# 3D Spectrum Sensing Map via Drone Mounted Receiver

Creating a 3D signal map using
a drone as a mobile receiver

01.13.2017 Presentation

Location

# Rutgers Wireless Information Network Lab

- **Research mission**: To advance the development of wireless networking technology by combining the resources of government, industry and academia
  - Working to address the need for connecting large numbers of people and objects wirelessly
  - Some problems being worked on:
    - Scaling wireless system capacity from Mbps/Sq-km to Gbps/Sq-km.
    - Promoting spectrum efficiency and increased co-existence between unlicensed band services.
    - Achieving ultralow-latency in wireless access networks.

- **Educational mission:** To train the next generation of wireless technologists via graduate research programs that are especially relevant to industry.
  - Typically has a pool of ~40-50 graduate and undergraduate students
  - Most students work on projects that lead to their MS or PhD thesis in either the ECE or CS departments at Rutgers
  - Runs annual WINLAB Summer Internship Program that offers internships in a university research setting to highly talented high-school, undergraduate and graduate students

WINLAB
WIRELESS INFORMATION NETWORK LABORATORY

Mentor

# Prof. Wade Trappe, Ph. D

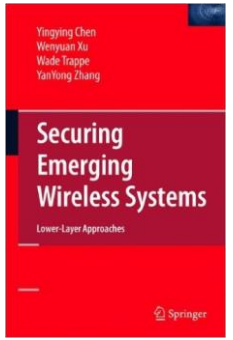
**Education and Position**

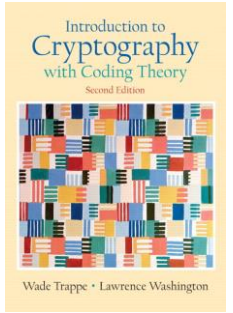
- **B.A.** with Highest Honors, Mathematics, University of Texas at Austin, 1994
- **M.S.** Applied Mathematics and Scientific Computing**,** University of Maryland, College Park, 1999
- **Ph.D.** Applied Mathematics and Scientific Computing, University of Maryland, College Park, 2002
- **Professor** in the Electrical and Computer Engineering Department at Rutgers University
- **Associate Director** of the Wireless Information Network Laboratory (WINLAB)

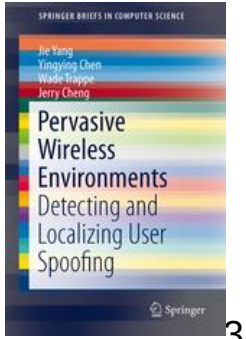
**Previously worked on projects including:**

- Cybersecurity
- Communication systems
- Security and privacy for sensor networks
- Physical layer security for wireless systems
- Development of wireless testbed resources (the ORBIT testbed)
- Led a DARPA initiative into validating and prototyping physical layer security mechanisms

**Currently** leading an Army CERDEC (Communications-Electronics Research, Development and Engineering Center) project on cognitive radio networks and MIMO (multiple input, multiple output) communications.



