COMSM4111: Robotic Systems
COMSM0012: Robotic Systems PG

Coursework 2: UAV Swarm Simulation

Updated 27th November 2015 by Arthur Richards (arthur.richards@bristol.ac.uk)

1 Summary

For this coursework, you will create a software simulation of a swarm of UAVs tracking a pollutant cloud. You will be provided with code to simulate the dispersal and movement of the cloud under different conditions. In addition to simulating the movement of each UAV, you will design and implement a guidance in a finite state machine to enable the swarm to spread out along the edge of the cloud.

An RQ-11 Raven UAV

Smoke plume from tyres burning in Renfrew (BBC)

2 Objectives

After successfully completing this coursework, you will be able to construct and evaluate a simulation of a robotic system including:

- a state space model of a robot's physical dynamics, with appropriate discretization
- a model of the environment and sensing
- sensing noise and disturbances
- finite state machine for guidance
- multiple robot agents

3 Deliverables

3.1 Undergraduates (COMSM4111)

Due	**Name**	**Contents**	**Feeback**	**Weight**
Week 12, in scheduled lab session	Initial test	Your initial code, shown to a demonstrator. It must show a UAV moving and responding to the pollutant cloud. **You do not need to submit a report at this stage**.	Comments and suggestions from demonstrator	5%
Monday Week 13, via SAFE	Code	**Matlab files** containing all your final code (*Note: the code deadline is deliberately set ahead of the report deadline to require you to freeze your development, evaluate your solution and write your report.)*	Pro forma (see back)	22.5%
Friday Week 13, via SAFE	Report	**Maximum 6 A4 sides, minimum 11pt font**, describing and evaluating your solution	Pro-forma (see back)	22.5%

3.2 Postgraduates (COMSM0012)

Due	**Name**	**Contents**	**Feeback**	**Weight**
Monday Week 24, via SAFE	Code	**Matlab files** containing all your final code (*Note: the code deadline is deliberately set ahead of the report deadline to require you to freeze your development, evaluate your solution and write your report.)*	Pro forma (see back)	25%
Friday Week 24, via SAFE	Report	**Maximum 6 A4 sides, minimum 11pt font**, describing and evaluating your solution	Pro-forma (see back)	25%

4 Tasks

You are recommended to tackle this assignment by breaking it down into the following tasks:

1. Create a Matlab simulation of the motion of a single UAV. Details of the dynamics model are provided later in this handout.
2. Add the simulation of the pollutant cloud (provided to you) and give your UAV a very simple response to the cloud, e.g. 'change direction when you're in it', implemented in an initial finite state machine.
3. Extend your finite state machine with more guidance behaviours to improve tracking quality.
4. Extend your simulation to include multiple UAVs, initially with the same guidance as before.
5. Extend your guidance system to avoid collisions and to encourage the swarm to spread out along the cloud edge.

5 UAV Dynamics and Performance

The UAV is required to remain at ***constant altitude*** and we assume it is ***unaffected by wind***. It can move only in the direction it points, but it can turn. Its governing equations are:

$$\dot{x} = v \sin\theta$$

$$\dot{y} = v \cos\theta$$

$$\dot{\theta} = v\mu$$

where (*x,y*) are coordinates in m, with the *x* axis pointing ~~each~~ and the *y* axis north, θ is the heading in degrees taken clockwise from north, *v* is the commanded forward speed in m/s and μ is the commanded turn curvature. The forward ***speed must be between 10 and 20m/s and the turn rate can be no more than 6deg/m*** (watch out for units: this should correspond to a turning circle of roughly 10m radius). All UAVs are ***launched at or near position (0,0) and must not travel more than 1km in any direction***, i.e. they must stay within a square of side length 2km centred on location (0,0). ***The UAV has an endurance of 30 minutes***.

The UAVs are able to ***sense their own positions*** using GPS and you can make use of this in your guidance system. The UAV does ***not*** have any heading sensor, such as a compass. If your solution requires the UAV to determine its own heading, this must be derived from the GPS measurements. A typical GPS having a good day is accurate to +/- 3m.

