Senior Design II UTDallas Summer 2018

In-Wall Infrastructure Mapping

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Project Motivation

The home-improvement market today lacks a device that allows for a complete depiction of the materials behind walls. While there exist devices that can detect various infrastructure materials, an inexpensive all-in-one device that can detect infrastructure as well as create a sharable visual representation is not available. Such a device would be useful to professionals and do-it-yourselfers alike – where users can scan the wall, save a mapping to their smartphone, and use the information for planning and execution of both large and small scale projects. Our project, WallHack, sets out to build an in-wall infrastructure mapping system using readily-available technology including smartphones, sensors, and microprocessors.

Project Objectives

- **Detection:** Identify and differentiate the following materials behind wall: Wooden stud, metal stud, electrical wire/PVC pipe.
- **Mapping:** Create a 2D visual display/map of the material behind wall. Relative dimensional feedback of identified materials will be displayed.
- **Mobility:** Device will be Bluetooth enabled for ease of use and freedom of movement, with battery powered capabilities.
- **Android Application:** Develop an app to visually display the digital data produced by the RF sensor and position tracking system.
- **Hazard Identification:** Detect live AC electrical wire and alert user via LED or other indicators.

Design Overview

Hardware Design

- Data acquisition is achieved by Walabot's 3D RF-based sensor. This board includes 18 linearly polarized broadband antennas operating at 3.3-10 GHz.

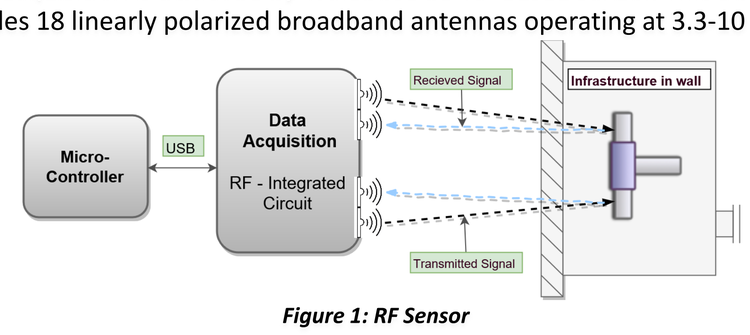

Figure 1: RF Sensor

- Position feedback is being implemented by a combination of optical sensor (ADNS 9800) and IMU (LSM9DS1). Similar to an optical mouse, a signal processor analyzes the change in position by comparing images of the surface as the device moves across the wall.
- IMU (LSM9DS1) consists of a three-axis gyroscope and accelerometer pair that allows for orientation awareness, thereby improving the accuracy of location tracking and eliminating the constraint of perpendicularity with the floor.

CAD Model

Figure 3: CAD Model of WallHack

AC Voltage Detector

- AC voltage detector is designed using an operational amplifier to bump-up the voltage off an antenna (16 gauge wire). The signal is then passed through a full-wave rectifier and capacitive circuit to convert the 60Hz AC signal to a DC signal.

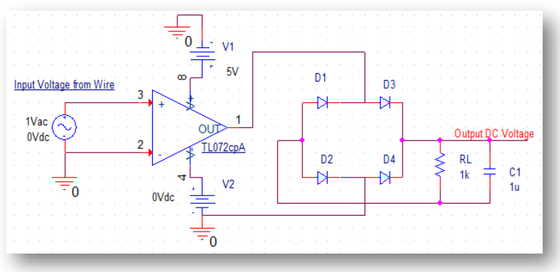

Figure 4: Schematic of Live-Wire Circuit

Software Design

- A Python script running on the Raspberry Pi reads signal amplitude from the RF sensor using the Walabot API, and assigns a material type based on the amplitude.
- Simultaneously, the Arduino Pro Micro uses the optical sensor and IMU to track the location of the device on the wall, and sends the location data to the Python script via a serial connection.
- Material type and location data are both sent over Bluetooth to the Android device.
- Android device receives location data and material type and marks the material type at the specified location on a picture of the wall.

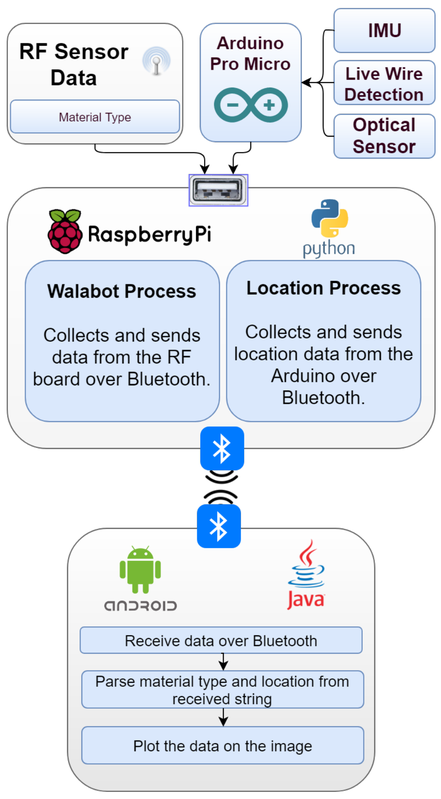

Figure 2: Software Design Diagram

Mobile Application

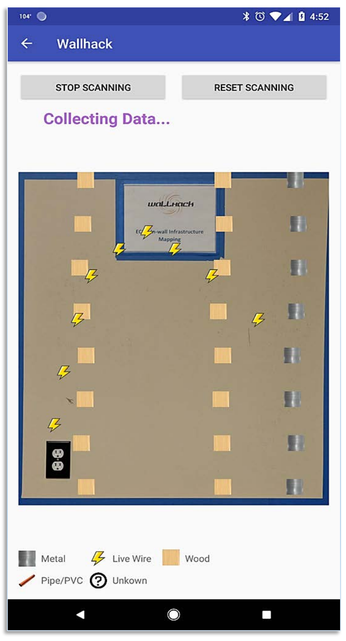

Figure 5: Screenshot of WallHack App

- The WallHack mobile application was designed and programed with Android Studio, using Java for functional programming and XML for layout design.
- Utilizing the Android Camera API and the Yalantis Ucrop image cropping API, the user can take a picture of the wall and crop it to include only the area they are going to scan.
- The application receives both material type and location data from the socket, parses them, and uses the Android Canvas API to draw the respective texture on the picture of the wall, as seen in Figure 5.

Conclusion

WallHack is projected to cost 50% less than competing products, while offering an improved feature set. The cost savings, along with the ability to generate an accurate depiction of the in-wall infrastructure will aid professionals and DIY enthusiasts save money, plan efficiently, and avoid potential project hazards. Furthermore, consumers can share mappings with contractors and inspectors, streamlining the process of home improvement.

Ethics Statement: All results from the WallHack should be tested and verified with other commercial wall scanning devices before drilling or cutting into any scanned wall surfaces.

Design Validation:

- ☑ The RF sensor is able to differentiate between wood studs, metal studs, PVC
- ☑ The device is able to detect any presence of live wire within 4 inches of WallHacks position on the surface of the wall
- ☑ Tracking system incorporates IMU with optical sensor to eliminate the constraint of maintaining WallHack's parallel orientation with the floor
- ☑ The represented materials displayed on the image overlay are accurate to within 4 centimeters of actual infrastructures location behind the test wall
- ☑ The WallHack Scanner runs on battery power and connects wirelessly to app
- ☑ App successfully receives and plots data from the WallHack Scanner

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