Summer 19: beamforming project

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1 Big picture

Cooperative communication with aerial vehicles has been a tremedrously develped area in wireless communication, therefore this project is about to explore the optimization on the control for N number of aerial vehicles to reach the maximum throughput. The reason we care about the problem is because aerial vehicles are heavliy used to take photos or video about various landscape, which requires a large data storage unit inside. however, this approach will have bad effect on the control of aerial vehicles, so that we want these aerial vehicles to transmit data wirelessly. In the future, we can extend our research to any aerial vehicles. the approach to the problem would require gradient descent(GD) and simulation in softwares. We have to build mathematical model of the system, solve the optimization problem and verify it in real world. In the first few weeks, we do research with only one aerial vehicle, analyze the performance of the system, then we can have N aerial vehicles together and find the path which maximize the throughput. I think I can have a solution following my research path listed below and this approach will provide an effective solution for future aerial-vehicle research.

2 Specific project scope

this research will focus on making mathematical model, simulation and field measurement(if possible). mathematical model will help us define the problem with math language, better understand our constraints and characterize the solutions. we can make different assumptions to generate the results. simulation is a way of verifying the functionality of our model and then we can see how close our ideal case assumption and real world measurement. In figure 1, it's a single aerial vehicle with base station(BS) communication. this case is simple to optimize because we only think of LOS case, in our assumption, there should only be one MPC(multipath component) from BS to aerial vehicle. However, in reality, it's impossible to achieve, we will have all the interference. Afterward, we have a more complicated case: several aerial vehicles are present to form a beamforming. My task for the project is specifically dynamic control of the aerial vehicles to achieve maximum throughput.

3 Background

before the project, we need to know a lot of things as prerequisites, such as quad-rotor dynamic control, differential equation, wireless communication and software languages. My previous research experience provides with solid base of wireless communication knowledge, such as channel model, calculating SNR. Matlab programming skill is a great plus. In this project, what I don't have is about quadrotor dynamic control and knowledge about reinforcement learning. The related problems are about estimating of the environment[1], generate function of SNR[2]. With these knowledge, we can divide the whole project into parts, each of us solve one of it.

4 Goals, deliverables and tasks

By the end of this summer, I should have drive the system model mathematically, generate some algorithms for maximizing throughput. Furthermore, I will mount all the documents together for future researchers to read through. In terms of deliverables, we will have paper ready for the ICRA 2019. My task is first to read math literatures about the estimation algorithms and get familiar with software defined radios. Applying the knowledge to design the algorithm and with simulation to verify my algorithm.

4.1 tasks break down

- **Before June 7** Finalize proposal, read and watch material about quadrotor control and reinforcement learning. Meet other researchers in our group and know the progress of all the project.
- **June 8 - June 16** In Canada
- **Before June 30** Roomba Operation Understood, Additional Literature Reviewed
- **Before July 7** Single-Antenna System Hardware Designed and Built
- **Before July 14** Estimation of Signal Strength Method 3 Completed
- **Before July 21** Double-Antenna System Hardware Designed
- **Before July 28** 2-Antenna Experiment Completed
- **Before August 4** Data Analyzed for Trends, Method 3* Model Literature Reviewed
- **Before August 11** Method 3* Model Developed and Tested
- **Before August 18** Best Model Determined
- **Before August 25** Model Tested under Changed Environmental Conditions

- **Before September 1** Model vs State-of-the-Art Compared
- **Before September 8** Networking Methods Description Finished
- **Before September 15** Conclusion Finished

[1]Y. Mostofi, M. Malmirchegini and A. Ghaffarkhah, "Estimation of communication signal strength in robotic networks," 2010 IEEE International Conference on Robotics and Automation, Anchorage, AK, 2010, pp. 1946-1951. doi: 10.1109/ROBOT.2010.5509677 keywords: channel estimation;multi-robot systems;probability;robots;telecommunication channels;communication signal strength;robotic networks;wireless channel;multi-scale probabilistic model;channel estimation;communication-aware motion planning;Robots;Communication system control;Robotics and automation;Mobile communication;Communication channels;Fading;Shadow mapping;Channel estimation;Frequency domain analysis;Motion planning, [2]A. F. Molisch, Wireless Communications, New York:Wiley, 2005.

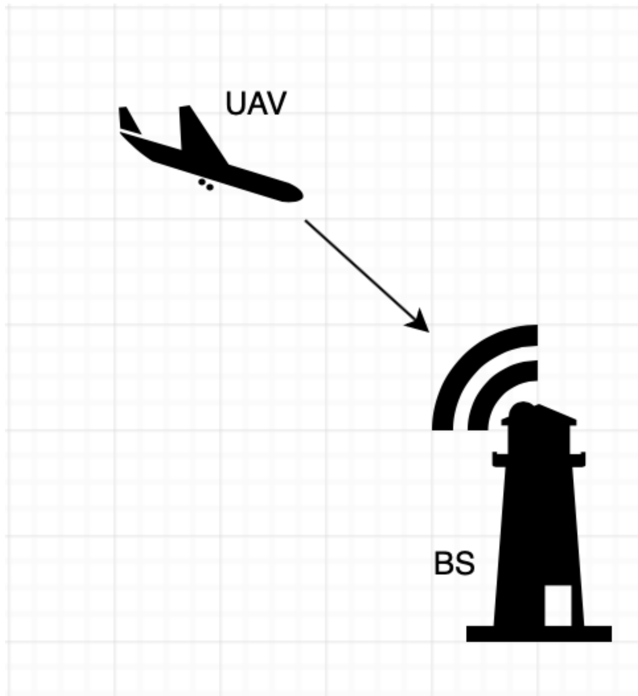

Figure 1: single aerial vehicle

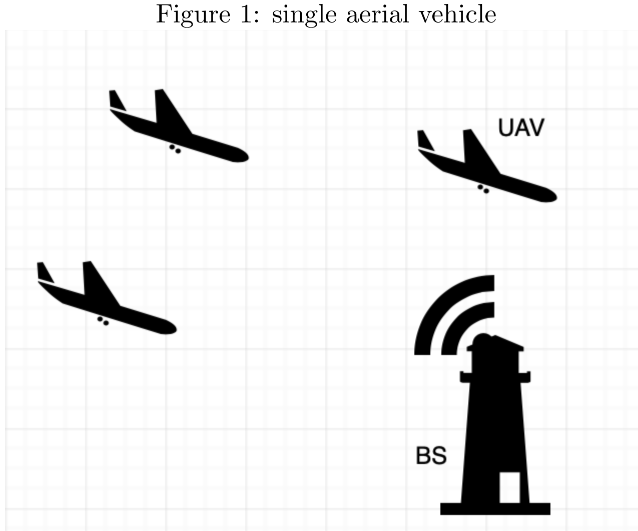

Figure 2: multiple aerial vehicles