A Smart Pre-Warning, Guide, Alarm, Recovery and Detection (GUARD) Network System for the Blind

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Abstract

This paper discusses the critical technologies that are used in the development of optical wireless communication network, in the protection of the safety, and in the provision of convenience to the vision-impaired population. The technologies of the realizations of the hardware, firmware, decision algorithms, communication protocols and application programs developed for Sensor Nodes in optical wireless communication network are applied for the Smart Blind-Guidance Network System. In addition, this technology is aided by the assistant equipment (cane) for the blind and the communication interface protocol for the computer, which is specifically designed for the blind. The smart blind-guidance system is a combination of optics, microprocessor, voice acoustics, and wireless electronics. This system also possesses the functions of distance measuring and environment parameters, collecting to finish a complete Pre-warning, Guide, Alarm, Recovery and Detection (GUARD) guide system for the blind and also completing a locating and addressing system.

Key Words: Wireless Optical System, Guide System, Smart Blind-guidance Cane, Sensor Node

1. Introduction

Technology has made great progress in recent years so blind-guidance equipments are no exceptions. But the blind still hopes that the blind-guidance equipments can clearly notify them of any obstructions in his walking path, any possibilities of incurring danger. It should also be capable of directing the correct path to the blind in order to save time. Furthermore, it should be able to lead the blind to their destination without much difficulty. All these issues have imposed us to consider the main task of how to massively manufacture practical but low cost blind-guidance equipments, which will be more convenience to the blinds. It will greatly improve the difficulty and inconvenient of the blinds' walking tasks if we can install a complete monitoring, locating and addressing network system and give them multi-function assistant equipment such as the guidance-cane. It will definitely be beneficial to the blind if we can invent a humanized blind-guidance machine to assistant them whenever they need help.

A blind-guidance system has been installed in Tamkang University campus for many years. The university has excellent experiences in the tasks of designing a special computer for the blind to use and the installation of blind-guidance bricks and the use of the guide dog for the blind. In order to provide the blind a safer, instant, and multi-variety of services, we will mingle our previ-

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ous experience in the development of blind-guidance system with the new technologies developed in the wireless and sensor fields to build a smart wireless system that possesses multi-functional capabilities of Guide, Alarm, Recovery and Detection (GUARD). In this paper, we will use the campus of Tamkang University as the field to build a Wireless Sensor Network (WSN) for the blind. While we are building the WSN, we need to take the power consumption as our design premise so that the installed WSN can provide service for the blind for a long time. In other words, we need to design a WSN with a long lifetime. Furthermore, we also hope this system will provide a more accurate location information to the blind because when he walks in the campus, he will like to know his current location and address. We need to default the parameter values when the WSN is installed, in order to generate the address data of each Sensor Node. Eventually, a perfect smart wireless GUARD system with correctly defaulted parameter values will be built. The designed GUARD system will benefit the blind to have him live and study in an unobstructed environment.

2. The Design of Wireless Optical Network

The Sensor network of the whole GUARD system is designed in the paper. We select the IEEE802.15.4-2003 (Zigbee) communication protocol as our main operation protocol for the Sensor network to meet the requirements of network certification, network safety, error compatibility, system robustness, system expandability, cost, hardware, topology, working environment and power consumption etc. [1–5].

In the paper we purchase the Zigbee development platform CC2420 DBK as shown in Figure 1 from Chipcon Inc. to proceed to the development of the communication protocol. In this Zigbee platform it carries Atmel's ATmega 128 microprocessor and Chipcon's CC2420 wireless transceiver.

In this development platform we can input the edited program codes to the platform to process the verification of the communication protocol and we then standardize the wireless transmission between two transponders through the use of program codes. Also in the development of the programs we adopt Chipcon's CC2420 DK, as shown in Figure 2, to proceed to the error correction and verification of each process. In this platform, we can extract signals in the Zigbee band and display the signals, through the GUI interface (as shown in Figure 3) at the PC port, in the IEEE 802.15.4 (Zigbee) standard packet format. We then determine the correctness of the developed codes and decide whether the communication protocol meets the IEEE standard.

Figure 1. CC2420 DBK.

Figure 2. CC2420 DK.

