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FLUORESCENT LIGHT-SENSOR-BASED TRANSRECEIVER

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Abstract: This paper describes a novel light-sensor-based information transmission system for indoor positioning and navigation with particular benefits for mobile and wearable computers. It can seamlessly extend outdoor GPS tracking to the indoor environment. In a novel manner, fluorescent light is used as the medium to transmit information, which is encoded by using a pulse frequency modulation technique. The user receives the encoded light information through a photo receiver. The information is passed into the wearable or mobile computer after the data are decoded. This information allows positioning information to be given to indoor mobile and wearable computers. We design an economical transmitter circuit by adding a few components to a commercial electronic ballast circuit for fluorescent lamps with a price of less than 10 USD. The proposed system can be used in Indoor guidance and navigation applications.

This system is to identify the different blocks in the organization by using the RF transmitter. And the employer can be able to find where the employee in the organization. All the multinational companies are having more than 50 blocks in a single building those are working for different projects. So it is difficult to find by the new employee to know which block is belongs to which category. For this we are going to develop a new system which is apt for the new employee's to know the different blocks in the organization. The internal architecture of the mechanism consists of a GPS receiver to track the position of the employee when he was at outside and a RF receiver receives the information from the individual blocks transmitters and he can be able to see the information which is regarding the block in the LCD display when he was entered in to indoor. For synchronizing all these blocks we arranged a micro controller for receiving the information through RF receiver and transmitting the position of the employee details. Every block in the organization is having a RF transmitter which is capable of transmitting the relevant information about the block name and relevant details about it. All the RF transmitters can be placed in 30m distance for avoiding the signal interference. We can increase the number of transmitters according to the organization requirements.

GPS is the acronym for global positioning system which receives the information from the satellite anywhere in the world and provides the same for controller. The GPS provides us the data like location, time, and speed. The controller accepts these data in a sequence of steps as per instruction set as provided to the controller.

Keywords- Augmented reality (AR), electronic ballast, fluorescent lamp, navigation, wearable computer.

I.INTRODUCTION

Mobile or wearable computers and augmented reality technology are finding applications in human position guidance and navigation [1].

AR merges virtual objects or text information into a real environment and displays this combination in real time. Unlike virtual environments, AR supplements reality, rather than completely replacing it. This property makes AR particularly well suited as a tool to aid the user's perception of and interaction with the real world. The information conveyed by the virtual objects helps a user perform real-world tasks [2], [3]. Some forms of indoor positioning, such as magnetic and ultrasonic sensing, are also available, but they are normally for a short range and expensive and require complex hardware installations [4]. Thus, there is a problem that such commercially available sensing systems for indoor tracking of mobile and wearable computers are accurate but impractical and expensive for wide areas.

As a research contribution, this paper presents a novel method of indoor sensing and tracking for mobile and wearable computers by using fluorescent-light-based sensors. This system can provide indoor tracking very cheaply with an accuracy on the similar order as outdoor wearable GPS sensors and can be used in very wide indoor areas. It does not require complex installations and is thus highly practical.

Wearable AR and interactive technologies can use this system as a valuable alternative for advanced indoor navigation systems. We propose using common and cheap fluorescent lamps [5] to transmit information for navigation, because using fluorescent lamps to provide illumination is so popular, widespread, and economical in existing buildings. By modulating the arc frequency of the electronic ballast without any human perceptible flicker (avoiding the visible spectrum, which is between 0.4 and 0.7 μm [6]), all the required information can be encoded into the light.

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With our proposed device, a user who has the developed small light receiver on his or her body can receive position information, which is suitable for applications such as AR. In this system, after a data stream of information is received and processed, it will be fed into the mobile or wearable computer through the serial port for further processing. When the user is at the different positions, different messages will appear on the head-mounted display (HMD).As this indoor tracking and positioning system is small and light, it can be worn by the user together with the outdoor wearable GPS tracking system at the same time. The system can detect which signal (GPS or indoor light) is being received, and tracking can be continued from the outdoor to indoor by simply switching from an outdoor GPS system to the Indoor light-sensor system. When the user enters the indoor environment, indoor information is provided by continuing the position information from the outdoor to the indoor environment. Thus, the indoor and outdoor positioning systems are seamlessly combined.

In this paper, Section II compares the proposed system with other technologies used in indoor tracking in terms of accuracy and cost. Section III reviews the hardware system design, in which the whole system circuits are detailed. Section IV describes the performance of the proposed system. Finally, conclusion and future works are provided in Section V.

II. COMPARISON WITH OTHER SYSTEMS

Other proposed methods for indoor tracking are mainly based on ultrasound, radio frequency, and IR. Although each technology has its own advantages and disadvantages, in general, there is a tradeoff between the accuracy of the tracking and the total cost of the system.

