Tracking small UAVs using a Bernoulli filter

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Background

The necessity for maintaining surveillance in airborne environments is ever growing. Criminals and terrorists are finding new and elaborate means of attack, and small UAVs such as quadcopters and hexacopters could be a possible threat.Their small size and agile movement will make them difficult to detect. This work aims to determine whether or not these small UAVs can be detected at short range using radar, and if so, track them over time using a suitable filter such as a Bernoulli filter.

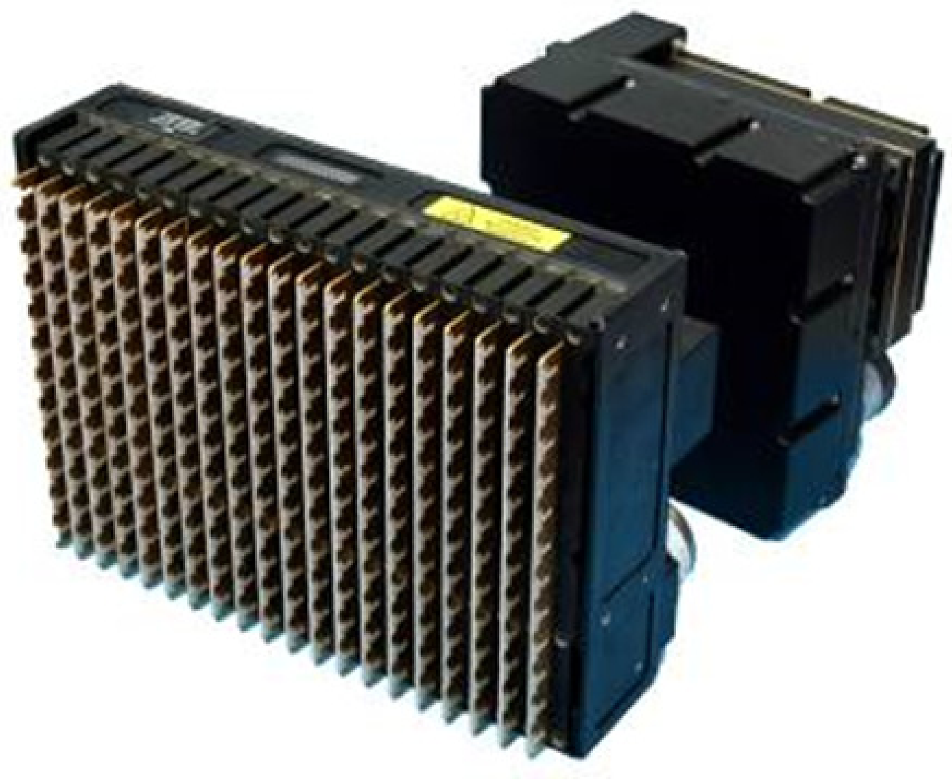

Figure 1: A variant of the small and lightweight PicoSAR radar developed by Leonardo was used to collect data

Small UAV Technology

The defence sector currently have an interest in detecting these small UAVs, and developing safe countermeasures to bring them down if necessary. At distances over 300 metres, they become almost invisible to the naked eye, hence the requirement of a suitable sensor to detect them over longer ranges.

Figure 2: DJI Inspire I Quadcopter

Figure 3: DJI S900 Hexacopter

An initial assessment of how detectable a common quadcopter should be, was performed inside a large anechoic chamber at Leonardo in Edinburgh. The quadcopter was placed on top of a large polystyrene pillar and rotated through a full 360°. RF energy is directed towards the target at increments of 0.25°and the returns analysed. Using the results shown in Figure. 4 and a form of the radar range equation,

$$\sqrt[4]{\frac{P_t \tau G^2 \sigma \lambda^2}{4\pi^3 k T_s L(SNR)}} \tag{1}$$

it was determined that the maximum possible range to detect one of these small UAVs using the PicoSAR variant was approximately 1.2 kilometres.

