Theme:

Title: **An On-Site Inspection Support System Using Radio Frequency Identification Tags and Personal Digital Assistants**

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Abstract: *Inspectors of buildings including power plants have to carry a bulk of documents and drawings to perform their tasks, otherwise they have to memorize extensive knowledge and data about the structures and facilities. Thus, a light and handy IT solution system for supporting inspectors is desired. In this research, we propose and develop a prototype on-site inspection support system. This system consists of a RFID tag system, a PDA connected to the Internet, a voice input/output system, and a digital camera.*

In our approach, senior inspectors' knowledge such as advices and warnings regarding each facility and structural member for inspection is input to RFID tags via voice at the site as if the inspector is teaching a junior inspector. And each RFID tag is glued to the facility or member. A junior inspector can obtain such valuable knowledge later on when he or she inspects the building alone from the reader-writer and PDA system. This system will enable senior inspectors to transfer their expertise that can be excited only at the site to a knowledge system. The information in the RFID tags can be altered or augmented when necessary.

RFID tags can carry not only inspectors' advices and warnings but also the ID, main feature and recent inspection data of each facility or member. The inspector can have access to the corresponding drawings, specifications, data of testing, etc. from the ID of the RFID tag by the PDA. When more information is needed, the inspector can get information by the PDA from the headquarters databases via the Internet.

The sound input system can be used to record sounds of various machines such as generators, compressors, sirens, etc. and the recorded sounds can be analyzed and evaluated on site by this system. Digital photographs can also be taken and stored in the database and compared with the previous ones for inspection purposes.

Keywords: *RFID, PDA, Knowledge Management, Inspection, Human Computer Interaction*

Introduction

Inspection during construction, operation and maintenance of buildings including power plants is an important task to maintain the structures and facilities safely and economically for a long time. To fully perform their tasks, inspectors have to carry a bulk of documents, drawings, and measuring equipment and they also have to record all measured data and notices unless they memorize various aspects of the buildings and facilities. But the amount of things they can carry and record is limited in practice.

The quality of inspection depends on the inspector's experience and knowledge. In order to make appropriate decisions when something unusual is noticed, extensive experience and knowledge are necessary. Thus, inspectors usually work in pairs, an experienced and an inexperienced. However, due to the pressure of cost reduction, it becomes difficult for building maintenance companies to make a pair and only one inspector has to work at a time recently. This may cause uneven quality of inspection and may hinder handing over the knowledge of the experienced to the inexperienced. And if the previous inspector is different from the current inspector, it would be difficult to compare the current data to the previous one correctly when something unusual happens.

For these problems, one solution would be to develop a compact, easy-to-carry, and heavy-duty device to support inspectors, and the other would be to develop a framework to retrieve knowledge from experienced inspectors and to store it in the knowledge base so that it can be used for inexperienced inspectors. So far, a handheld touch-screen computer has been adopted for a commercial bridge inspection system[1]. In the research field, Garrett et al.[2] proposed using wearable computers to deliver data and knowledge-based support to field inspectors. Mizuno et al.[3] used cellular phones and wearable computers to provide interactive knowledge-based support for visual inspection. We proposed an on-site inspection system by using radio frequency identification (RFID[4]) tags, a three dimensional product model, and a voice input/output system[5].

In this research, we have expanded our previous research and propose a new system model for supporting on-site inspection of buildings and facilities by using and combining information technologies (IT) including RFIDs, voice input/output, wireless Local Area Network (LAN), the Internet, and knowledge management by using VoiceXML[6] (Extensible Markup Language). We describe the proposed system model and the prototype system in this paper.

Outline of the Proposed System Model

The outline of our proposed system model is shown in Fig. 1. In our system model, a field inspector carries a personal digital assistant (PDA), a cellular phone, and a digital camera. The PDA can be a wearable computer or a handheld computer. But most PDAs are easy to use and commercially and widely available currently. In our system, the PDA has a "reader-writer," which can read and write information in RFID tags. The PDA has a microphone and a speaker so that the inspector can record his or her voice and some sound of a machine, etc. and reproduce the voice and sound. The PDA can equip a PC card of wireless LAN so that the inspector can have access to the local server at a local office and servers in research institute and the headquarters via the World Wide Web (WWW). Thus, the inspector can send data such as strange sound, a digital camera photograph, and measured data to the appropriate office in order to obtain technical support. If the information contained in the RFID tags is not sufficient, the inspector can retrieve various advice and information stored in the knowledge base in the VoiceServer by using the cellular phone conversationally.