For example, ultrasound tracking can be highly accurate, such as the IS-900 system developed by the Intersense Company [8], with a price of over 15 000 USD, or it can be designed in a cheap way like the system proposed by Randell and Muller [10], which costs about 150 USD with an accuracy of 10–25 cm.

COMPARISON OF DIFFERENT INDOOR TRACKING SYSTEMS
Table 1

System	Cost in USD	Accuracy	Technology
Intersense IS-900	Over 15000	1 mm	Ultrasound
Randell's System	150	10-25 cm	Ultrasound
Ekahau	100-200	1m	Wi-Fi
Proposed system	Less than 10	3-4 m	light

In Table I, we listed the cost and accuracy of different indoor tracking systems in comparison with our system. As can be seen in this table, the proposed system has the lowest tracking performance (on the order of outdoor GPS), but it is the cheapest one as well. As a result, our system is not suitable for applications that need highly accurate tracking, such as virtual reality applications, and because it is one of the cheapest methods for indoor tracking, it is a good candidate for applications such as navigation and guidance (which does not need highly accurate tracking).In comparison with different technologies for indoor tracking, the proposed system is similar to IR tracking systems such as the method used in [9], which used an IR tracking system in an AR application. The next main difference is that the IR transmitter device is a point-emitting transmitter; therefore, it has less functional area than our system. Therefore, in our system, the user has more chance to be in the functional area and receive the signal, which would be more usable in practice. Based on comparison, we can conclude that the proposed system can be useful in applications such as guidance and navigation where the user seamlessly receives the information by passing through the functional area. For instance, we can put the transmitter on both sides of the entrance of each room in a building; then, the users will receive the position information (or other information about the room) by entering the room or by leaving it.

III. HARDWARE SYSTEM DESIGN

In this section, we will outline the hardware system used for constructing novel and economical navigation and positioning systems using fluorescent lamps. The whole system is divided into two parts: the transmitter and the receiver. The transmitter sends out messages encoded by the fluorescent light whose flicking is imperceptible to human vision, while the receiver detects the light using a photo detector.

In the transmitter section, information can be encoded into the light through arc frequency variation [see Fig.1(a)]. Here, we use a fluorescent lamp for our system since, first, it is highly used in office buildings and, second, nowadays, it is triggered by electronic ballast circuits, so there is no need to design a costly circuit for controlling the arc frequency of the lamp, and by simple modifications on the current widely cheap and available circuit, we can furnish our goal. We add a simple low cost microcontroller chip to control the light frequency from 35 to 40 kHz.

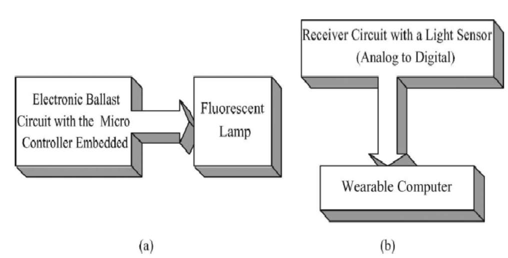

Fig. 1. Simple schematic scheme of the system. (a) Transceiver. (b) Receiver.

The receiver circuit [Fig. 1(b)], with a photo detector detecting the fluorescent light, processes the data that are eventually fed into the wearable computer. With the information received, the wearable computer can tell the user what the surrounding situation is. In the rest of this section, we detail our transmitter and receiver circuits, and then, we explain the wearable computer system in terms of how the receiver and other components are integrated together.

A. TRANSMITTER CIRCUIT

The hardware for the developed transmitter is shown in Fig. 2, and the schematic circuit diagram is depicted in Fig.3. As shown in this figure, the electronic ballast circuit used for the transmission purpose consists of three parts: the ac–dc rectifier, the dc–ac converter (inverter), and the resonant filter circuit.

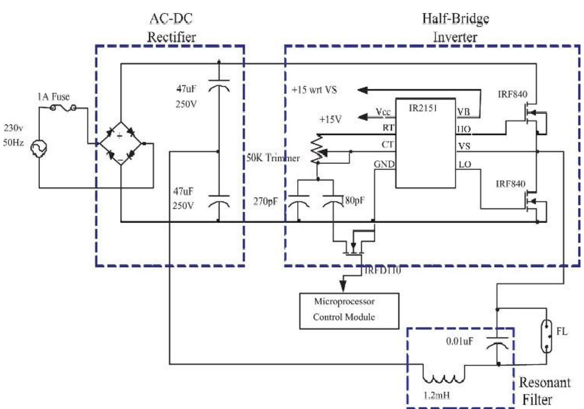

Fig. 2. Electronic ballast circuit.

