Poster: Phones and Robots: Brains and Brawn

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Abstract

Our project demonstrates the capabilities of a symbiotic phone-robot hybrid device, wherein the robot provides gross motor control and the phone provides fine course corrections and sensing capability. The crude robot generates movement subject to mechanical wheel asymmetries and non-linear motor effects; the inexpensive phone provides a variety of on-board sensors and a reasonably powerful CPU/memory. We demonstrate the utility of the combined device to provide a reasonably accurate autonomous signal mapping on an untrained floor plan in our building.

1 Introduction

Signal mapping is an essential but tedious task for analyzing and improving the availability of the growing network of wireless technologies. As our everyday lives become more dependent upon wireless electronics, improvements in signal strength are needed. Though many devices have been created to improve signal reception at a given location in a network, the important question of *where* to place these devices is usually answered only after performing thorough signal mapping.

Signal mapping comes in many different forms and for many different purposes. One of the more well known projects was taken on by Google to improve their online maps. Google uses the "Google car", which is driven around with a camera mounted on the roof. This camera collects pictures for street view maps. Other more closely related works use signal strength data collected from multiple smartphones [1] or mobile robots [3] to locate a base stations or dead spot in a network. Yet others utilize a sensor-embedded network to act as a navigation system for a robot [2].

In this paper, a new efficient technique using a combination of a VEX Robot and a smartphone is described for autonomous signal mapping. The combination of the sensitivity capabilities of the phone and the robot creates a small sensor network allowing the robot to navigate autonomously through a building while mapping out the signal strength.

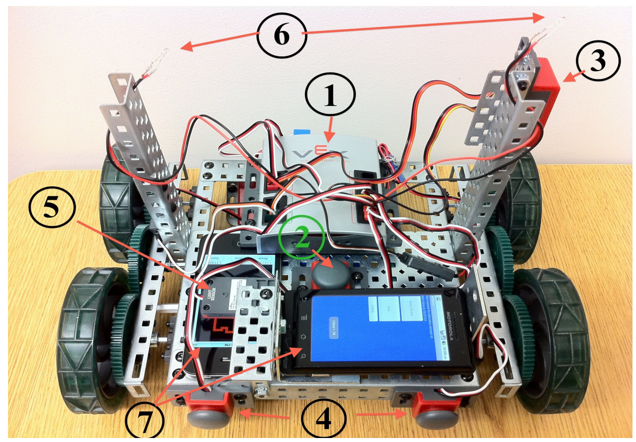

Figure 1. Phone Robot Hybrid: 1- VEX Microcontroller, 2 - Start button, 3 - Ultrasonic Range Finder, 4 - Front bumpers, 5 - Light Sensor, 6 - LED's used for debugging, 7 - iPhone 4 and Motorola Droid.

2 System Design

2.1 Components

Our automated signal mapper uses an iPhone, a Motorola Droid, and a VEX Robot all in tandem to navigate through an unknown area and collect signal data. The VEX Robot is equipped with multiple sensors (Fig. 1) and a VEX Microcontroller allowing the sensors to interact with our code. The robot's front two bumpers notify the robot when it has reached a dead end. The ultrasonic range finder allows the robot to notice a possible left turn, and it aids with straight movement (a serious challenge for the crude device!). The light sensor on the robot provides feedback data from iPhone in the form of encoded messages through flashing the iPhone's screen. A simple application was developed that utilized the iPhone's internal gyroscope and accelerometer to create and accurate map of exactly where the robot has traveled. Finally, due the lack of a public API for collecting signal strength on the iPhone, a Motorola Droid is utilized to log signal strength data.

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2.2 Functionally

Our hybrid device can be placed on any smooth clean surface, without jagged walls, and is able to map out the floor plan. The robot performs an engineered depth-first traversal of its floor space. At its core, the robot attempts to travel straight until a left turn is available. If there is no left turn the robot continues straight until it senses a wall. Once at the wall, the robot will make a right turn and again follow the simple guideline of traveling straight until a left or a wall. If the robot cannot continue straight or turn right, it will travel back to the last left turn and continue straight from there. Each turn and its timestamp is logged in the robot's program on the stack and is deleted once the robot has traversed those steps backwards to the last left turn.

While implementing this algorithm the robot can get stuck in a loop circling an object or path. For example, if the floor plan has a crate in the middle of the corridor, the robot will eventually get stuck making left turns around the crate. In order to correct for this error, the iPhone uses its map to sense if the robot is stuck in a loop and flashes its screen appropriately; the robot's light sensor recognizes, decodes, and then interprets this as a signal to go back to the last left turn.

2.3 Challenges

Through many trials conducted on this hybrid device, certain challenges surfaced. These problems stem from the mechanical errors in the structural and hardware design of the robot. Using the sensor network created by the hybrid device, some of these errors were minimized.

Firstly, the robot struggled to travel completely straight mainly due to the mechanical asymmetry of robot. Meaning, one wheel wobbled or slipped more frequently than other causing the robot to veer off path. Also, the increase in temperature of the motors as the robot travels longer distances results in less accurate speeds and likely contributes to this error. Finally, these issues contributed to an inconsistency of the robot in implementing exact 90 degree turns.

In order to correct for the robot's veering motion, the ultrasonic range finder (URC) is used in a sensor feedback loop to adjust the speed of each motor. Additionally, the URC corrects for the robot's failure to perform exact 90-degree turns by straightening the robot's path to follow a wall. This correction relies on the robot's proximity to a wall. In large open areas, the URC fails to correct for the robot's veering due to the maximum range of the sensor only being three meters. In such cases, the iPhone's compass is used to help the robot stay on path. Again the compass is used in a sensor feed back loop to adjust the speed of each motor. Messages sent from the iPhone in the form of its screen flashing, are detected by the robot's the light sensor and decoded to adjust its motors appropriately. The robot's program does not solely rely on the compass because the iPhone's magnetometer is affected by fields generated from the moving motors.

3 Results

The hybrid signal mapper was tested in an office building. It successfully collected and mapped the signal for a floor plan of the building that was not known to the system.

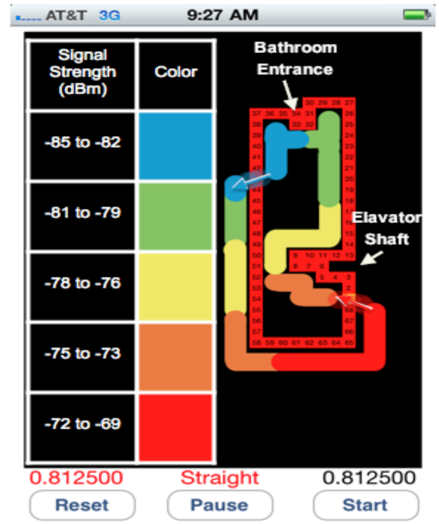

Figure 2. Signal Map: Red = Strong Signal, Yellow = Medium Signal, Blue = Weak Signal.

Ten trials were run and averaged in order to obtain accurate readings of the signal strength (in units of dBm). Fig. 2 is a sample output of the iPhone's map with the superimposed averaged signal reception data. The color scheme depicts the change in signal and the red boxes with numbers represent the ordered path traveled by the robot.

4 Conclusion

In conclusion, the phone-robot hybrid device successfully created and utilized a sensor network to improve the functionality of the robot. The hybrid device effectively mapped the signal reception of a previously unknown floor plan. Signal mapping is just one of many possible applications for this given hybrid device. In a broader statement, this project has illustrated how the creation of a small sensor network through a hybrid device with an everyday smartphone can provide valuable autonomous applications.

5 Acknowledgments

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6 References

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