A Knowledge System

An Advice System Using RFID Tags

The RFID system consists of an RFID tag, a reader-writer, a computer, and data input/output software as shown in Fig. 2. The tag contains a small integrated circuit and an antenna, and is encapsulated in a protective shell[7]. The reader-writer contains an antenna, a transceiver, and a decoder. The reader-writer emits radio waves, and when an RFID tag passes through the electromagnetic zone, it detects the reader-writer's activation signal. The reader-writer decodes the data encoded in the tag's integrated circuit and the data is passed to the host computer for processing[4]. Since the ordinary reader-writer is too large to carry for inspection, we have developed a small reader-writer that can be attached to a PDA as shown in Fig. 3.

As described previously, inspectors have to work alone recently and thus, less experienced inspectors cannot obtain necessary advices and warnings regarding each facility and structural member from senior experienced inspectors who used to work in pairs. Our approach is to acquire such important knowledge at the site from senior inspectors by interviewing and record each of their advice in an RFID tag and paste it at an appropriate location. A junior inspector can obtain the advice from the tag later on when he or she inspects the facility.

For a long time, researchers and engineers have been claiming the difficulty in knowledge acquisition for developing expert systems. We believe that most inspectors may not think of or recall good advices and warnings if they are interviewed sitting in an office. On the other hand, we observe that their knowledge is excited when they are working at a site or facility, especially when they are training their young co-workers. Thus, this methodology will enable senior inspectors to transfer their expertise to a distributed

