Using Ontology and RFID Technology to Develop an Agent-based System for Campus-safety Management

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***Abstract*—This study proposes a distributed multiagent system combining radio-frequency identification press (RFID) technology with an ontology for real-time monitoring in support of dynamic campus-safety management. Safety management on campus typically involves relevant supporting measures and manuals, but serious safety-related incidents continue to take place on campuses. The goal of campus security should be to identify an incident and resolve it effectively and in real time before the incident evolves into an actual crisis. Our purpose here is to improve the traceability of students involved in campus activities—that is, to identify students' whereabouts throughout the entire school day. When an incident occurs, our system will notify the relevant parties immediately. In the present study, the agents real-time event processing increases their situational awareness and reduces the likelihood and the severity of unwanted outcomes.**

Keywords- multiagent system; RFID; campus-safety management; real-time event processing

I. INTRODUCTION

Campuses should provide students with educational activities, and safety on campus is fundamental to all education. Safety incidents occur year after year, resulting in injury to students. To enhance the management of campus safety, schools should consider real-time monitoring of the campus environment. In recent years, campus-safety issues have garnered considerable attention, some of which has taken the form of studies on campus-safety technology. Many studies have integrated information technology into campus-safety management. In [5], the authors explored the relationship between communication technology and campus safety, and presented some ideas about early-warning mechanisms. In [3], the authors proposed an intelligent campus-safety tracking system using radio-frequency identification (RFID) and Zigbee technology. In [13], the authors proposed an innovative application for RFID systems in special-education schools. RFID technology is an important tool in many fields of study. In [11], when the RFID tag cost is very small, employing the RFID technology yields an improved larger expected profit and smaller risk. In [9], the authors developed an application system using contactless IC card and RFID reader related to the improvement of the campus safety protection. RFID middleware is one of the main research areas in the field of RFID applications in the near future [1]. We have been using agent technology to solve RFID middleware overloading problem. Our system uses artificial intelligence techniques to learn and automate certain processes. Many experts found that characteristics of intelligent behavior do not rely on individual agents that can be generated. According to researchers in the cognitive sciences [2], agents use mechanisms that facilitate communication and cooperation. Agents interact with one another in networks' open environments, and in this type of scenario, two conditions must be met: first, agents must be able to find one another [7]; and second, agents must be able to interact with one another. To permit interactions among multiple agents [8, 10], designers must give the agents a common language and rules. In [4], the authors developed a conceptual framework based on multi-agent systems and ontology technology in order to create a virtual observatory with semantically enriched web services. In [6], the author proposed an ontology-based and rule-based relevant learning objects discovery.

The purpose of this paper is to improve the traceability of campus-safety management systems on the basis of RFID technology and ontology technology. We propose an agent-based system for tracking students during campus activities, thus permitting knowledge of students' whereabouts throughout the entire school day. Our system would help school staff monitor many types of situations in schools. This paper's focus is on how to utilize ontology-based campus-safety management for multi-agent systems. We explore campus-safety management problems associated with imported multi-agent systems. Our proposed system should strengthen campus safety. This paper is organized as follows. Section 2 describes related problems and presents a scenario analysis. Section 3 describes the agent-based system's design using ontology and RFID technology. Section 4 presents the actual implementation and evaluation of the proposed system. The final section presents our conclusions.

II. PROBLEM STATEMENTS AND SCENARIO ANALYSIS

A. Case study

We discuss campus-safety management at the Tainan School of Special Education in Taiwan. According to the

 ISBN: 978-1-61208-273-8

inspection results regarding to our campus visits, most of the students studying in Tainan School of Special Education have multiple disabilities. Therefore, we take the situation of students with special needs into consideration and let them know how we can assure a safe-learning environment. In this paper, we first surveyed the whole campus environment and some areas where students' activities take place. From our survey, we can understand the students' everyday life at school during the whole school days. We then analyzed the findings, paying particular attention to student-safety incidents associated with specific areas on the school campus.