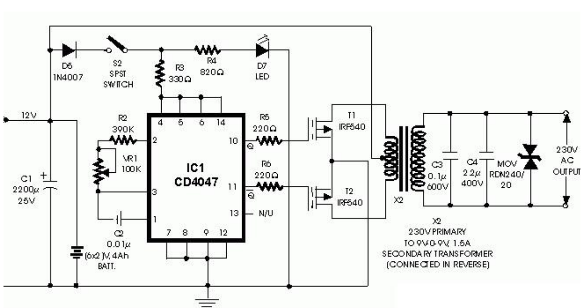

Fig.3 100Watt Inverter 24VDC to 220VAC

This is another 100watt inverter circuit diagram. Built based on IC CD4047 and Mosfet IRF540, this inverter have ability to supply electronic device -which require 220VAC- up to 100w from 2-3A transformer. The lighting of the fluorescent lamp is due to the arc current running through the lamp. When the amplitude and frequency of the arc current is appropriate, the lamp will light up. Amplitude and frequency are the two key factors for the lamp output. Therefore, changing the frequency of the arc current may encode all the information into the fluorescent light. If the modulation frequencies are high enough, the information will be transmitted without flickering due to the characteristic of human vision [6]. Since we wanted to design a very cheap and economic circuit for indoor tracking, we use a commercial electronic ballast system for a fluorescent lamp and performed small modifications on the circuit. As shown in Fig. 3, the only components that we added to the original circuit were a microcontroller, a low-power MOSFET, and a simple capacitor (80 pF). The MOSFET is used for switching purposes and is controlled by the microcontroller. Whenever the MOSFET is on, the 80-pF capacitor is parallelized with the original 270-Pf capacitor, which will change the lighting frequency from 40 to35 kHz. Therefore, we can simply transmit digital data through the light. Since we used simple and very cheap modifications on an available electronic circuit, by changing the frequency, we observed that the amplitude of the light is slightly changed as well. Consequently, after transmitting a byte such as “00001111,” a flickering effect will be sensed by normal human eyes. To solve this flickering problem, the first solution was to change our design and add more components to the circuit, but it would increase the total cost of the hardware. The second solution was to solve the problem in software. Since we are using a microcontroller in our circuit, we can encode the data in such a way that data level frequently changes in a short time, and therefore, human eyes cannot sense the changes in the light.

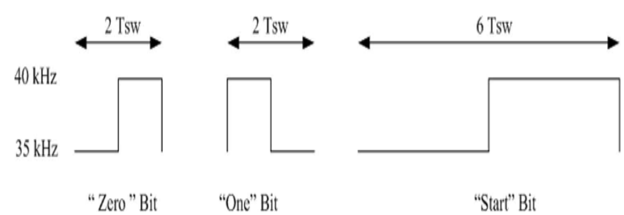

Fig. 4. Bit patterns in Manchester coding.

One of the encoding protocols for this solution is the Manchester coding method [7]. In this method, the signal edge in specific time periods is used to indicate the 0 or 1 logic. The bit pattern of Manchester coding is illustrated in Fig. 4.To transmit a byte using this code, a start pattern is sent first to synchronize the receiver. After sending the start pattern, the 8-bit data are transmitted. In this system, we set the signal period *Tsw* to be 1 ms. It is quite easy for almost all types of microcontroller to respond during this period. We set bit 1 to stand for the frequency shifting from 40 to 35 kHz and bit 0 to stand for the shifting from 35 to 40 kHz. Note that the period of every bit is 2 ms (2 *Tsw*) with a 0.5 duty cycle. Therefore, the total time taken for transmitting a byte is $8 \times 2 + 6 = 22$ ms. This means that the average data rate for this system will be 8/22 ms = 363 b/s. With the codes fed into the electronic ballast circuit, the fluorescent lamp is lit up, while the arc frequency is changed according to the bit patterns without perceptible flickering to the human vision. Manchester codes are encoded into arc voltage by frequency variations. Although the voltage level for frequencies of 35 and 40 kHz are slightly different, since there is frequent changes in signal due to Manchester coding, there will be no flickering effect in the transmitted light.

B. RECEIVER CIRCUIT

The receiver detects the fluorescent light and transforms the analog signals to the digital ones that can be sent to the user's mobile/wearable device. Fig.7 shows the block diagrams of the receiver part with a wearable computer. The core part of this receiver system is the receiver Circuit, which is shown in Fig. 5.