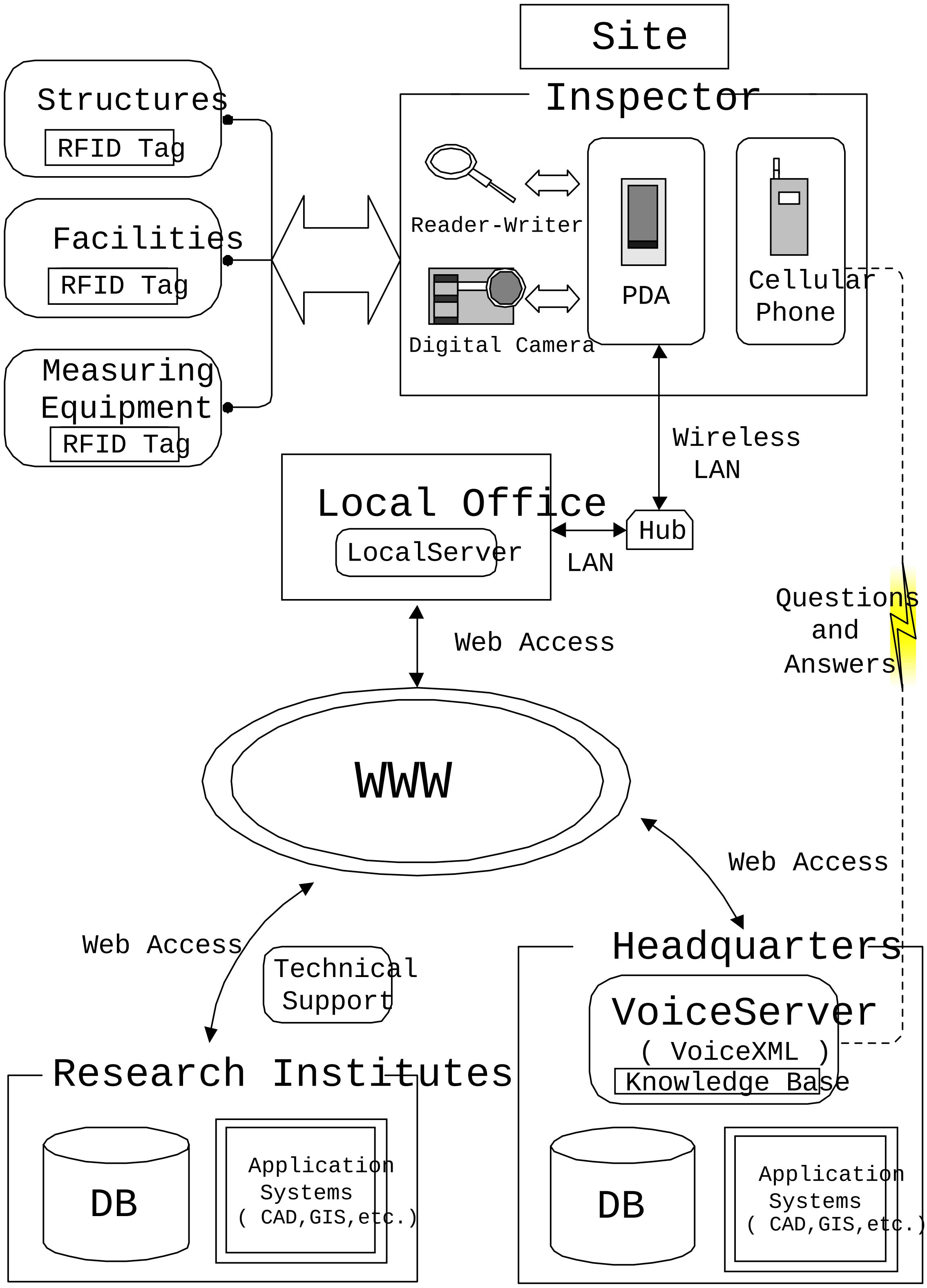

Fig. 1 Outline of the System Model

knowledge system, i.e., RFID tags. The advice or warning can be shown as a message on the PDA screen as shown in Fig. 4 The advices can be displayed on the screen and can be heard as voice as well.

Knowledge Management System Using VoiceXML

Knowledge management is development and utilization of a technique for acquiring, storing, and utilizing individual knowledge and intellectual properties in an organization in order to improve efficiency and leveraging values. Knowledge management involves merging explicit knowledge such as data and information and implicit knowledge such as know-how possessed by individuals to create new knowledge for better performance of an organization.

Since both amount and organization of knowledge stored in RFID tags are limited, more sophisticated methodology is necessary for knowledge management. It is still difficult to carry a large knowledge base system in a PDA due to the limited amount of memory and computing power. It would be suitable for inspectors to access a knowledge system in the headquarters from the PDA via wireless LAN or some other device. We have selected a cellular phone and VoiceXML, as shown in Fig. 5.

VoiceXML is a Web-based markup language for representing human-computer dialogs utilizing audio input/output, or a voice browser, instead of a graphical web browser[6]. A user can communicate with a computer through VoiceServer by utilizing VoiceXML and a telephone. VoiceServer is software that corresponds to human voice automatically and provides audio output as forms of reproducing a recorded voice file, playing a live audio source, or reading a text file aloud automatically. The apparent benefit of the VoiceXML technology includes releasing hands and eyes free for communication with computers. A part of the VoiceXML code for inspectors is shown in Fig. 6. An inspector can call the VoiceServer by a cellular phone and retrieve necessary knowledge and advice by asking or answering questions verbally.

In our system, when an inspector finds something new or thinks of a new idea, which is worth of storing, he or she can record the information in the knowledge base in the VoiceServer. Then, a knowledge engineer renews the knowledge base to improve the performance and leveraging the values of the organization's intellectual properties and inspection quality.

Fig. 2 RFID System

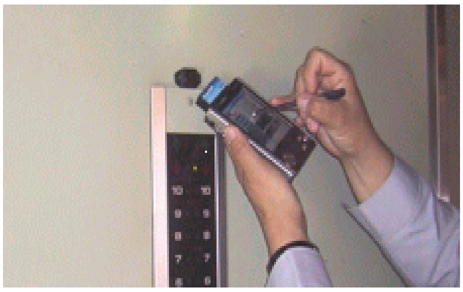

Fig. 3 RFID Tag and PDA with Reader-Writer

Inspection Database

Each RFID tag attached to a facility or a structural member can contain not only advices and warnings but also feature of the facility, inspection notes, measured data, etc. The amount of memory of the RFID tag we used in our research is 256 bytes. But the memory can be extended to 3 MB if we attach a battery and a MPU to the tag. Since the PDA has an access to the WWW via wireless LAN, very large amount of data can be stored in the local server and WWW. And the PDA can store some amount of data. The issue is where and what information should be stored.

One extreme case is to store only the ID data in RFID tags and to store all data in the server. The other extreme case is to store all the data in RFID tags locally and not to store any data in the server. The former case may be called the "central server method" and the latter may be called the "distributed memory method." And the case in between may be called the "PDA method." The apparent drawback of the central server method is that the inspector cannot get any information if the LAN is not working due

