Control of Collaborating Entities: An Introductory Approach to Target Location Systems

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Introduction

For many applications, teams of robots can prove to be cheaper and more effective than a single complex unit. In space missions, for example, smaller satellites are much cheaper to build and infinitely easier to launch- if the satellites are small enough, they can piggyback on larger rockets that have unused space. A more earth bound example lives in the realm of quadcopters. Quadcopter technology is rapidly advancing. Sensors are becoming smaller and more accurate, flying mechanics are becoming more precise and air time is increasing. The purpose of this research is to conceptualize a system to aide in Search and Rescue (SAR) missions.

Currently, most SAR missions are done either by foot or by helicopter. These methods are slow, dangerous and one dimensional. Quadcopters could conduct quicker and more efficient SAR missions. The deployment of drones is starting to become more common in aiding SAR teams by taking overhead snapshots of disaster areas. These snapshots are helpful but don't come close to the potential quadcopters have for aiding in SAR missions. This research aims to improve the functionality of drone systems in one key area: formation-flying. A flying formation of quadcopter drones can sweep a larger area than one alone and could pinpoint any signals coming off of devices, such as a cellphones, and converge upon the target.

Using a team of three Raspberry Pis communicating through XBee radio modules a formation and location algorithm will be simulated, first in MATLAB and then a full scale test on a football field will be realized- the results of which can be implemented by a team of quadcopters much more efficiently, autonomously, and over a larger area than that tested.

Methods

- The target locating algorithm was first simulated in MATLAB for a proof of concept and for building a foundation to work from.

- The relationship between the Received Signal Strength Indicator (RSSI) readings and the distance between two XBees was then determined by setting up two Raspberry Pis on stools a set distance away from each other and pinging for RSSI values every yard.

- An equation to model the RSSI/Distance data was discovered. Using this data the algorithm and simulation was improved.

- A full scale test was performed on a football field. The triangle formation of Pis were placed on boxes at mid field, the target was placed near the 10 yard line. The Master Terminal Unit (Laptop) retrieved the RSSI values from each Pi. These values were inputted into MATLAB which ran the algorithm and outputted a x and y value which to move the formation. This process was repeated until the target was located.

