Emergency Evacuation Base on Intelligent Digital Signage Systems

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Abstract—As buildings become taller and more complex, establishing clear evacuation routes becomes very important in the event of a fire or other emergency. In this paper, Wireless Sensor Networks (WSN), Radio Frequency Identification (RFID) and real time escape route guidance are integrated to accomplish a real-time fire evacuation system to guide along an evacuation route. When the emergency event occurs, the system provides evacuation route guidance to people for them to be able to avoid danger. Moreover, in the proposed system, an intelligent evacuation route is provided by indicating in digital signage the best evacuation route as well as pertinent information to improve the chances of survival for users. The proposed system also supplies real time environmental information to fire fighters assuring better efficiency in their rescue operations.

Keywords—Wireless Sensor Network; RFID; Evacuation Plan; Digital Signage

I. INTRODUCTIONS

There have been 1620 fires fewer in Taiwan in 2011 than in 2007 according to the statistics of the National Fire Agency. However, the number of people who have died in the fires has not decreased in an equal proportion: environments occupied by people are becoming more complex and guidance is not always explicit. Therefore, in this study, a ZigBee wireless sensor network, RFID indoor localization technology and real time evacuation guidance were integrated to set up real-time fire evacuation in order to guide people along evacuation routes. Also, in the study, an intelligent digital signage, provided via the central control system, was used to display the evacuation guidance to guide users in the building in case of fire leading to quick escapes and reducing casualties.

This paper is organized as follows: In section 2, related work on wireless sensor networks, indoor locations as well as emergency evacuation are presented. The system architecture is briefly described in section 3. Section 4 discusses the implementation of the proposed system. Conclusion and discussion are given in Section 5.

II. RELATED WORKS

Zigbee is a specification for a suite of high-level communication protocols. It is based on an IEEE 802.15 standard. Zigbee’s protocol layer can be divided into the Physical layer (PHY), Media Access Control (MAC), Network layer (NWK), and Application layer (APL). Also, Zigbee can be divided into the Zigbee Coordinator, Zigbee Router, and Zigbee End Device. It supports the network topologies with Star, Tree, and Mesh. It has been widely used in environmental monitoring, safety control, electronic equipment automation, medical care, housing and other applications. It is one of the short distance wireless communication technologies in wireless sensor networks commonly recognized.

In providing guidance for users on an indoors route, getting to an exact location, is a problem. Many methods using different techniques have been proposed in recent years. Radio Frequency Identification (RFID) is one of the popular techniques to study [2, 3, 4]. It usually consists of an RFID Reader and an RFID Tag. Since GPS is still problematic for indoor positioning accuracy, the RFID-based indoor positioning technology has gradually begun receiving more attention. The best known RFID indoor positioning technology is the LANDMARC[5] system. The main approach of LANDMARC is using fixed positions with electronic tags to create reference points in assisting operators. Either the RFID Signal Strength Information (RSSI) or the power level can be used to judge the distance from an RFID Tag. Each reader receives multiple electronic tags and distinguishes them according to each tag’s unique serial number, discerning them according to their signal, and then calculating the distance using the reference point within the range of each unknown electronic position of the label/tag. However, the precision of the LANDMARC system declines sharply when the distance between reference tags is larger than one meter and, furthermore, setting up the system is quite costly. Lee et. al. proposed VSLS [6] to overcome the drawbacks of LANDMARC. In VSLS, the authors used
virtual source sampling and purification procedures to enhance the accuracy and reduce the deployment cost.

It has been studied extensively in emergency evacuation [7-10]. However, many of these studies focus on the shortest evacuation paths. Zhou et. al. [11] present the multiple streaming crowd guidance (MSCG). According to the MSCG algorithm people are navigated separately/individually according to the distance and capacity of exits. Wu et. al. [10] propose a personal guidance system using smartphones; users register on entering a building and automatically receive environmental information as well as emergency evacuation messages when a fire breaks out. Also, personal evacuation guidance is installed in a user’s smartphone to help them escape from the fire. However, the size of the panel of the smartphone is inadequate and may be unclear indoors.