Fig. 4 Ascreen Shot of a PDA, Showing an Advice

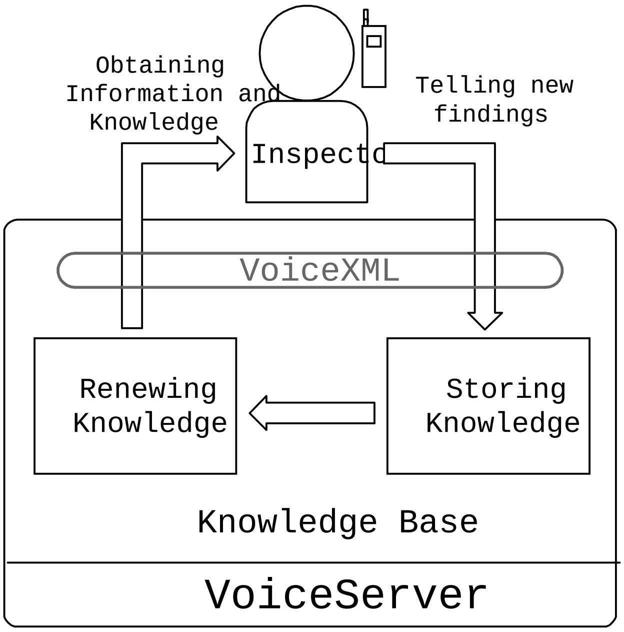

Fig. 5 Knowledge Management System by Using VoiceXML and a Cellular Phone

to a failure or disaster such as an earthquake. But the data consistency can be maintained easily. On the other hand, the distributed memory method is very expensive and users cannot get any information unless they walk to the location where RFID is installed, although it works even when LAN is not working. We investigated the cost, efficiency, availability, advantages and disadvantages of these methods, and we have concluded that the "hybrid method," which is a combination of the central server method, the distributed memory method, and the PDA method, would be most suitable for practical purposes.

In the hybrid method, RFID tags contain basic data about the facility or member, such as the ID, main feature or specification, inspection procedures, latest measured data, latest inspection notes, etc. The PDA contains measured data, digital photographs, digital sounds, information about inspection routes, etc. The LocalServer in the local office contains all the inspected data, document and drawing files.

The hybrid system, which utilizes appropriate memory storage systems for various purposes, enables the following:

- Improvement of both common and emergent measures by storing inspection management and recent inspected data at a site,
- Improvement of inspection quality by storing inspection procedures at a site,
- Improvement of support for inspectors by providing ways to connect their PDAs to the server,
- Improvement of reliability and speed of inspection and data management.

The sound input system can be used to record sounds of various machines such as generators, compressors, sirens, etc. and the recorded sounds can be analysed and evaluated on site by this system. Digital photographs can also be taken and stored in the database and compared with previous ones for inspection purposes. Fig. 7 shows a screen shot of the PDA displaying a photograph of a concrete crack and its width.

Conclusions

In this paper, we proposed an on-site inspection support system model utilizing RFID tags and PDAs, and we developed a prototype system of the model. In our system, RFID tags are used for storing not only inspection data and procedures but also senior and experienced inspectors' advices and warnings. VoiceXML and cellular phones are utilized for knowledge management in order to improve the quality and efficiency of inspection. We intend to expand this system model by using a new PDA that has a cellular phone function in it, and by incorporating decision making strategy, and by developing a sophisticated sound and image analysis system.

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<?xml version="1.0" encoding="Shift_JIS"?>
<!DOCTYPE vxml PUBLIC "-//Nuance/DTD VoiceXML 1.0b//EN" http://voicedml.nuance.com/dtd/nuancevoicex ml-1-2.dtd>
<vxml version="1.0">
 <form id="reply">
  <block>May I help you?</block>
  <field name="select">
   <prompt>Tell me your location.</prompt>
     <grammar src="REPLY.grammar#Reply"/>
     <catch event="help">
     Tell me the ID number of the RFID tag□</catch>
   </field>
   <filled namelist="reply">
      <if cond="reply=='one'">
       <prompt>No.1.Right?</prompt>
       <goto next="#buzai"/>
       </if>
     </filled>
```

Fig. 6 A Part of an VoiceXML Code

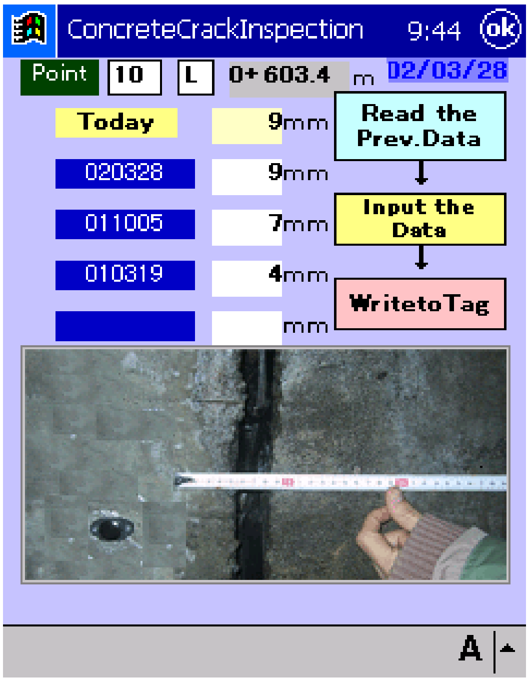

Fig. 7 A Screen Shot Showing a Photograph of a Concrete Crack

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