B. Problem statements

The Tainan School of Special Education in the past only installed surveillance camera at specific fixed points. Students were particularly prone to damage in such dangerous areas as restrooms, where the school had installed emergency call buttons that maybe could not provide immediate assistance. After the occurrence of safety incidents on campus, school staff began discussing in greater depth various issues related to possible improvements in accident-prevention mechanisms. Relying on just one specific surveillance camera is difficult to monitor students' activities. If we want to track the current state of the students on campus, it is a really difficult task. When school staff traced the cause and whole story of the incident, they might not reach an accurate conclusion. In this case, school staff doesn't seem to figure this accident out in the meeting hence it is inevitable that the similar accident may happen again in the future. Once we fail to guarantee a safe campus environment where the students' activities take place, it will result in the inefficiency of campus safety protection. If we do not really realize the reasons causing dangerous accidents, it may result in very serious consequences regarding to the maintenance and operation of the follow-up campus safety issues. We will find out the potential safety problems, which make the maintenance of campus safety and operational efficiency too low when we survey a safe-learning environment issues in school.

C. Scenario analysis

We developed several scenarios regarding campus-safety management service by using RFID ubiquities technology and ontology.

- Student-tracking management service

In the classroom, this service can accurately determine student's identity, while recording students attend status information. If students have not yet entered a classroom after the start of class, the teacher should immediately track the location by using RFID technology of the students.

- Dangerous-area warning service

When students enter danger zones, the proposed system can immediately determine the students' position and identify the pertinent characteristics of real-time situations. Then the system can inform guards that students are to be removed from the danger zones.

- Body-temperature monitoring service

An RFID tag can measure the student's body temperature that it can also measure the indoor temperature. Each student wears an RFID tag which has an important function measuring body temperature on the wrist. When students into the classroom after 20 minutes, this service can accurately determine student's identity, and began to measure the student's body temperature up to 5 minutes average temperature.

- Mobility-impairment assistance service

When mobility-impaired students wear RFID tags into the restroom after the system accurately determine the student's identity, the system will start record time of students into the restroom. If a student stays in the restroom for a long time, the system will automatically determine the student in the restroom for unusual events. Then this service will inform school staff go to the restroom and confirm the status of the students.

- The school-bus roll-call service

The school bus is identified through GPS positioning. We set up an RFID reader in the school bus. When a student goes to school by school bus, he only must access the bus. If a student by school bus after school, he only must leave the bus. A teacher will connect to RFID reader using mobile phone's Bluetooth. Therefore, once there are any students fail to catch the bus on time, the only thing that the teacher on the school bus has to do is report the abnormal situation to the school's back-end management system via 3G mobile phone.

- Extracurricular-education roll-call service

The teachers should be able to keep abreast of the location and the status of the students during extracurricular-education events. Therefore, the teacher should use a dynamically configured RFID reader and a wireless access point to communicate over wireless networks so as to judge students' status. When a student's RFID tag signal disappears from a monitoring range, the system will send a message to teachers' PDA, and then the teachers can find the student according to the student's final position.

III. AGENT-BASED CAMPUS-SAFETY MANAGEMENT SYSTEM

We propose an agent-based system for the management of campus safety, and use RFID devices to determine students' identity and location on campus. We also use ontology to provide for efficient communication among agents.