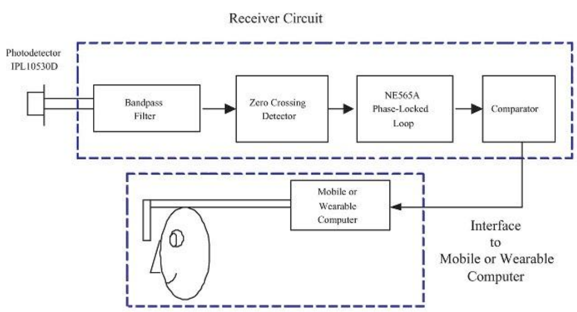

Fig.5.Block diagram for the receiver

As can be seen in Fig. 5, the main parts of the receiver circuit are as follows:

a) *Band pass filter:* The band pass filter is designed to remove noise that is received together with the Manchester-coded information in the light.

b) *Zero-crossing detector:* This block converts the analog input signal to digital signal. Note that only the frequency of the signal contains information and not its amplitude.

c) *Phase-locked loop (PLL):* This block converts the incoming digital signal to an analog voltage proportional to the frequency of incoming signal.

d) *Comparator:* Finally, we put a comparator in the last stage to compare the voltage level of the PLL output to see whether the incoming frequency is for the 35-kHz or 40-kHz signal.

The light sensor, i.e., photo detector IPL10530D, which is to provide an output voltage proportional to the light level, is used in our receiver system to detect the output from the fluorescent lamp in this prototype. Because the light intensity detected by the photo detector varies with the arc voltage magnitude and not by its phase, the received signal frequency is doubled. While the arc frequency is from 35 to 40 kHz, the received signal's frequency is from 70 to 80 kHz. Fig. 9 presents the comparison between the arc voltage waveform of the lamp and the band pass filter output, which clearly shows that the frequency is doubled when the light is detected.

C. Wearable Computer System for the Testing of the Positioning System

To test the positioning system and to provide an example application of AR, a wearable computer system was developed. The system is integrated onto the user's body to make it a wearable prototype, with emphasis on the mobility, comfort, and convenience of the end user. The light sensor receiver circuit is rigidly fixed onto a cap worn on the head. An HMD is clipped onto the user's spectacles. The remaining parts of the hardware are carefully integrated into a vest, and most cables are routed under the vest to avoid hindering the user's movement.

IV. EXPERIMENTAL RESULTS

In the previous sections, we discussed the hardware of the indoor navigation system in detail. The indoor system can seamlessly be activated by simply switching from the traditional outdoor GPS system to this indoor system. The transition reacts as follows. When a GPS signal is no longer received, a fluorescent lamp data code is sought after by the wearable computer. The data codes of the fluorescent lamp are directly tied to a GPS position relative to the outdoor GPS reading. Thus, the indoor fluorescent lamp position is direction correlated to an outdoor GPS position. As mentioned in the previous section, the proposed system can be used in guidance and navigation applications. Here, we describe a scenario that the user enters a building, and he or she wants to go to a specific location there. With our light modulation device, the user can be Positioned and tracked in the following ways. First, the user can receive the information related to his or her position and environment. Then, he or she can input his or her destination number. The wearable computer will help the user choose the shortest way to the destination.

For example, taking an application in an airport, assume the user's current location is "Gate 71" and his or her destination is in "Singapore Gift Shop". The user just needs to enter "Singapore Gift Shop," while the wearable computer will help him or her choose the shortcut to "Singapore Gift Shop" and tell the user his or her next stop is "Gate 60" with text messages displayed on the HMD, for instance, "Next stop: Gate 60. 60◦ clockwise, walk 30 meters."When the user arrives in "Gate 60," he or she will be noted by a text message "Gate60! Your next stop is Macdonald's Restaurant," etc. If the user finally arrives at the destination, he or she could be welcomed by "Congratulations, you arrived!" If the user changes his or her destination midway, the wearable computer will repeat the whole process again.

V.CONCLUSION AND FUTURE SCOPE

This guiding system can also effectively be used in some big urban indoor environments such as airports, hospitals, and

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shopping malls because fluorescent lamps are so widely used in these places and some signs there can be made as markers for recognizing. In hospitals, the patients can be guided to the destination in various wards with this system. In airports, people can use this guiding system to help them get to their flight. If the airport needs to broadcast some urgent messages such as flight delay and taking off notices, the system can fully be implemented since some text messages are displayed as reminders.

Some forms of indoor positioning, such as magnetic and ultrasonic sensing, are also available, but they are normally for a short range and expensive and require complex hardware installations [4].Thus, there is a problem that such commercially available sensing systems for indoor tracking of mobile and wearable computers are accurate but impractical and expensive for wide areas.

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