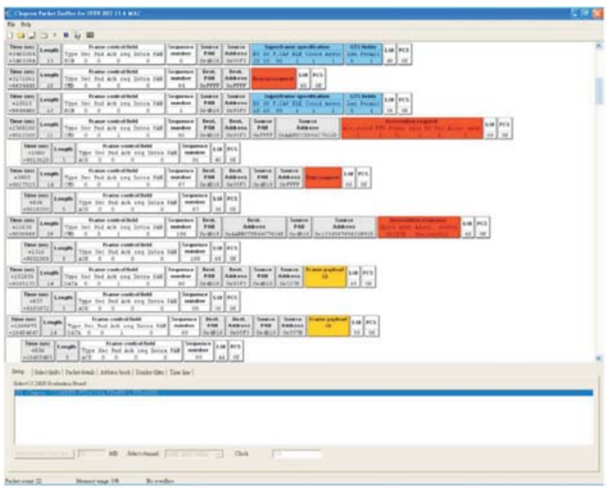

Figure 3. Graphic-User-Interface (GUI) at PC port.

3. Smart Wireless Pre-warning, Guard, Alarm, Recovery and Detection System (GUARD) for the Blind

3.1 The Installation of Wireless Sensor Network for the Blind

We emphasize in this paper the installation of a wireless sensor network for the blind, the default values setting of the network, the system realization, the system implementation, and the integration of the GUARD system. The installation of wireless sensor network can be divided into two categories. One is using manual method to randomly install the network while the other is using a robot-like method to progressively process the network installation. The WSN system without any basic installation, usually locates the network of Sensor Nodes to be installed through prior calculations. Then the Sensor Node processes independently the construction of network topology. Depending on its sensing mission, every WSN has different factors to consider in the construction of the network. In the previous design, every Sensor Node is designed to have its maximum coverage, and it is assumed that the Sensor Node possesses the moving capability so that the Sensor Node can be moved to undetectable areas to expand the whole WSN sensing range.

In addition to the WSN as discussed, a lot of researches emphasizes on the subjects of no-rule, layered WSN, try to determine to install cluster in WSN, how to select the cluster head in the cluster, how to increase the lifetime of this kind WSN, and how to place the sinks. The layered WSN needs to have equilibrium on the number of members in the cluster (so that each cluster head will have almost the same lifetime) without considering how to select the cluster head. Consequently, the cluster head may consume too much power. Therefore, we also need to consider the selection of the cluster head so that it is possible to balance the power consumption in the WSN and to improve the lifetime of WSN.

In order to construct the best WSN with the best lifetime, we need to consider the installation method, which includes no-layered and layered WSN. We also hope the Sensor Node will have the maximum coverage in the WSN.

3.2 The Setting of the Defaulted Parameter Values of the Wireless Network for the Blind

In the stage of network management and maintenance, addressing and geographical information discovery are two important research topics in the setting of defaulted parameter values of the network. In the addressing method, Ad Hoc in the wireless sensor network usually takes autonomous and distributed way to complete the network installation. Consequently if each main machine in the network is identified by one and unique identifier, it needs to be operated in the distributed way. Another way to addressing is to use the centralized operation. The network administrator takes control of the network management; he unifies the management and coordinates all members in the network. When conflict occurs he will notify the sender to improve the reliability of the information transmission.

The second research topic is the geographical information discovery. There have been many proposals regarding addressing techniques in the wireless detection network. The area-addressing system uses some reference points to aid in the location calculation. In other addressing system it uses ultrasonic detection method to measure the actual distance.

From above considerations we know that when the complexity of network installation increases, the complexity of the installation or re-installation of an ideal WSN system has also increases. Therefore, it makes the network management and maintenance more difficult. Although many research projects are under consideration, it does not have a WSN designed and installed for the blind. There still exist a lot of unresolved problems in the WSN installation. So we would like to conduct advanced researches and studies in WSN system hopefully, we can solve the theoretical and practical problems that may arise in the installation of WSN designed for the blind.

4. The Design and Implementation of a Smart Wireless GUARD System

In the theoretical study we use the robot-like design method to install the Sensor Network and to develop its communication protocol to conquer the obstacles and to use the minimum number of Sensor Nodes to attain the full coverage capability. In the implementation we extend and expand the functions of Sink Node and Sensor Node. We write communication protocol for the sensing and transmitting of wireless signals between Sensors and between the Sensor and the Sink Node. We also aggressively develop the interfaces for the blind-guidance system to insure this guide system will work closely with the blind sensor network.

