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An Arduino-based Indoor Positioning System (IPS) using Visible Light Communication and Ultrasound

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Abstract—A versatile outdoor and indoor position detection mobile prototype has been successfully constructed and tested. The receiver consists of a GPS module, a GSM shield, a visible-light data receiver, and two ultrasonic sensors, all controlled by an Arduino Mega and an Arduino Uno microcontroller. Each ultrasonic sensor detects distance in the X and Y axis respectively. The transmitter system consists of four LED shields each attached to an Arduino Uno which is programmed to transmit the global position relevant to the position of the LED lamp. When a person is outdoors, the GPS module receives global position from the satellite. When a person goes indoors, his or her global position will be given by the LEDs and ultrasound sensors. The location data can be transmitted via GSM to a monitoring system or to an individual smartphone. This system is extremely useful in elderly care service. It ensures specific accuracy in locating senior citizens during cases of emergency.

I. INTRODUCTION

Visible light communication (VLC) has come to an age where light receivers can also be utilized to detect position indoors. There is no literature on the construction of such devices. However, there are projects on the different techniques of getting location indoors. In [1], position information is encoded and sent via LEDs. In [2], position data is computed by the degree of Wi-Fi signal strength. In [3], we see the use of information embedded in ultrasound signals as a means to transmit location data.

GPS is often only accurate up to 5 or 10 meters. It becomes worse if you are surrounded by tall buildings. The GPS receiver does not function properly indoors, although you can still get weak satellite signals near the windows. Wi-Fi indoor positioning shows a promising future, but it is not practical to install Wi-Fi in places where very few people need to access the network.

In an enclosed environment such as an apartment or office, transmitting position by the use of LED lamps becomes more useful. Since every room or every part of the office will at least have a lamp, we are able to capture the precise location of a person if the person happens to have fainted or have a heart attack. In this project (Fig. 1), ultrasonic sensors are used to complement the visible light positioning system because they can have accuracy up to centimeters. If any of the LED lamps goes off, the ultrasonic sensors can still be used to locate a person.

II. VLC AND ULTRASOUND: HOW IT WORKS

Every LED lamp transmits unique global coordinates relative to its position on earth. The global position of



Fig. 1. Project setup and prototype of the 12V positioning receiver.

the lamp is determined using this particular tool site: <http://www.mygeoposition.com/>. As we zoom in, we are able to see the perimeter of a building. When you click on any spot, the pointer will indicate the global position of that spot. To add more information, we obtain the floorplan of our research centre and map the floorplan onto the outline of the building. Now we are able to see a more specific picture of our office. For instance, the global position of my work desk (which is also the global position of the LED light above my seat) is approximately $Y: 1.343669$, $X: 103.682324$. However, the distances between these lamps are usually about 3 meters. To improve the readings to centimeters, minute distances can be detected using ultrasound sensors (Fig. 2 and Fig. 3). Ultrasonic sensors measure distances by transmitting an ultrasonic signal and let it bounce back. It computes the distance from the duration taken by the signal to return to the receiver.

• Method 1: Boundary mapping

can pinpoint your rough position.

```
if (x<2 && y<2) //2 meters
{
  Led.print("Y: 1.322345");
  Led.print("X:103.343673");
  Serial.print("R Corner front door");
}
If you take that corner to be your
reference point (0,0).
```



Fig. 2. Determining receiver position using boundary mapping method.

In our scaled-down prototype, position is hardcoded into an Arduino Uno microcontroller, onto which an LED lamp shield (Fig. 4) is attached. Digital Pin 2 of the Uno will keep

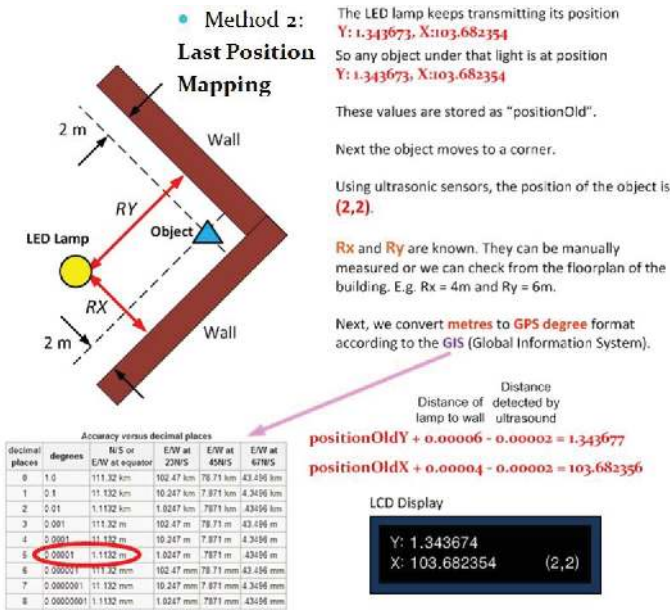


Fig. 3. Determining receiver position using last position method.

sending out these coordinates through the LEDs. If the entire house is installed with this type of LED lamps, then as long as a person carries a smartphone integrated with such a receiver, global position can be determined. We can even track a person by enabling the received position to be sent to a monitoring system or to another person. This is very useful for monitoring elderly patients at home or at the hospital.