# Project objective

**To create a 3D signal quality map using a drone as a mobile receiver carrier**

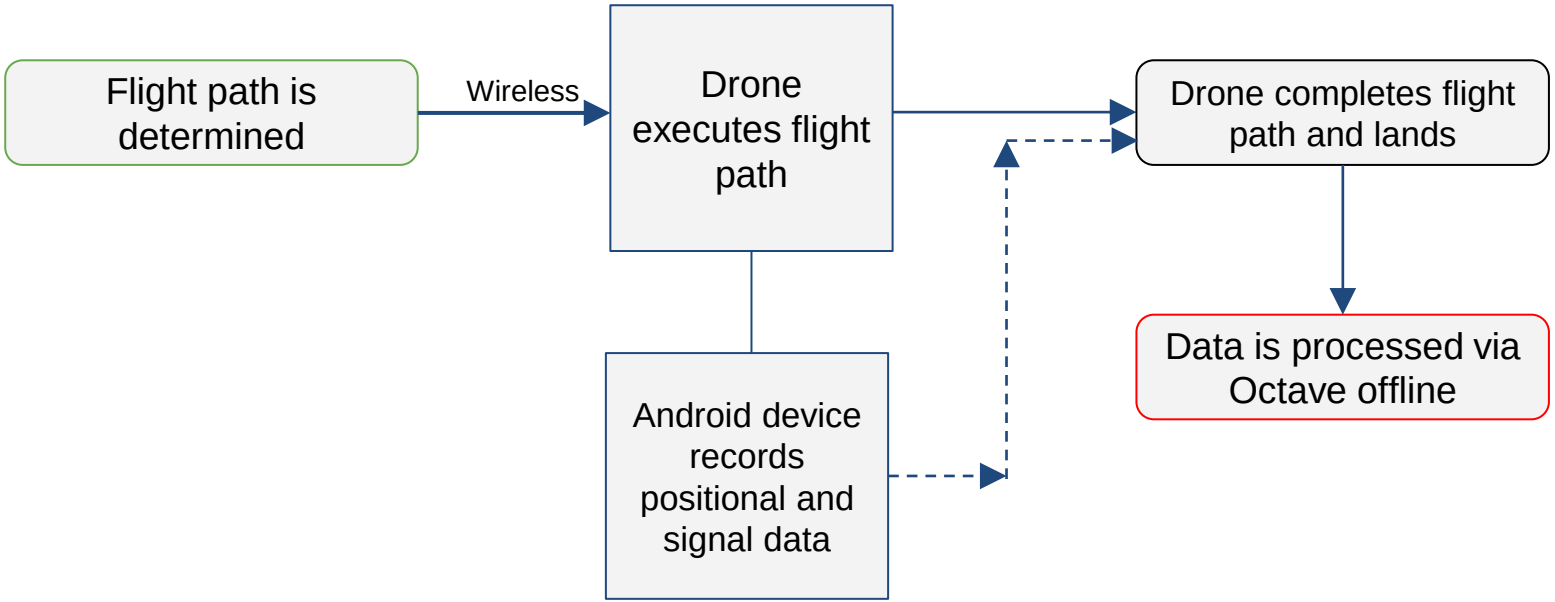
This will be accomplished through the usage of the following:

- 3DR Solo drone
  - Courier unit for mobile receiver
- Mobile Android device
  - Continuously stores the signal strength indicator, GPS coordinates, altitude and time in a log file
- Octave program
  - Reads the data from the receiver log files
  - Plots data points in three dimensions
  - Fills in the space between data points using custom algorithm

Blue represents successful completion, green represents in progress/pending approval, red represents an unresolved issue

# Purposed Design Diagram

**Simplified diagram of the various components and their interactions**



# Drone Flight Path

- Accomplished through the program Mission Planner
- Determined before launch via waypoints
  - Can also generate an autogrid
- Saved to a “mission” file
- Uploaded to drone via wireless

*Mission Planner auto-generated grid*

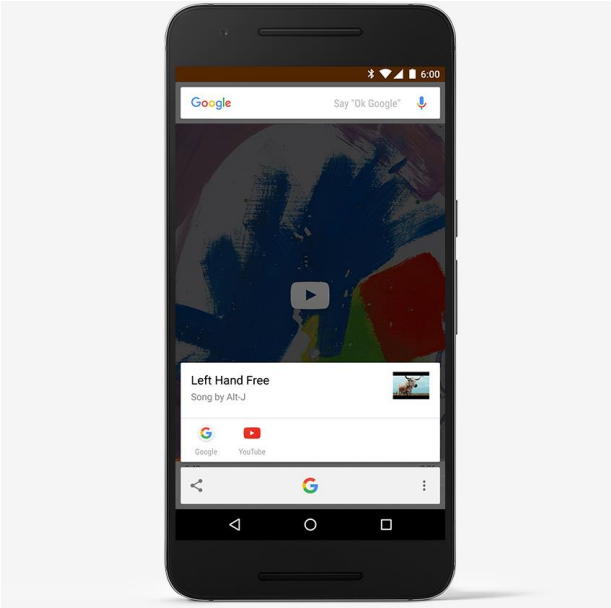
# Specific Drone Flight Path


Test Flight Pattern in Field Across the Street

Flight Data Interface (Disarmed)