4.1 The Installation of Wireless Sensor Network for the Blind

In the network, we set up one or many PCs or notebooks that are used as the Sink nodes to connect with the modules of Mote MICA2 [6]. Many Mote MICA2 modules form a sensor network. We also assemble Mote MICA2 modules to form a self-moving mobile unit to function as a mobile sensor and a mobile robot. The Sensor Board also possesses six functions of sensing light intensity, sound, temperature, relative humanity, magnetic strength, and plane acceleration velocity. When the Sensor Board senses the environment information, it will transmit this information to the MICA 2 through the Analog to Digital Converter (ADC) for processing and calculating. The basic constituent elements in the Sensor Note are Micro Control Unit (MCU), RF module, Sensing Component, Power unit, and I/O interface as shown in Figure 4. The MCU is the data processing unit used to process the received or sensed data according to the requirement in the application layer. RF module is the wireless communication module used to make a point-to-point wireless communication. Sensor Component is a sensor and by using different kinds of sensors, we can sense and get numerous environment information. I/O interface is the input/output port for the Sensor Node, and the Power unit provides power to all constituent elements of the Sensor Node.

We use the self-moving mobile to replace the Sensor Node, which possesses sensing functions, to make the sensing operation by its partial movement or to search for the damaged Sensor Nodes via the patrolling method. The self-moving mobile, through centralized computation and by considering the connectivity of the sensor network and its possible sensing range, uses the minimum power consumption to attain the tasks of full coverage and autonomous repairing. The components in the self-moving mobile consist of Ultra Sonic Module, MICA 2, MICA 2 Connector, Motor Control Integrated Circuit, Motor, Power Unit and Location Generator. It uses Ultra Sonic Module to transmit ultrasonic waves to detect the existence of obstacles and measure their distances. It also conveys the information to the MICA 2 for analysis and processing. The MICA 2 is the data processing center to process information sent from all modules and to make proper decision. It can also transmit the processed information to all neighboring Static Sensors by using the RF module.

The software used in the Mote Mica 2 module is the operating system implemented in the TinyOS [7] developed by University of California at Berkeley. The characteristic of this operating system is that it has component-based small-scale architecture and it uses another scheduler, TinyOS Scheduler, to manage and execute the task and event. It does not use virtual memory but adopts static memory arrangement to effectively use the power. The language it used is nesC, a program language similar to program language C.

We use nesC as the development language. An application program written in nesC is an executable program formed from interconnections of one or more than one devices. The implementation also has two kinds of interfaces: one of them is the Configuration shown in Figure 5. It is used to combine and define the interrelations between devices, i.e. it is the interface between the implementation of devices. It can, through the defined interfaces, make communications possible between devices. The other kind of interface is the Module. It generates program code for the application program, i.e. it is the program codes to define the function in the implementa-

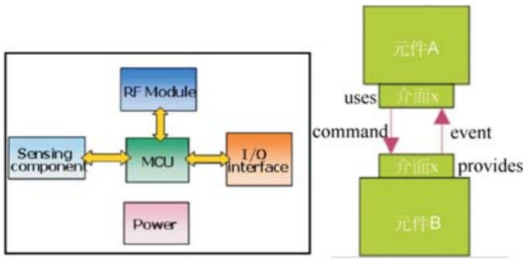

Figure 4. Basic elements, interface architecture.

```
//Blink.nc
Configuration Blink {
              }
 implementation {

   components Main, BlinkM, SingleTimer, LedsC;

   Main.StdControl-> BlinkM.StdControl;
   Main.StdControl-> SingleTimer.StdControl;
   BlinkM.Timer-> SingleTimer.Timer;
   BlinkM.Leds->LedsC;
}
```

Figure 5. Some code statements in the configuration program.

tion of the interface. The Module is the smallest device unit as shown in Figure 6.

4.2 The Implementation of Blind-guidance System

In the interface implementation for the blind-guidance system, we use FLASH as the development tool. The use of FLASH has the following advantages:

- It uses the basis of vector drawing in the FLASH implementation, therefore has more flexibility in the display presentation. Moreover, it will not display any distortion in the processing of map enlargement or reduction.
- The use of FLASH has elegant effects in the multimedia presentation and therefore it enables the acceleration of the dynamic map development. It also generates the convenient function to enable the visualization of the information message.
- Flash has the integration capability to completely combine the functions of network and database. It can combine user's certification system and it also enables users, through network, to process system operations, instantly and without space limitations.