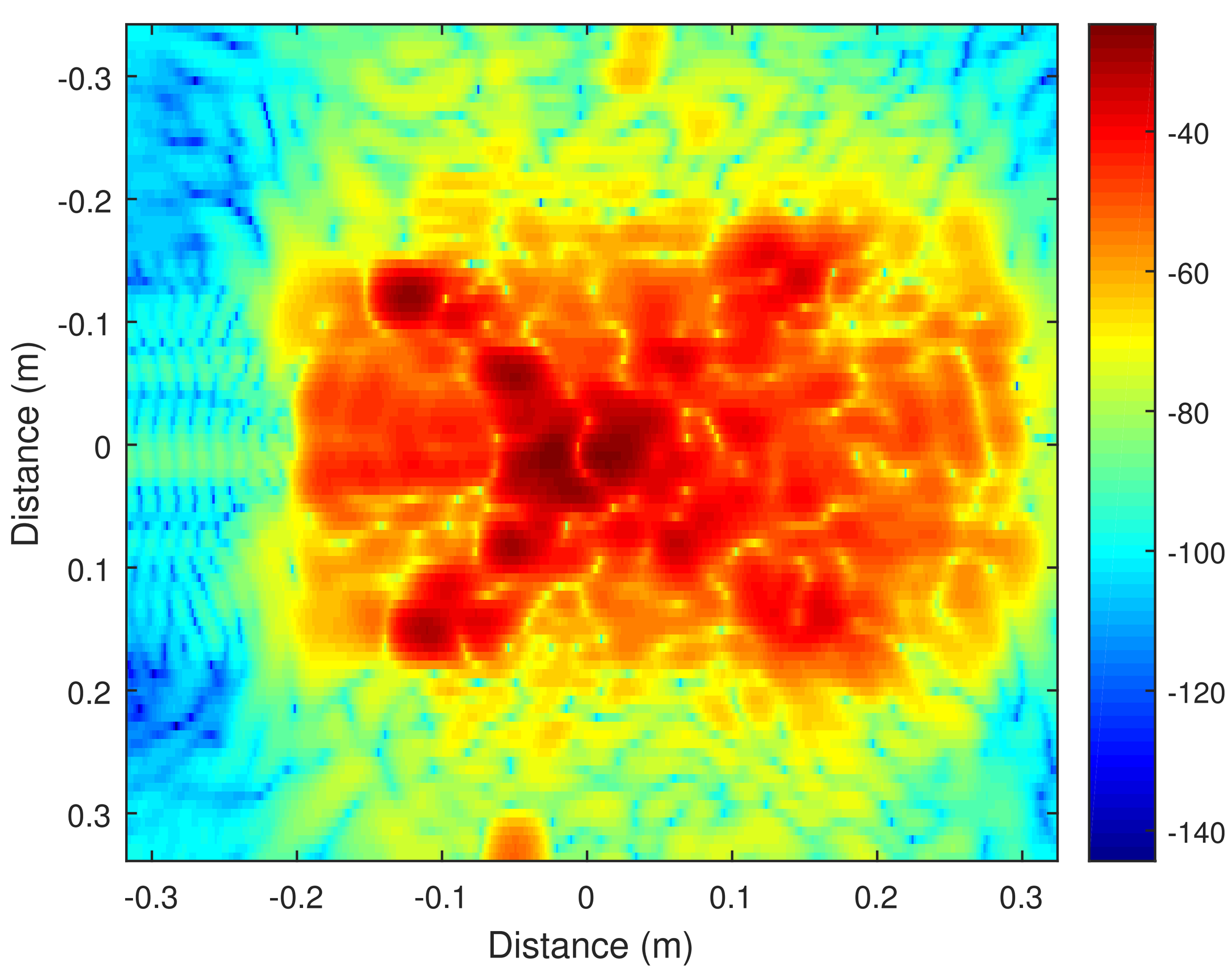

Figure 4: RCS plot for a DJI Phantom II Quadcopter. The RCS at each point on the plot has been frequency-averaged between $6GHz$ and $18GHz$ to give the result. The colour scale is given in $dBsm$ with a peak return across the target of approximately $-25dBsm$

Data Collection

A ground based trial was set up to see if the small UAVs would be detectable using AEXAR, an experimental variant of the standard PicoSAR. It uses a larger array antenna than the standard radar, and transmits more power, making it more likely to detect smaller targets, especially at shorter ranges. The data collected during this trial has been used to develop the tracking model. Data was collected on both of the UAVs shown in Figures 2 and 3.