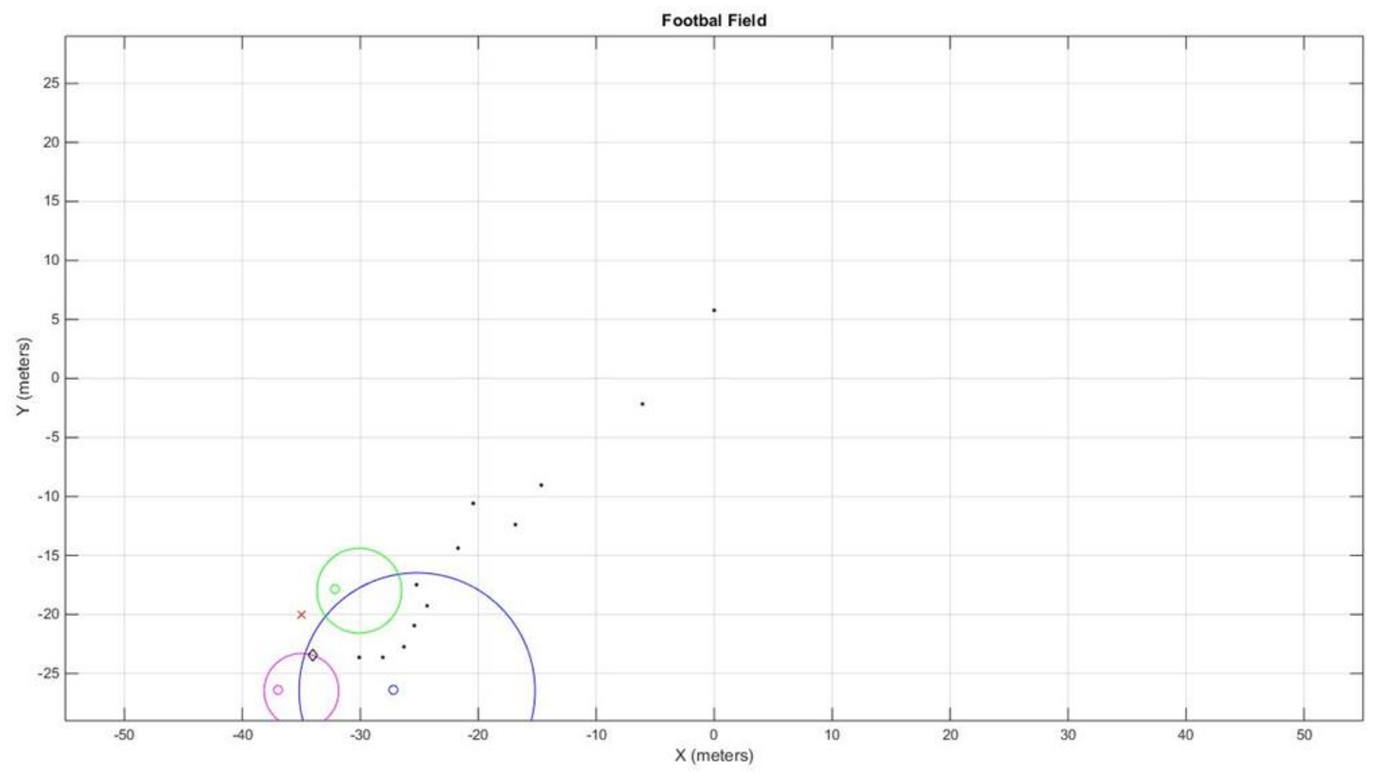
Full Scale Test

1. Formation at mid-field.

2. Target at 10 yards.

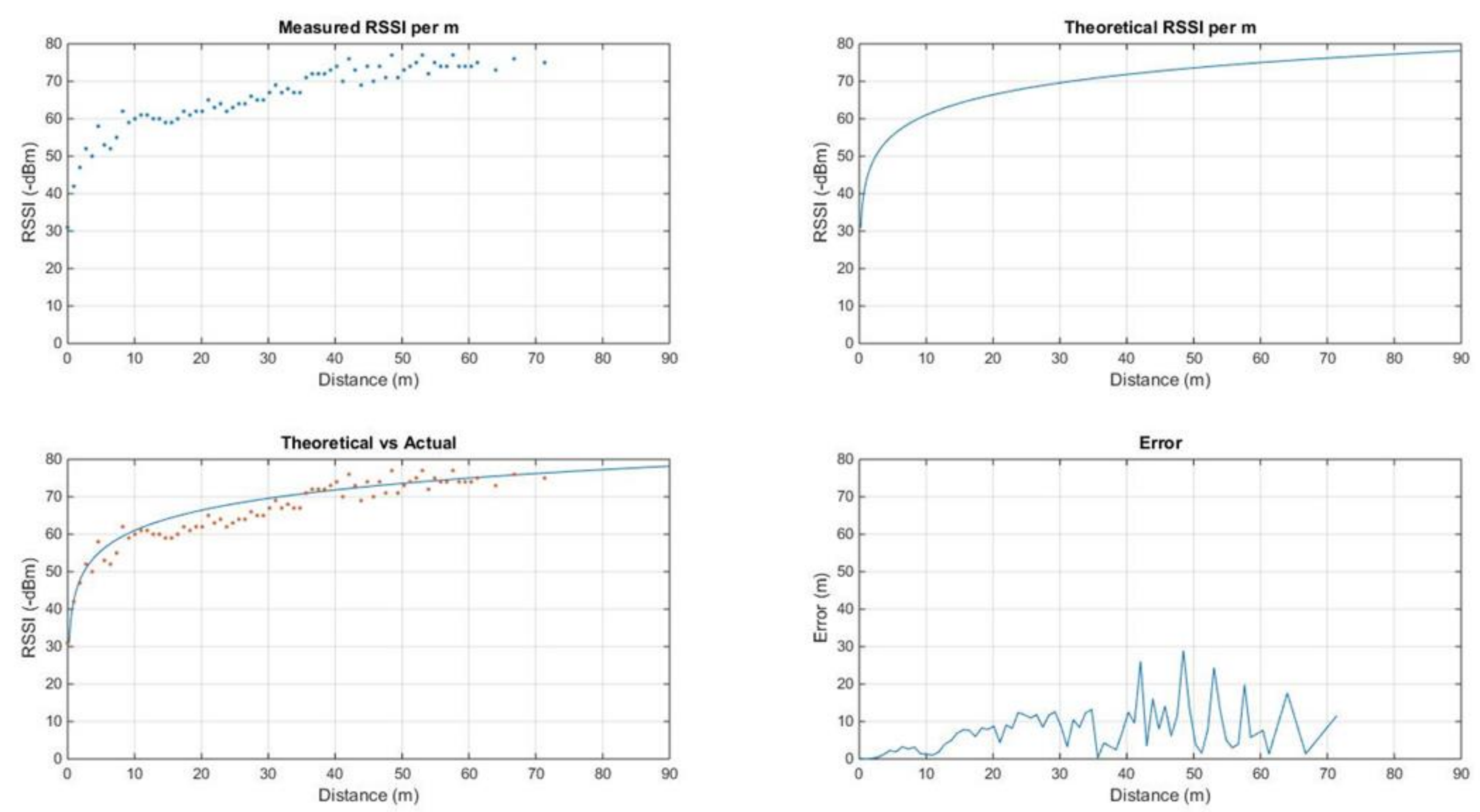
3. Final result.

MATLAB Simulation



The MATLAB simulation outputs the following figure. The circles around each drone are for visualizing the algorithm. The black diamond is the predicted location of the target. The red X is the target. A black dot at the center of the formation is plotted every step for visualizing the formation path.

RSSI/Distance Data



Analysis of the data obtained from the RSSI/Distance test. The trend is best modeled by the following equation[1]:

$$distance = 10^{\frac{(RSSI-43)}{18}}$$

This equation had parameters that were optimized for the football field. The error never exceeds 30 meters.

