Project Nomad – Indoor Robot Navigation Using Wireless Radios

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Abstract – **It is the goal of this paper to propose and describe a series of intended implementations for wireless location finding, and describe the unique challenges encountered with each. It will also discuss the ultimately settled-upon simple approach, and what meaningful results can be determined from such an algorithm.**

1 Introduction

There are a variety of wireless technologies readily available in consumer products. As an example, most modern smart phones can contain the following radios capable of being measured inside of a building: IEEE 802.11b/g/n/ac, Bluetooth 3.0/4.0, Near Field Communication, Infrared, GSM, CDMA, and LTE. Also, despite not being a radio, speakers broadcasting at high frequencies would also be useful for locating a human. Needless to say, there's a diverse set of data that could be used to assist with finding a human in an indoor environment, should they provide their information – for this paper, we will be focusing on Wireless Ethernet.

As time has gone on, the ubiquity of wireless Internet has become increasingly apparent. The continued growth in the sales of devices of the laptop, phone, and tablet form factor have gone on to outpace that of any other technology-related device [1] – it is for this reason that we propose that location tracking via the wireless radios found in these devices should be given serious consideration. We believe there to be a great amount of potential in the applications for this technology. Such application is not the topic of this paper, but suffice to say, there is significant motivation for research of this topic to be conducted.

This is a problem that dates back as far back as 2004, when Wireless Ethernet location finding first began picking up traction. At the time, location prediction would work with roughly 70 percent accuracy[2]. However, a recent attempt to re-tackle this problem in 2013 had more successful results, with a best-case average accuracy of 90 percent, and total accuracy across all data sets of greater than 80 percent [3]. We will not be attempting to recreate these results, but rather, attempting to approach the problem in a more simplified fashion whilst maintaining a semblance of accuracy.

This paper describes the process we followed, over the course of an academic semester at Clarkson University, to arrive at a simplified model of location finding via wireless access points. It will also detail the challenges encountered along the way, and the end results of our work.

2 Challenges

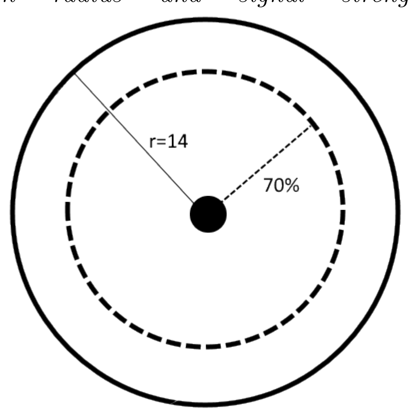
The initial project plan was to model an algorithm around a set of real world data collection, avoiding the problem of building a complex simulation of wireless networks in an enclosed space. However, this in itself presented a series of unique challenges – after several months of ongoing troubleshooting and misconfiguration issues with both the hardware and software involved, with entirely different sets of hardware and software swapped out on more than one occasion, this approach was dropped in favor of a simulated model.

This, too, posed a complex set of challenges. The initial approach for this idea seemed relatively simple: using a compilation of research papers from other academics, attempt to replicate the relative results of any given one, and construct a robust enough simulation to verify these results. However, as two third year Computer Science undergraduate students, neither author possessed the proper skill set in mathematics to see this task through to completion. Additionally, no papers could be found that actually utilized or provided any proper simulation techniques – all tests and analysis were performed on real equipment. With this roadblock encountered, the intended method switched once more.

The final idea proposed and explored prior to switching to the current model was that of wave propagation simulation. The rationalization for this approach is that it is one well-provided for via physics simulation libraries, with a plethora of robust information presented via freely available resources on the Internet. This presents an unexpected difficulty of its own: compute time. Jason Cole provides an excellent example of the exact problem we hoped to tackle in his article *Helmhurts* [4]. Performed upon a generated map of his apartment, Cole presents an algorithm to conduct Wireless Ethernet Wave Propagation from a single point throughout the small area. This will take into consideration the reflectivity of the material walls are constructed out of (though ceilings/floors are not considered), allows for moving wireless signals, and could be used in multiple sweeps to emulate more than one access point. However, even after thorough optimization attempts, the best run time of this algorithm takes hours and large amounts of computer memory to generate a result of just a few seconds of propagation – the quoted simulation speed is 1 millisecond per second on a modern smart phone, on an image of resolution 350x600, without any walls. While computing the wave patterns for a given area in advance using the floor layout/access point locations on that floor, and attempting to devise a way to use their intersection to find a user is possible, it is far beyond the scope of this project.