A. Analysis of the proposed system

We have tried to design an agent-based campus-safety management (ACSM) system, and in this endeavor, we have used RFID technology to solve campus-safety issues. Figure 1 illustrates our proposed campus-safety information system. Part one of this paper discussed deployment of RFID systems in campus scenarios, with particular regard to data collection and transmission systems. We summarized students' behavior patterns in different types of scenarios. These RFID readers can cover a wide range of student activities, including off-campus education and recreational activities. The gateway interface would be responsible for real-time data collection and transmission. In part two, we will discuss how our proposed information system integrates RFID technology into ACSM systems. We developed the RFID monitoring system to aid students at an assisted-living facility during the school day. The system displays students' location and other pertinent information via a web interface. The system uses active tags to communicate with a number of fixed active readers. The early-warning system is a component of real-time monitoring and recording of data in a campus environment. The early-warning system would involve the transmission of automatic alerts and real-time information to appropriate personnel. In part three, we will discuss software and hardware features of database system with RFID middleware. In part four, we will discuss automatic early-warning information systems, which can alert parents, teachers, system administrators, and other school staff of potential problems.

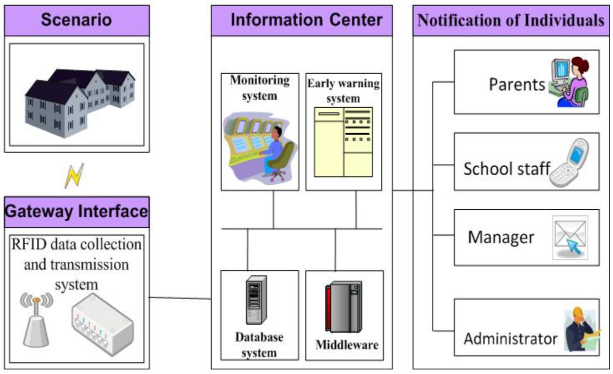

Figure 1. Campus-safety information system.

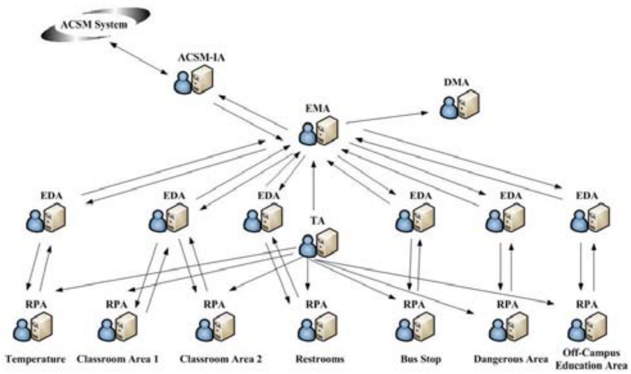

Figure 2. Multi-layered agent system

B. Multi-layered agent system

The multi-layered agent system can be observed from two perspectives. The first one involves individual agents playing their own role, while the second one involves the interactions of all agents with one another. If one agent requires the assistance of another agent in order to achieve a goal, then we can say that a relationship of dependence exists between the two agents. Agents need to take requests from and communicate the results back to school staff. Our aim is to help multiple agents collaborate intelligently and effectively with one another, so that they can provide immediate assistance to students in campus environments. We designed the proposed system on the basis of the multi-layered agent model shown in Figure 2. We define six types of agents, as described in the following bulleted points.

- RFID Process Agent (RPA): We have deployed an RPA in classrooms, restrooms, bus stops, dangerous areas, and off-campus education areas. The RPA is responsible for gathering all the information in these zones. This agent is deployed in each region. Combining an RFID reader with middleware on a local PC facilitates the real-time monitoring of students' temperatures. After collecting information about students' status, the RPA sends the information to the event-decision agent (EDA).
- Trace Agent (TA): This agent is responsible for monitoring the operating status of the RPA. The TA will continue to detect whether the RPA is engaged in normal operations or not. The TA will report the actual situation of the regional RPA to the event-management agent (EMA) at any time.
- Event-decision Agent (EDA): Every region of the campus has an EDA. When the EDA receives information collected from the RPA, the EDA will be responsible for analyzing this information to determine whether the students' independent behavior is normal or abnormal. The EDA will make use of the appropriate decision-making mechanism, and at the same time inform the responsible units in the region. The EDA will process independent events, and will then process the results and send them to the EMA.
- Event-management Agent (EMA): This agent plays a role in coordination and communication with several different agents. The EMA will receive all campus information from TAs. The EMA is also responsible for receiving each region's EDA decision-making

 ISBN: 978-1-61208-273-8

event results and for managing all events. The EMA will notify the agent-based campus-safety management interface agent (ACSM-IA) while EMA stores event-related information in the database-management agent (DMA).

