric signs, which is to control entering vehicles.

4.1.4. Test procedure and the result

1) Plan or non planned RFID tag material vehicle enters GateSensor.

2) RFID antenna identifies the vehicles tag.

3) If a planned tag, like Figure 6 the electric sign panel will show the vehicles information and process course.

4) Like Figure 7, which is a non planned tag, the warning light goes off and a 'Do not enter' signs shows.

Figure 6. 'Enter' Message

Figure 7. 'Do not enter' message

There was not one malfunction for the warning light and the electric sign panel on both circumstances during the Material Control Test.

4.2. Field Test

For the field test a life size model mock up GateSensor was made to test on a actual construction site.

4.2.1. Recognition Test Outline

The recognition possibilities gained through the pilot test were now tested through a field test on a life size truck and GateSensor.

4.2.2. Procedure and Result

1) Figure 8 shows GateSensor set up at a entrance of a construction site.

2) On the frame of GateSensor are a RFID reader, 4 antennas, a camera and a electric sign panel.

3) On the dash board and front window of the vehicle positioned a RFID tag and monitored the results (Table 2).

Figure 8. Field Test

Table 2. Test Results

case	1	2	3	4	5
Dash board	O	O	X	X	O
	6	7	8	9	10
	O	X	O	O	O
	11	12	13	14	15
	O	O	X	O	X
	16	17	18	19	20
	X	O	O	O	O
Wind shield	O	X	O	O	O
	6	7	8	9	10
	O	O	O	O	O
	11	12	13	14	15
	X	O	O	O	X
	16	17	18	19	20
	O	O	X	O	O

The test was run 20 sets and even when the RFID tag was placed within the vehicle there was no problem reading it. However 6 times (30%) on the dash board and 4 times (20%) on the front window were unrecognizable.

This was caused by the placement of the tag and antenna, which suggests to get 100% would need more tests.

5. CONCLUSION

Studying about the next generation intelligent delivery system, of material control in and out of a construction site and real time update on information, lead to the development of GateSensor.

Also through pilot and field test confirmed the technological possibilities. Test results suggest that through GateSensor material management and traffic control is possible.

Still, field tests also show that the placement of the tag affects the recognition rate.

Future studies and test will be on the placement of the antennas and tags to maximize the RFID tag recognition to 100%. Furthermore from the idealized test results field test will be preformed to test the application of GateSensor on real sites.

6. ACKNOWLEDGEMENT

This research (Grant No. 2006 R&D D1603) is financially supported by the Korean Institude of Construction and Transportation Technology Evaluation and Planning(KICTEP).

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