Conclusions

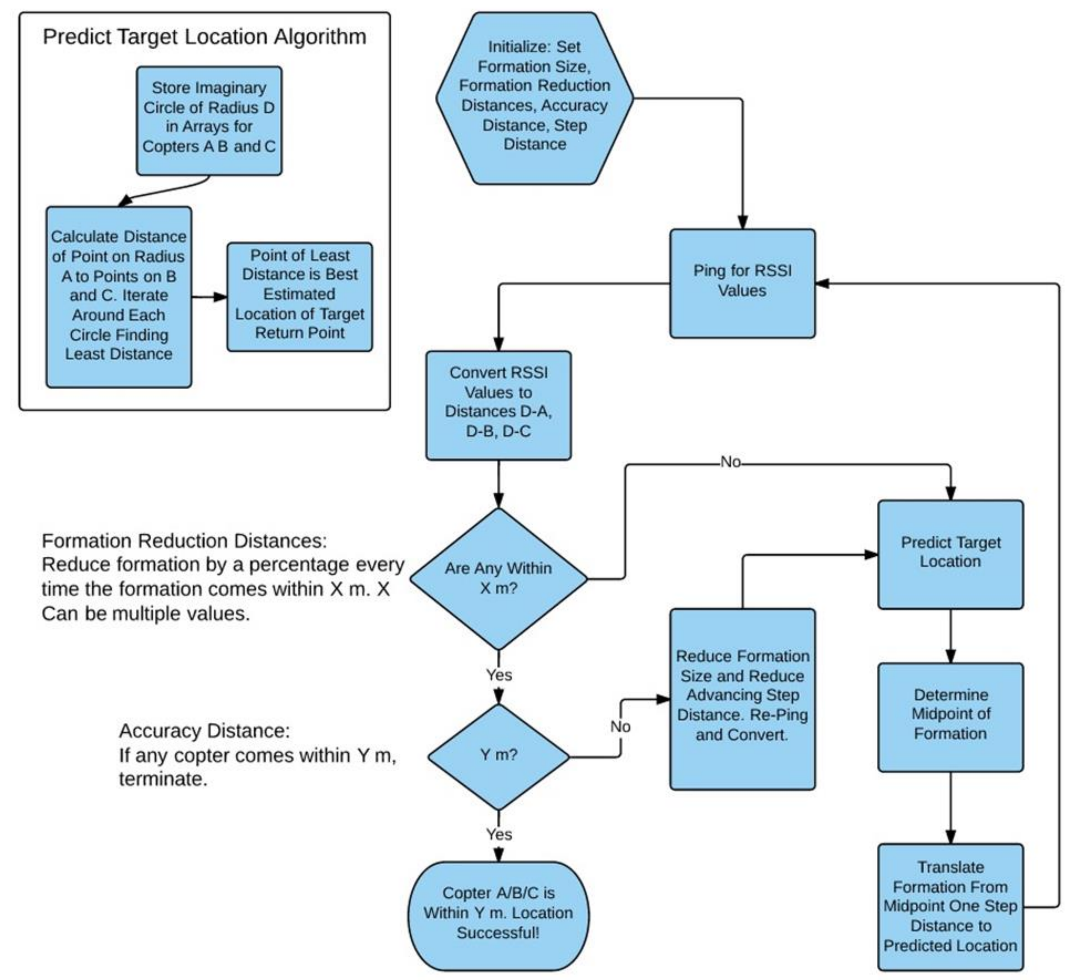
The full scale test was more of a success than predicted. On first try, the formation tended towards the target very efficiently. Considering the imprecise nature of measuring and moving the boxes by hand, the algorithm seems to be very flexible. As long as the formation stays relatively stable, the predicted point will almost always be in the general direction of the target.

The full scale test was conducted in two dimensions, the formation and the target being on the same level. Real drones would fly much higher than the target and enter three dimensional space. By inspection, this could be handled either by creating imaginary spheres instead of circles or by converting the RSSI readings into a radius length provided that the copters can determine their height above the target. Further investigation is needed on this aspect.

A real search and rescue system would encounter many problems not considered in this research. By using XBees, the radio signals were isolated in frequency and protocol. Picking up a lost hikers cell phone or wifi signal would require different hardware or protocols. Also, the environment will most likely be much more noisy or extreme. Many things should be considered if building towards a final product. But in a controlled environment this system works well as an undergraduate lab or final project.

This research proved the concept that a team of drones can locate and converge upon a target. This project can be repeated through learning radio communication, algorithm development, feedback, and embedded systems. This project lays a foundation for a target location system using formation flying drones and leaves room for advances and improvement.

Algorithm Flowchart



References and Acknowledgements

[1]B. Lee and W. Chung, 'Multitarget Three-Dimensional Indoor Navigation on a PDA in a Wireless Sensor Network', *IEEE Sensors Journal*, vol. 11, no. 3, pp. 799-807, 2011.
[2]P. Malmsten, "python-xbee Documentation", Release 2.1.0, 2013.