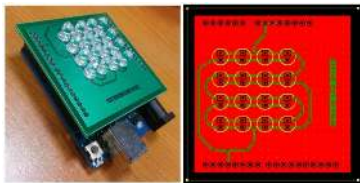


Fig. 4. Left: Arduino Uno with LED shield attached; right: PCB design of the shield.

The receiver hardware consists of a pair of ultrasonic rangefinders (limit 4 meters), a VLC receiver circuit (with nine BPV10 photodiodes), a GPS module, a GSM module, an Arduino Mega, and an Arduino Uno. Fig. 1 is a picture of the receiver and Fig. 5 shows its schematic.

III. HIGH CURRENT 12V TRANSMITTER

For higher power applications, e.g. ceiling installation, a 12V high-current LED is required. The whole circuit needs to change for compactness. Instead of an Arduino (because it can only output a current that is enough to drive a 1W LED), a simple PIC microcontroller 12F508 is used to hardcode the coordinates. The output signals are then driven by the high-current operational amplifier LM7171. This will be enough to power the LED shown in Fig. 6.

IV. CONCLUSION

The system works well under present experimental conditions. It would be very useful if we can integrate this

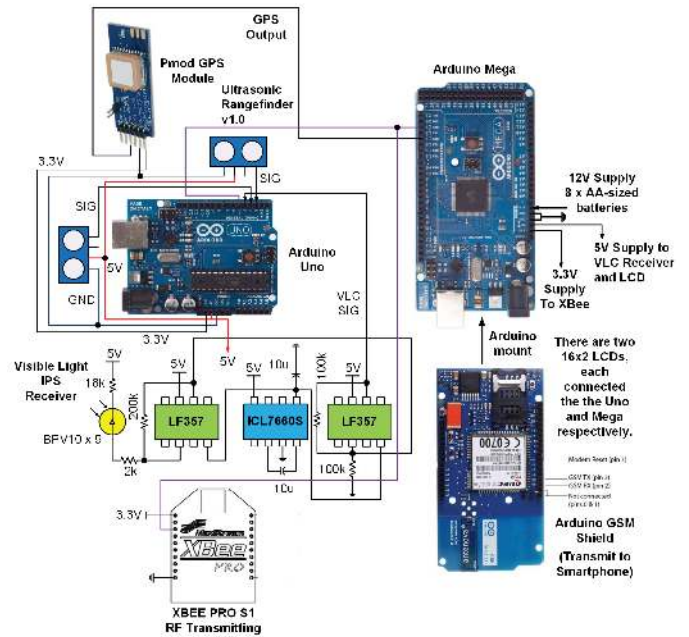


Fig. 5. Circuit diagram of the outdoor-indoor positioning receiver. The XBee Pro transceiver is optional. A GSM module would be enough for most applications and it is more reliable.

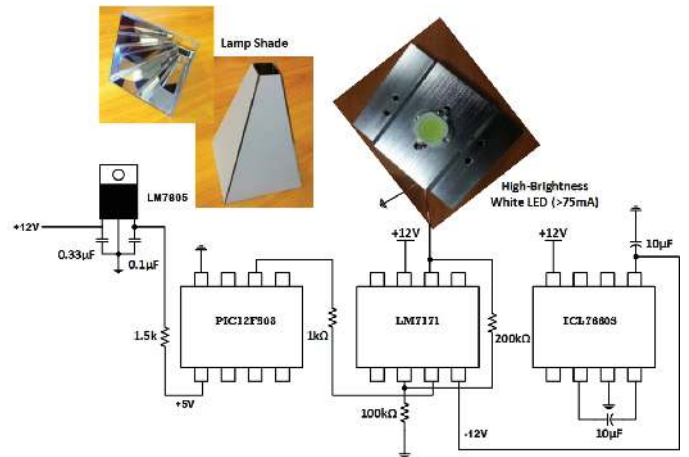


Fig. 6. Circuit of a ceiling-mount LED position data transmitter. A mirror lamp shade is recommended.

technology into the future LED illumination system (at least 12V operation) and Android. By then, we would have a mature network of position emitting white LEDs that will be applicable in old folks' homes, hospitals, and open-concept large offices.

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