At present, public spaces (shopping centers, for example) are relying on fixed signage indicating the direction of exits. Most of them lack clear route guidance and there is no way to confirm whether an escape direction is correct. It’s easily lead people to make wrong judgments at the time of fire, and may enter danger area when emergency. Many shopping centers, however, do have digital signage displaying commercial ads and entertainment. Digital signage operates in real time, changes dynamically, and has multi-media characteristics [12]. The propagation characteristics of multimedia digital signage have other applications as well. Lots of electronic signage products and various types of communication control systems are available in the market since digital signage are flexible, fully customizable support services, audio sound and light effects to attract the attention of consumers, and can save cost and time in production and distribution.

III. SYSTEM ARCHITECTURE

In this paper, an intelligent fire evacuation Map and evacuation guidance system are proposed based on a demo site built for the study. Wireless sensor networks (WSNs) consisting of nodes were used for monitoring physical environmental conditions such as temperature, humidity, light, etc., and RFID was used as an indoor location sensing system. The system continuously monitored the environmental conditions and marked/identified the origin of the fire. Moreover, the system immediately drew/designed/set up a real-time fire evacuation map to guide along an evacuation route and notified the people in the building about the fire while using digital signage to display the evacuation route. In the proposed system, Zigbee wireless transmission function sensors and RFID detection points with apperception of the environment were provided and these were also integrated with environmental information and digital signage devices for a complete evacuation guidance system. Moreover, the proposed system not only provided guidance regarding escape routes during the evacuation of people, but also appropriately dispersed the people to prevent overcrowding. Furthermore, the digital signage provided posting and publishing messages in real time. It also provided other digital signage applications in a safe and secure environment. In order to achieve system reliability and functional integrity, modularity was adopted as a technique in developing the system. There were four function modules in this system: 1. ZigBee Sensor and Controller Module, 2. RFID Location System Module, 3. Central Monitoring system and Database System Module, 4. Intelligence Digital Signage System Module. The architecture of the system is shown in Figure 1.

1. ZigBee Sensor and Controller Module

This module was responsible for monitoring environmental information by using WSN to collect environmental data, such as temperature, humidity and illumination, to determine whether it was a normal or emergency state. A TICC2530 chipset was used to set up the ZigBee sensor communication module, to carry out environmental information delivery and send commands. Illumination, temperature, and humidity sensors were loaded on the hardware of the wireless communication module to measure environmental changes. Moreover, the module was set to the frequency of environmental information collection in accordance with the various needs of a particular area; the environment data were transmitted in real time to reflect the current situation. Three transmission modes were chosen in ZigBee: 1. Fixed sampling interval time and automatically return data after sampling. 2. The channel detecting analog input values or input changes automatically returning data after sampling. 3. The host issuing the instructions and returning the sensor measured data. It was found that Mode 1 and Mode 2 caused data collision in the data collection procedure and the database could not digest the huge amount of returning data. Therefore, Mode 3 was chosen as the transmission mode.

In the work, the overall system impact on different data collection rates was also studied for hardware, software as well as databases in the module. When, the environmental ZigBee wireless sensor network was deployed, the sensing range covering all regions and each sensor measurement range did not overlap with each other, which got the best results. This deployment approach immediately identified the fire and generated an early warning. However, this deployment approach caused excessive hardware costs, not matching the benefits. In this study, the second best way was chosen. The sensors were deployed in regional centers as well as sensitive regions (kitchen, bath room, etc.)
2. RFID-based Location Module

This module was mainly for determining the number of people in each room and then computing the evacuation route according to the evacuation algorithm. In this module, the RFID reader received the signal from all electronic tags and determined the location of each tag by using the unique serial number and the strength of the signal. VSLS [6] methodology was used to calculate the location of each tag in a room. An RFID reader was placed in the ceiling, via TCP/IP, in the IoT Research Center of Chung Hua University to transmit the tag signals. A signal received by the reader was stored in a backend database to proceed to the positioning computation. The structure of the RFID-based Location Module is depicted in fig. 2.

Figure 2. Structure of the RFID-based Location Module

3. Central Monitoring System and Database Module

The central monitoring system was responsible for controlling the information flowing through each module, and provided easy monitoring user interface. The Central Monitoring System used the Windows Framework to provide the monitoring UI for the manager. In addition, it also helped security personnel to monitor environmental information, determine personnel status and provide fire early warning information. The Central Monitoring System supported three modes: 1. Environmental information under normal state, 2. Environmental information during fire, 3. Management Interface.

