Device Free Indoor Localization Using Infrared

Brent Schiller, Shan Lin
Stony Brook University
Electrical and Computer Engineering Department
Stony Brook, New York, USA
{brent.schiller, shan.x.lin}@stonybrook.edu

Kin Sum Liu, Jie Gao
Stony Brook University
Computer Science Department
Stony Brook, New York, USA
{kiliu, jgao}@cs.stonybrook.edu

ABSTRACT
We present a system for device-free indoor localization using infrared (IR) sensors and emitters. The system is able to localize a target in an indoor environment by monitoring changes in how IR light from its emitters is read by its sensors.

1. INTRODUCTION
Device free localization has received a lot of attention in the recent years since it doesn't require users to carry any tag or device. Therefore a device free system can be implemented with minimum intrusiveness. These types of systems rely on passively detecting physical phenomena caused by targets such as: wireless signal [1], Motion [2], ultrasound [3], and pressure [4]. Our system was designed to achieve device free localization through the use of infrared sensors and emitters. Infrared technology offers a number of advantages over sensing modalities such as RF signals, cameras, and ultrasound. RF signals have complex propagation properties in an indoor scenario; therefore the change of signal in the presence of human targets can be fairly complicated. It often requires careful and tedious fingerprinting of the covered domain. Cameras may raise privacy concerns and ultrasound may disturb some pets at certain frequencies. Comparably, infrared sensing poses no privacy concerns as it does not render images with sufficient details to identify the target. Additionally IR poses no harm to human or other animals in the indoor space.

Sensing the propagation of infrared light can be exploited in two ways to achieve localization. Firstly, sensing the shadows created by a target blocking the light of an IR emitter can be used to localize the target. This is because a pair of IR transmitters and passive IR sensors form a tripwire sensor. Secondly, reflections of IR light caused by a target can be sensed as the target interferes with the normal propagation of the IR light. This can be used to determine the targets location because the sensed reflection represents a relation between the target and an emitter sensor pair. By utilizing both the sensing of shadows and the sensing of reflections the system is able to increase the sensing coverage per deployed sensors/emitters as well as the overall accuracy of the system. The systems uses IR light emitters in two forms; passive wide angle IR LEDs and directional IR LEDs mounted on servos. Each style of IR emitter has advantages utilized by the system.

An additional advantage of using IR is that IR emitters can be modulated. This capability will increase the robustness of the system. This is because modulation gives the system the ability to tell which emitter that light detected by an IR sensor originated from. This ability increases the systems robustness against IR noise from the environment. It also allows the system to better characterize changes in the environment which results in increased localization accuracy. Additionally, it allows the system to be able to generate a basic floor plan of the indoor environment. The accuracy of the generated floor plan is enhanced by using directional IR emitters mounted on servos. This is because directional LEDs mounted on servos will give more accurate readings of the angles and distances between emitters and sensors.

2. Robust Guarding
Since the system mainly uses angle of arrival for localization; we consider the problem of robust guarding in a polygon to model the quality requirements of the sensor deployment problem. We place transmitters as guards and require that each point of the polygon to be robustly guarded, in the sense that each point is visible to at least two guards (namely, the transmitters) with a sufficient angle of separation. Our formulation of the robust guarding problem is beyond the scope of this paper; however we conclude that for rectilinear polygon with n vertices and with the placement of guards on the vertices, which we consider a realistic setting for indoor sensor deployment, that [n/2] guards are needed.

3. System Hardware Overview
The system consists of 3 main component types; a Coordinator, multiple Sensor Strips, and multiple IR Emitters. Figure 1 shows the interconnectedness of the system components.

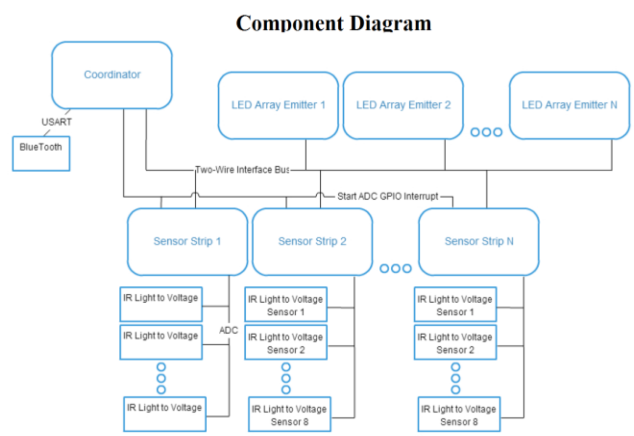

Figure 1: This diagram shows the main components of the system; the Coordinator, Emitters, and Sensor Strips.