- Database-management Agent (DMA): The DMA is responsible for records all the event process results. The DMA also conducts database management and provides queries for specific events that match a specific criterion.
- Agent-based Campus-safety Management Interface Agent (ACSM-IA): This agent serves as an interface to the ACSM system.

We have used the model of the block-like representation of interactive components [12] (BRIC) to build and simulate the behaviors of a multi-layered agent system. We have also used the BRIC model to characterize agents' internal status and agent–agent interactions. We will describe agent modeling because the internal structure of event-management agent is more complex than the internal structure of other agent types. Figure 3 illustrates the BRIC model for the EMA, and TABLE I describes in details the agent modeling to the EMA. In the BRIC model described in Figure 3, one symbol denotes 'Input/Output' representing the relationships between agents and their environment while the other symbol represents the agent's internal mechanisms and actions.

C. *Agent-ontology model for an ACSM system*

It is important for agents to interact with one another on campus. In our multi-agent environment, agents need to exchange results with one another. We use ontology in order to knowledge sharing agents' establishment of effective communication in a multi-layered agent system. For our current study, we began the ontology-modeling phase by conducting an extensive case analysis of campus scenarios.

This study proposes a campus knowledge base (CKB) design for ontology modeling and implementation. The CKB defines a new efficient and flexible resource-ontology model able to be immediately applied to multi-agent environments. Organization of a hierarchical CKB is illustrated in Figure 4. The CKB maintains all campus data in semantic storage. These resources are available to agents, and can help agents maintain the safety of campus activities. The ontology of data collection and transmission supports efficient data collection, transmission, and management.

Events ontology deals with real-time incidents. An event must have location information, an event time, agent information, event-trigger factors, and student identifications. Our rules ontology plays a key role in the hierarchical architecture of agents' coordination of accident-prevention mechanisms and communications with other

TABLE I. DESCRIPTION OF A BRIC MODEL FOR AN EVENT-MANAGEMENT AGENT

P01 Receiving data from an event-decision agent
P02 Processing data
P03 Creating an event-management agent based on campus information
P04 Initiating an event-management agent with log information
P05 Dispatching an event-management agent to an agent environment
P06 Receiving requests from a trace agent
P07 Evaluating requests from a trace agent
P08 Sending requests to an ACSM-IA agent
P09 Receiving feedback information from an ACSM-IA agent
P10 Consolidating feedback information from an ACSM-IA agent
P11 Sending consolidated feedback to a database-management agent
P12 Receiving requests from an event-decision agent
P13 Evaluating an event's priority
P14 Sending requests to a database-management agent
P15 Receiving feedback information from a database-management agent
P16 Evaluating information from all sources
P17 Sending results to an ACSM-IA agent

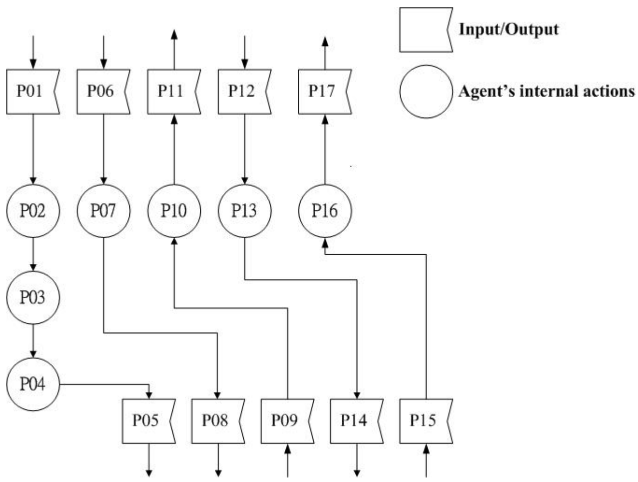

Figure 3. A BRIC model of an event-management agent

agents. Environmental ontology deals with the definition of the roles and behaviors corresponding to agents in charge of executing resource-related tasks.