The database module was responsible for analyzing the data obtained from the ZigBee sensors and RFID readers. These data determined whether the system status needed to be changed. When the value of data collected from the sensors was beyond the normal range, the system notified the professional staff and set off the fire alarm. The operating system platform and database specifications of the Central Monitoring System and Database module are shown in Table 1.

Table 1. Platform and database specifications

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating system</td>
<td>Windows 7</td>
</tr>
<tr>
<td>Website Framework Platform</td>
<td>Microsoft Visual Studio 2012 C#</td>
</tr>
<tr>
<td>Database Systems</td>
<td>PostgreSQL 9.1, MySQL 5.2 CE</td>
</tr>
</tbody>
</table>

4. Intelligent Digital Signage Module

The Intelligent Digital Signage System Module received the information from the Central Monitoring System and Database module and published on digital signage. The digital signage system used 22-inch and 18-inch LCD monitors combined with an APC Rock developer latest edition. The embedded Android APC Rock Development Board played an important role in the system having a simple design and readily available hardware. It had the following functions: 1. Through VGA or HDMI it sent video output to the monitor. 2. Through a wired network or USB Wireless LAN Card it connected to the Internet. Information was received from the database and sent to the monitor using the USB Wireless LAN Card. The architecture and specifications of the Intelligent Digital Signage Module are given in Table 2 and Figure 3.

Table 2. The specification of Intelligence Digital Signage Module

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Signage</td>
<td>Eclipse 3.7</td>
</tr>
<tr>
<td>System Development</td>
<td>Android SDK R18</td>
</tr>
<tr>
<td>APC Rock version</td>
<td>Android 4.0</td>
</tr>
<tr>
<td>Hardware</td>
<td>22-inch LCD monitor, 18 inch LCD Monitor, APC Rock, D-Link DWA-125</td>
</tr>
</tbody>
</table>
(A) Initialization of digital signage
1. When the digital signage was initialized, the system asked operator to manually enter the ID of the digital signage and the signage stored the ID in the internal memory of the embedded Android OS.
2. After completing the input, the system was officially launched and started to read and compare the status.

(B) Reading mode
1. The system switched between different modes according to the configuration database managers after receiving the current status from the Central Monitoring System and Database Module.
2. When the status of the digital signage was the same as that of the Central Monitoring System, the mode did not change; otherwise, it changed.

(C) Display mode
1. When the mode changed, the digital signage displayed a message.
2. When the status was advertising mode then the digital signage displayed ads, or otherwise, it displayed the evacuation information (evacuation mode).

Evacuation Mode: In this mode, the digital signage displayed the guidance and direction for evacuation from the Central Monitoring System. The control flow of evacuation mode is shown in fig. 7 and 3 snapshots of the evacuation mode in digital signage are given in fig. 8, fig. 9 and fig. 10. The system continuously monitored the environmental information form the ZigBee Sensor, Controller Module and RFID-based Location Module. When evacuation routes were updated, based on a change in the environmental data, the digital signage immediately updated the direction of evacuation.

Figure 4. Control flow of the proposed system

Figure 5. Control flow of advertising mode

Figure 6. Snapshot of advertising mode shown in digital signage

Figure 7. Control flow of evacuation mode

Advertising mode: In advertising mode, digital signage received the dissemination of information from the Central Monitoring System. The control flow of advertising mode is shown in fig. 5 and a snapshot of advertising mode shown in digital signage in given in fig. 6.
V. CONCLUSION AND DISCUSSION

In case of an emergency, efficiently providing an evacuation route becomes quite important. Efficient guidance equipment is key for personnel survival. In this study, an emergency evacuation system was implemented with a wireless sensor network, RFID positioning technology, and digital signage. In addition, the construction of a ZigBee sensor network covering the whole area with the smallest number of sensors was also studied. Moreover, personnel location information was also applied to detect unexpected accidents and re-route the evacuation path. In future, the evacuation system can be linked to fire-fighting equipment based on real time environmental information to enhance the efficiency of rescue.

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