A sensor strip is responsible for performing an ADC on each of its IR sensors' analog outputs and transmitting the results when instructed to do so by the coordinator. A Sensor Strip is shown in Figure 2.

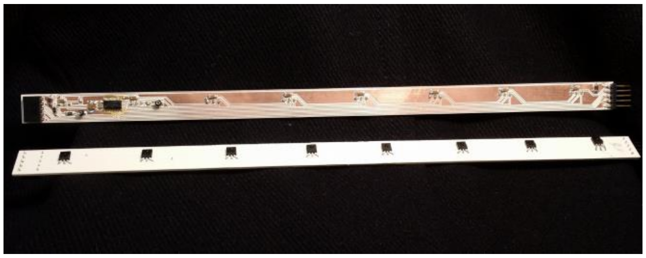

Figure 2: The above picture shows 2 Sensor Strips. The Sensor Strip at the bottom of the picture shows the side with the IR sensors. The Sensor Strip on the top of the picture shows the side with the microcontroller and supporting circuitry.

The Emitters are responsible for illuminating the indoor environment with modulated infrared light as instructed by the coordinator. The emitter utilizes wide angle IR LEDs for maximum coverage of the room as well as directional IR LEDs mounted on a servo. The wide angle LEDs are used for general localization since the provide the best illumination coverage whereas the directional LEDs are used in much more specific scenarios such as floor plan generation and a long range tripwire function. Figure 3 shows an array of wide angle IR LEDs used by an Emitter.

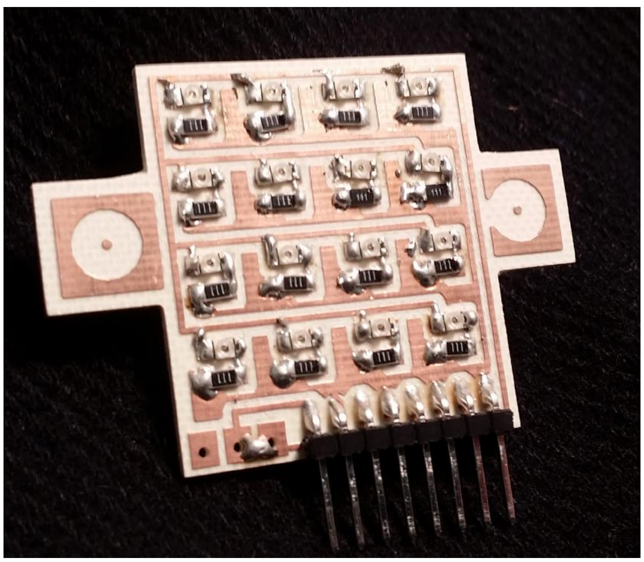

Figure 3: This picture shows an Array of wide angle IR LEDs which is used in conjunction with directional mounted on servos by the Emitters.

The Coordinator is responsible for coordinating the functions of the system. This includes modulating the IR Emitters, initiating and collecting the sensor readings of the Senor Strips and transmitting the results through Bluetooth to a PC where the results can be displayed in a windows application. The Coordinator is shown in Figure 3 and an Emitter is shown in Figure 4.

Figure 4: The above picture shows the Coordinator on the left and the Bluetooth module in the middle that attaches to the underside of the Coordinator.

4. REFERENCES

[1] M. Youssef, M. Mah, and A. Agrawala. Challenges: Device-free passive localization for wireless environments. In *Proceedings of the 13th Annual ACM International Conference on Mobile Computing and Networking*, MobiCom '07, pages 222-229, New York, NY, USA, 2007. ACM.

[2] D. De, W.-Z. Song, M. Xu, C.-L. Wang, D. Cook, and X. Huo. Findinghumo: Real-time tracking of motion trajectories from anonymous binary sensing in smart environments. In *Proceedings of the 2012 IEEE 32Nd International Conference on Distributed Computing Systems*, ICDCS '12, pages 163-172, Washington, DC, USA, 2012. IEEE Computer Society.

[3] T. W. Hnat, E. Gri_ths, R. Dawson, and K. Whitehouse. Doorjamb: Unobtrusive room-level tracking of people in homes using doorway sensors. In *Proceedings of the 10th ACM Conference on Embedded Network Sensor Systems*, SenSys '12, pages 309-322, New York, NY, USA, 2012. ACM.

[4] J. Ranjan, Y. Yao, and K. Whitehouse. An RF doormat for tracking people's room locations. In *Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, UbiComp '13, pages 797-800, New York, NY, USA, 2013. ACM.