IV. System design and implementation

In order to validate the proposed system architecture, we tested various scenarios which the students may encounter in Tainan School of Special Education. In this paper, we discussed the implementation of a system, including different scenarios for the subsystems and hardware devices and clear demonstration for the proposed system design.

A. *Development environment*

The development environment for the prototype system is described below:

- Operating Systems: server = Microsoft Windows Server; client = Web-based operating system.
- Backend Database Server: Microsoft SQL Server.
- Application program: Microsoft .NET Framework, ASPs (Active Server Pages), PHP (Hypertext Preprocessor), J2EE technology stack.
- Frontend RFID Middleware Server: Windows Server.
- Frontend RFID Application Server: Windows Server.
- WiNOC (Wired/Wireless Network Operations Center.
- RFID tag: 2.45GHz Active RFID tag. RFID reader: 2.45 GHz Active RFID reader (shown in Figure 5).

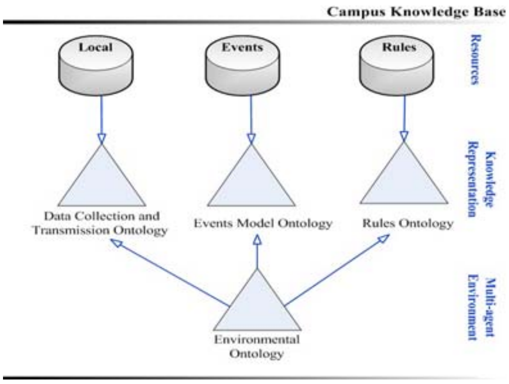

Figure 4. Organization of a hierarchical campus knowledge base

Figure 5. RFID reader and tag

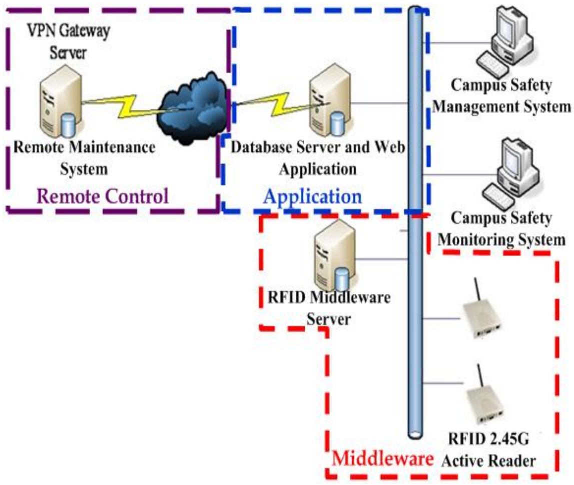

Figure 6. RFID system for campus safety

B. *System implementation*

This paper presents an integrated information system that real-time monitoring in support of dynamic accident-prevention mechanisms. Our research in an agent-based system is built upon a Java Agent Development (JADE) framework. JADE involves a set of agents that execute tasks and interact with one another by exchanging messages according to FIPA specifications governing the agent communication language (ACL). The agents work collectively to achieve common goals in a JADE environment. JADE simplifies the implementation of the multi-layered agent system through a set of graphical tools that supports the deployment phases. The agent platform can be distributed across machines and the configuration can be controlled via a remote graphical user interface. The system is divided into three parts: remote control, web application and RFID middleware server, as shown in Figure 6.