Therefore, as shown in Figure 7, when we install a wireless sensor network in Tamkang University, the main operations of the blind-guidance system will have the display as shown in Figure 8. It consists of two parts, namely, the control panel area and the map display area. In the control panel area, the contents to be displayed in this area are controlled by the user. Depending on the user's requirements, he can change the contents in the display area. It will follow the user's control to display the information he requests for in the display area. The information includes the location of the blind, the planned route, and the obstacle information. The following points are introductions of the main functions of the interfaces:

● **Route Display and Plan**

The user can, instantly, ask for the location of any blind in the campus and search for his walking route. He can dynamically change or correct the guide path for the blind

● **Rotate/Reduce/Enlarge/Move/Restore**

The user can display the map in various fashions such as using rotation, reduction, enlargement, and movement functions; he can dynamically adjust the appearance of the map. He can use the restoration function to restore the map into its defaulted settings.

● **Obstacle Display and Setting**

When the blind's walking is impeded due to the construction, repairing and events held in the campus, the system will provide, display, and set the obstacle information the blind and help him to find an alternate walking route.

5. Conclusion

A blind-guidance system has been installed in Tamkang University campus for many years. The university has excellent experiences in the tasks of designing a special computer for the blind to use, the installation of blind-guidance bricks, and the use of the guide dog for the blind etc. As the technology progresses, we can realize and implement the Sensor Node with the characteristics of being small in size, low weight, low cost, low

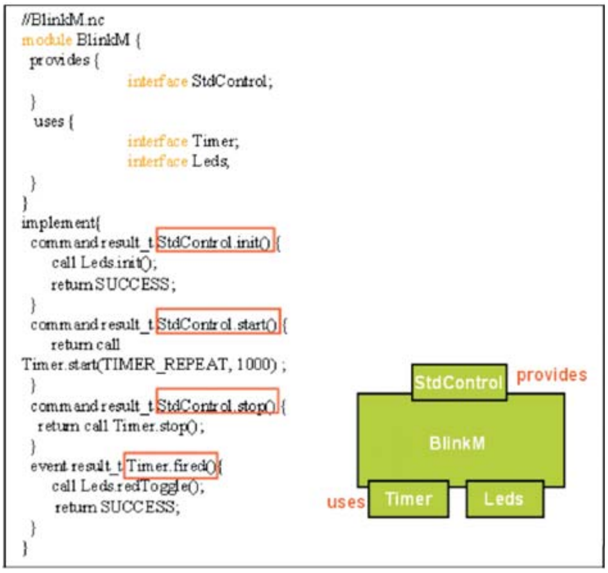

Figure 6. Some code statements in the module program.

Figure 7. Sensor node installed in the campus of Tamkang University.

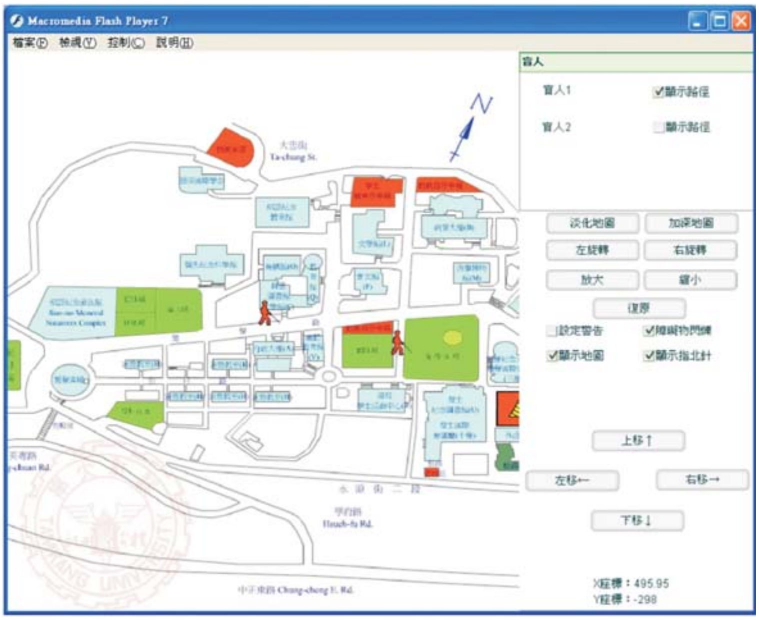

Figure 8. Campus system interface of Tamkang University.

power, multi-functional, and wireless sensing capability. Due to the installation of this kind of Sensor Node, it enables us to widely use the Wireless Sensor Network in various application areas to provide a safer, instant, and a wider range of services for the blind. This system possesses the capabilities of Guide, Alarm, Recovery, and Detection (GUARD) functions. In addition, the currently developed Sensors are unsuitable for usage in our planned GUARD system. Therefore, we are also making extensive studies, researches and implementations of Sensors required for the new system.

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