# Mobile Receiver Programming

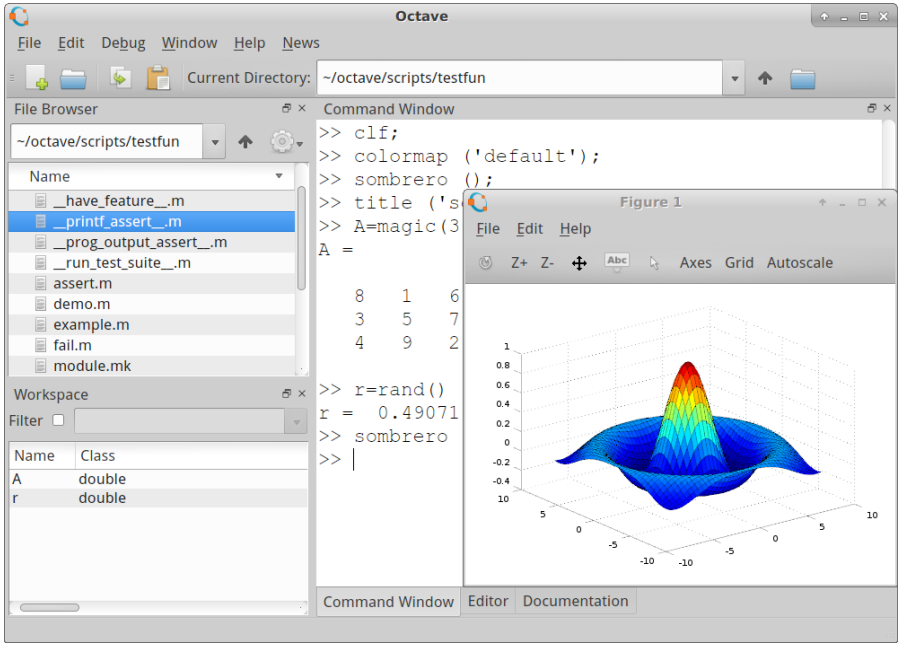
- Receiver is an Android device
- Linked via LTE to WINLAB base station
- Logs signal strength and position at regular intervals
- Log program primarily written in Java
- Receiver is mounted on the drone




Android device similar to one used

# Octave Overview

- Programming environment that supports mathematical analysis and visualization of data
- Used to provide a graphical interpretation of the data
- Allows for custom written interpolation algorithm to fill in the gaps in the data




Sample Octave Interface

# Octave Data Retrieval

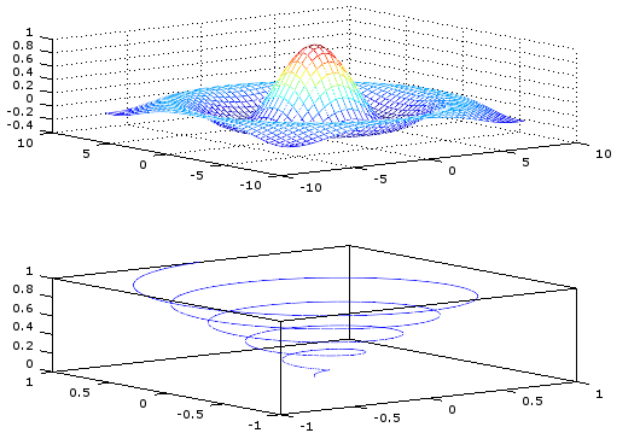
- App used is called “Network Signal Info”
- Data is logged on mobile device in labeled files
  - Available in app interface
  - CSV log type
- Octave is used to convert these logs into usable data

```
A=textread("file.csv", "%d", "delimiter", ",");
B=textread("file.csv", "%s", "delimiter", ",");
inds = isnan(A);
B(!inds) = num2cell(A(!inds))
```

Octave Code to Read a CSV file into a 1 column cell array

# Graphing the Data

- Done through “plot” command
- Graphing is done through discrete points not functions
- Strength is represented by color change (red is strongest, blue is weakest)
- Several data types can be placed on one 3D graph



```
x = linspace(0, 2*pi, 100);
y = sin(x);
plot(x, y);

x = [0:5:100];
y = x;
plot(x, y)

x = [0 : 0.01: 10];
y = sin(x);
g = cos(x);
plot(x, y, x, g, '.-'), legend('Sin(x)', 'Cos(x)')

x = [-10 : 0.01: 10];
y = 3*x.^4 + 2 * x.^3 + 7 * x.^2 + 2 * x + 9;
g = 5 * x.^3 + 9 * x + 2;
plot(x, y, 'r', x, g, 'g')
```

```
tx = ty = linspace (-8, 8, 41)
[xx, yy] = meshgrid (tx, ty);
r = sqrt (xx .^ 2 + yy .^ 2) + eps;
tz = sin (r) ./ r;
subplot (2,1,1)
mesh (tx, ty, tz);

t = 0:0.1:10*pi;
r = linspace (0, 1, numel (t));
z = linspace (0, 1, numel (t));
subplot (2,1,2)
plot3 (r.*sin(t), r.*cos(t), z);
```