6 Cloud and Sensing

You are provided with data from cloud simulations for multiple scenarios in Matlab ".mat" binary data files. The command "load cloud1.mat", for example, will load the data for scenario 1 into the variable "cloud". You can then use the function "samplecloud" to simulate a measurement of the pollutant concentration in PPM for given position and time. Each simulation lasts one hour.

The boundary of the cloud is taken to be the 1PPM contour. This is the line you should attempt to track with your UAV. Assume that ***each UAV is equipped with a sensor able to take a point measurement of the concentration*** at its current location. The function "plotcloud" draws the cloud contours into the current plot axes for a given time: you can use this as the backdrop for your simulation output.

The UAVs cannot directly sense each other, *i.e.* there is no radar or other ranging device to indicate the present of another UAV. However, UAVs can use communications to share position information with others. See Section 7 for information on communications.

7 Multi-Agent Swarm

A requirement of the swarm system is that all ***UAVs have identical software***. This is intended to simplify the system and avoid vulnerabilities due to loss of a "leader" agent or any other particular role. There is no required number of UAVs. You are encouraged to make your solution scalable and investigate performance for different numbers of UAVs in your report.

Each UAV is able to broadcast a message which will be received by all other UAVs. UAVs are not able to send messages to specific recipient UAVs, nor can a recipient recognize the sender of any given message. Messages may include PPM measurements, positions, or any other information deemed relevant, ***up to 32 bytes in size***, equivalent to an array of four double-precision numbers or 32 characters. You may assume perfect communications subject to a delay of one second. There is no range limit on communications.

Note: in reality, you'd need to model potential problems in the communications. They are never this reliable, especially with lots of simple transmitters all broadcasting over each other. However, simulating that network would be another assignment in its own right. We'll assume that there is an underlying network layer that makes it all work, provided we wait 1s for each message.

The UAVs should **attempt to spread out along the cloud boundary** (or boundaries), as this is more useful for identifying the cloud limits than if the UAVs cluster together. **UAVs should also remain more than 50m apart** to avoid collisions.

8 Report

Your report should cover both single and, if attempted, multi-UAV simulations. It is ***limited to six side of A4 or fewer, with minimum font size 11pt***. The content should address two primary topics:

- The design and rationale of your guidance system, including a diagram of the finite state machine(s) employed
- The results of your simulations and an evaluation of the performance of your guidance system(s).

It is anticipated that much of the report will be taken up with figures. It is not necessary to provide an extensive background discussion: go straight from the abstract to the guidance design.

9 Requirements Summary

- The simulation shall be written in Matlab
- Each simulated UAV should represent an RQ-11 Raven using the model represented in Section 0.
- Each simulated UAV shall sense *only* (i) its position, via GPS, subject to GPS errors (see Section 0); and (ii) the pollutant concentration at its current location (see Section 6).
- Each UAV shall be controlled by identical software including a finite state machine.
- Each UAV shall attempt to remain at least 50m from every other UAV.
- Each UAV shall attempt to track the 1ppm contour of the cloud.
- Each UAV shall only communicate with others subject to the limits in Section 0.

10 Pro Forma

To help understand how we'll mark your work, the pro-forma to be used for all three assessments is given below. You'll get this back with your final mark.

For each component, standard elements to be assessed are arranged in three columns. From left to right, they represent pass (50-60%), merit (60-70%) and distinction (70%+) descriptors, respectively. Roughly, if you get all the "pass"-level items and nearly all the "merit" level items, you are likely to get a "merit" mark, and so on. Marker's judgement is final.

<table>
<tr><td>Name</td><td>User ID</td></tr>
<tr><td>Test and code review</td><td></td></tr>
<tr><td>
Swarm tracks cloud
Test1 Test2 Test3
OK code structure
Avoids collisions
Even swarm spread
Readable code
Original method
UAV cooperation
Efficient code
Comments:</td><td>Mark / 25</td></tr>
<tr><td>Report</td><td></td></tr>
<tr><td rowspan="2">
Behaviours discussed
Results discussed
Conclusion drawn
State chart
Evaluation of results
Well-written
Insight / analysis
Concise / easy read
Comments:</td><td>Mark / 25</td></tr>
<tr><td>Total / 50</td></tr>
</table>