C. *Performance evaluation*

We will now present a test scenario for the dangerous-area warning service. Figure 7 presents a diagram of the dangerous-area test architecture. The danger zone size is 2.5M by 2.5M. When a student from point A into the danger zone that the average walking time requires is 4.5 seconds, the average running time that a student requires is 1.5 seconds. When a student from point B into the danger zone that the average walking time requires is 4.8 seconds, the average running time that a student requires is 1.9 seconds. In order to prevent students from entering the danger zone, both RFID Reader 1 and RFID Reader 2 can simultaneously detect an active tag. We used ten active tags to carry out this simulation. The percentage of accurate tag readings is illustrated in Figure 8. Figure 9 presents the tag-reading response times.

V. Conclusion

Through RFID technology and ontology technology, we can transform passive security systems into active security systems. When students encounter emergencies, their RFID tags can send out a distress message from any corner of a campus. Basically, in this paper, we aim to demonstrate the feasibility and applicability of utilizing agent-based technologies to the special-education students. In summary, this research makes the following contributions to improving the traceability and the efficiency of campus-safety management systems.

- We proposed a distributed multiagent system combining RFID technology with a hierarchical campus knowledge base ontology model to strengthen real-time monitoring and dynamic accident-prevention mechanisms in respect of ubiquitous campuses.
- We classified students' behavior patterns regarding different types of scenario relationships.
- The proposed framework can indeed improve the traceability of students throughout the entire school day.
- Our system can provide both school staff and parents with real-time information, helping them both respond to the status of students in real time and make better decisions in handling independent events.

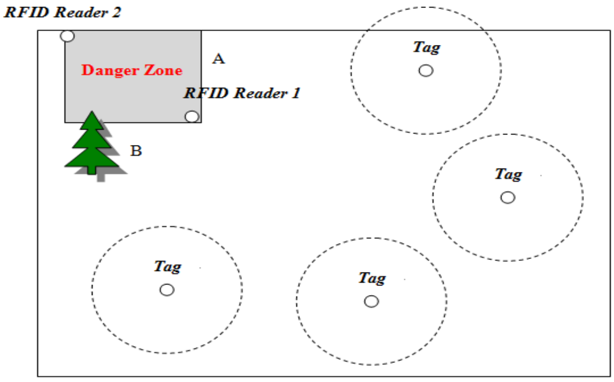

Figure 7. Diagram of the dangerous-area test architecture

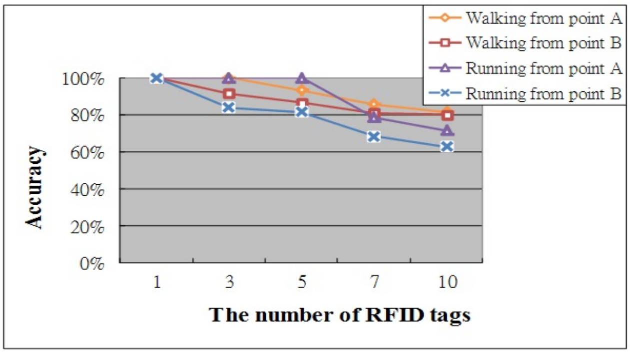

Figure 8. The percentage of accurate tag readings

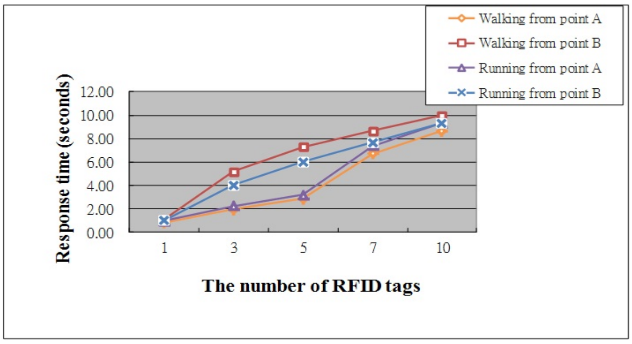

Figure 9. Tag-reading response times

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 ISBN: 978-1-61208-273-8