Modified tutorial code and graph produced

# Interpolation Algorithms

- Nearest Neighbor
  - Point is given the value of the closest data point
  - P0= S1
- Inverse Distance Weighting
  - Point is given value based on distance from nearby data points
  - P0= ([1/d01]*S1)+([1/d02]*S2)+([1/d03]*S3)
- Natural Neighbor
  - Similar to Inverse distance weighting, but with area

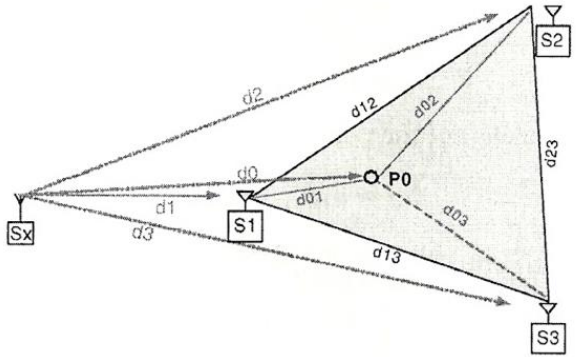



Fig. 1. Sensor Triangle – General Case

# Problems Encountered & Solutions

Lack of prior knowledge

- **Octave**
  - Completed numerous online tutorials
  - Consulted StackOverflow for specific problems
  - Talked to Dragoslav Stojadinovic for graphing help
- **Java**
  - Completed Codeacademy online course
  - Did several sample projects
- **General signal principles**
  - Read Wikipedia topics detailed by Prof. Trappe
  - Watched radio interference conference videos
- **Interpolation algorithms beyond NN**
  - Spoke to Shweta Sagari regarding paper on spectrum cartography
  - Read other paper (provided) on path loss estimation
- **Orbit**
  - Completed basic tutorial
  - Worked on LTE tutorial (SB3 does not have dongle)

# Problems Encountered & Solutions

- SB3- no LTE dongle
  - Re-run tutorial on node1-1.sb6
- Graphing
  - Representing time, location (x,y,z), strength on one graph
    - Strength=color, time dynamic
- Material/staff availability
  - Planned ahead of time
  - Scheduled via email
  - Regular interval updates

# Timeline of Events

**September 2016**

- Discussion of possible project
- Read papers on “Transmit Only”
- Researched SDR basics
- Learned basic interference principles & mitigation techniques
- Spoke to Dravoslav who provided additional resources
- Project finalized 09.30.2016

**October 2016**

- Refined project definition
- Read previous project work
- Learned to use SDRSharp
- Prepared external Linux boot drive
- Downloaded and began learning Octave
- Spoke Shweta Sagari about interpolation algorithms
- Created project timeline and description
- Began programming flight pattern
- Began learning graphing concepts in Octave

# Timeline of Events

**November 2016**

- Downloaded and installed MissionPlanner
- Created alternate flight pattern for testing
- Successfully tested flight pattern twice
- Update about configuring mobile receiver to WINLAB base station
- Continued graphing work in Octave

**Dec. 2016- Jan. 2017**

- Tested first custom written Octave graphing program
- Re-installed Octave graphics packages
- Created optimized zig-zag flight pattern and saved waypoints
- Scheduled mobile receiver usage
- Began documentation
- Began learning how to use ORBIT
- Completed “Basic Tutorial” and SSH
- Attempted “LTE Tutorial” on SB3
- Outlined Octave final program
- Finished documentation

# Accomplishment Overview

- Proficiency in Octave, Java
- Development of efficient flight plan
- Creation of Octave data retrieval/graphing program
- Deployment of Nearest Neighbor interpolation algorithm to data
- Linkage of mobile receiver to ORBIT sandbox node

- Gained an understanding of:
  - Basic wireless transmission and networks principles
  - Complex interference
  - Power loss/leakage
  - Signal encryption
  - Broadcast overlaps
- Increased proficiency in reading research papers and consulting outside references

# Deployment and Applications

## Project

- ID of signal leakage
- Optimization of signal output
- Ease of troubleshooting
- General diagnostics

Mobile and easy to use for above purposes

## Career

- Aerospace major
- Direct:
  - Drone flight path programing
  - Reading research papers
  - Consulting references to learn new material
  - Coding in a new programing language
- Indirect:
  - Signal decay
  - SSH
  - Interpolation algorithms
  - Signal optimization

# Final thoughts

- Exposed to a new area of research, but also in an area that I have an interest
- Work alongside undergraduate and graduate students
- Opportunity to fly a large drone
- Learned a great deal in the field of wireless technology
- Successful, but could've used more time

Very enjoyable experience overall, not just academically

**Special thanks to Wade Trappe and Ivan Seskar**

# Questions?