3 Methodology

Fig. 1 – circle with a potential position 'ring' based on radius and signal strength



The model that we ultimately came to use is a vastly simplified one compared to the original intent. For each access point on a map defined by the user, we construct a circle of potential broadcast area that a wireless access point can reach. We assume a linear decay of signal strength throughout the broadcast region, for the sake of simplicity – that is, the center of the broadcast region is at 100 percent signal strength, and the outer rim is at 0 percent.

Initially, we had a base implementation for ignoring all wireless signals that encountered wall collision. However, as it turns out, Wireless Ethernet waves are capable of penetrating through materials even as dense as concrete, albeit with some signal loss. [4,5] As such, we do not modify the radius of the circle at points that are beyond a wall, as any given material would have a different level of transmission through its surface.

From there, we construct a series of 'estimation rings' that the user may be located in. These are calculated based on the provided signal strength of the user in their present location, with a five percent randomized signal noise applied every ten steps. That is, for any given wireless access point the user is in range of, the radius of that given wave representation has its radius multiplied by the value of the user's signal strength. This constructs a sub-circle that represents all the possible locations the user may be standing in for that access point, plus or minus five percent of random signal noise variance due to Wireless Ethernet waves not propagating identically each time they're transmitted, due to existing waves and potential impeding objects around the access point.

From there, the algorithm attempts to find a point of intersection of all wireless access points that the user is capable of seeing. Upon travelling to that point, it will check to see if the user is within the predicted range of its camera (which is a 15 pixel radius around the robot). If the user is not spotted from this location, the algorithm will then send the robot along a travel path that follows the ring of strongest signal strength. If the user is not spotted along this ring, it will travel upon each subsequent ring of signal strength greatest to least, before giving up.

4 Results

As described in earlier sections, this project saw more than its fair share of unplanned tangents and changes. The difficulties encountered in the development of this project resulted in a greatly simplified and rough implementation of the plan that was originally laid out. The simulation of a Turtlebot with a known map of its environment is acheived using the turtlebot_stage package. Following this, a pathfinder based on a modified RRT implementation, with added elements of the Wifi localization algorithm described in previous sections is applied to the world that has been simulated. This path finding node attempts to localize the human goal, and devise a path between them. This path is developed in the form of a series of points which are intended to be the end points of straight line segments in free space. Following the generation of these points, they are passed through to another node, which is intended to pass them as appropriate MoveBaseGoal messages to the move_base node. This node is intended to take the goals passed to it as attempt to move the Turtlebot towards them.

In the current implementation, the

simulation of the Turtlebot works. The path-finding algorithm does work moderately well, but has many failures, including no guarantee that it will actually find the correct path to the user. The intermediate points, when found, are published properly, but many issues remain with setting up the proper reference frame between stage and the image. Other issues using the move_base node include difficulties with the generated cost map for the world file. These issues result in the action server never receiving a correct response, and thus any subsequent points which are called for by the visualizer are never considered. Thus, while the visualizer continues to try to find a path, the simulated robot never moves, while the move_base node continues to struggle with the goal passed to it.

5 Summary

This project, while it never saw a working implementation fully complete, was a great deal of work, primarily in the realm of setting up and configuring ROS and the development and simulation environments. Despite the less than complete final product, and the great many difficulties encountered along the way, this project was highly educational. Both of the authors learned many specific implementation details about ROS and the Turtlebot platform. Other topics which this project shed light on were the fields of advanced mathematics (particularly calculus and abstract linear algebra), as well as probability and statistics. The specific problem of Wifi simulation and localization within Wifi fields was another valuable learning experience for both authors, shedding light on topics we had either never considered or never had the chance to fully explore. In the end, while this project concluded with an only semi-operational simplified model of the original concept, it served as an invaluable learning experience for both authors, and will likely be a source of knowledge for future endeavours in the field of mobile robotics.

6 References

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