Figure 5: Site of trial at East Fortune Airfield, East Lothian, UK.

The data collection was performed in August 2015 at East Fortune Airfield, East Lothian. The radar was located inside the back of a van which was positioned at the West end of the runway. The UAVs and the pilot were located around 1 kilometre away at the other end of the runway. The UAVs were first flown in a linear motion towards and then away from the radar position to gain a maximum Doppler shift. After completing these tests, the UAVs were flown in a much more random pattern inside the surveillance region, including circular paths and tight agile turns.

Results

The results shown are for an early run using the DJI Inspire I shown in Figure 2, where the UAV was flown directly towards the radar multiple times.

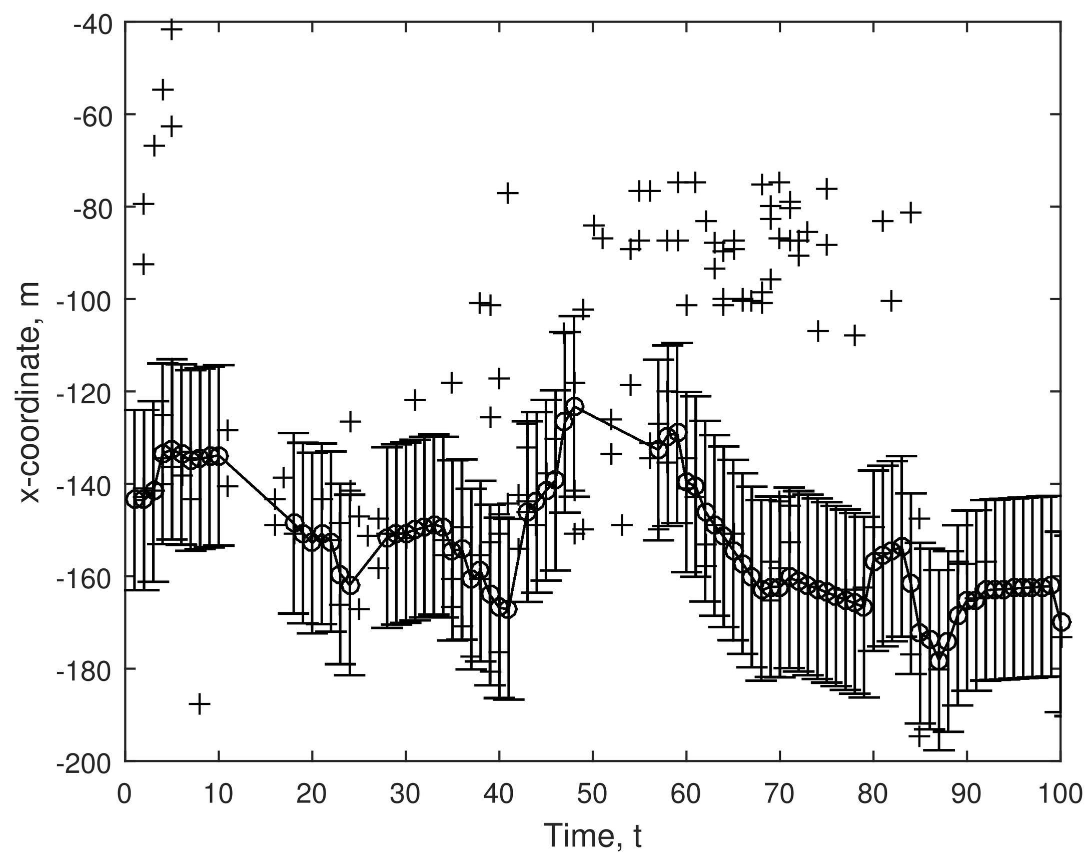

Figure 6: X coordinates of detections and estimates plotted over time. '+' symbols represent radar detections, 'o' symbols represent filter estimates with a $\pm\sigma$ uncertainty.

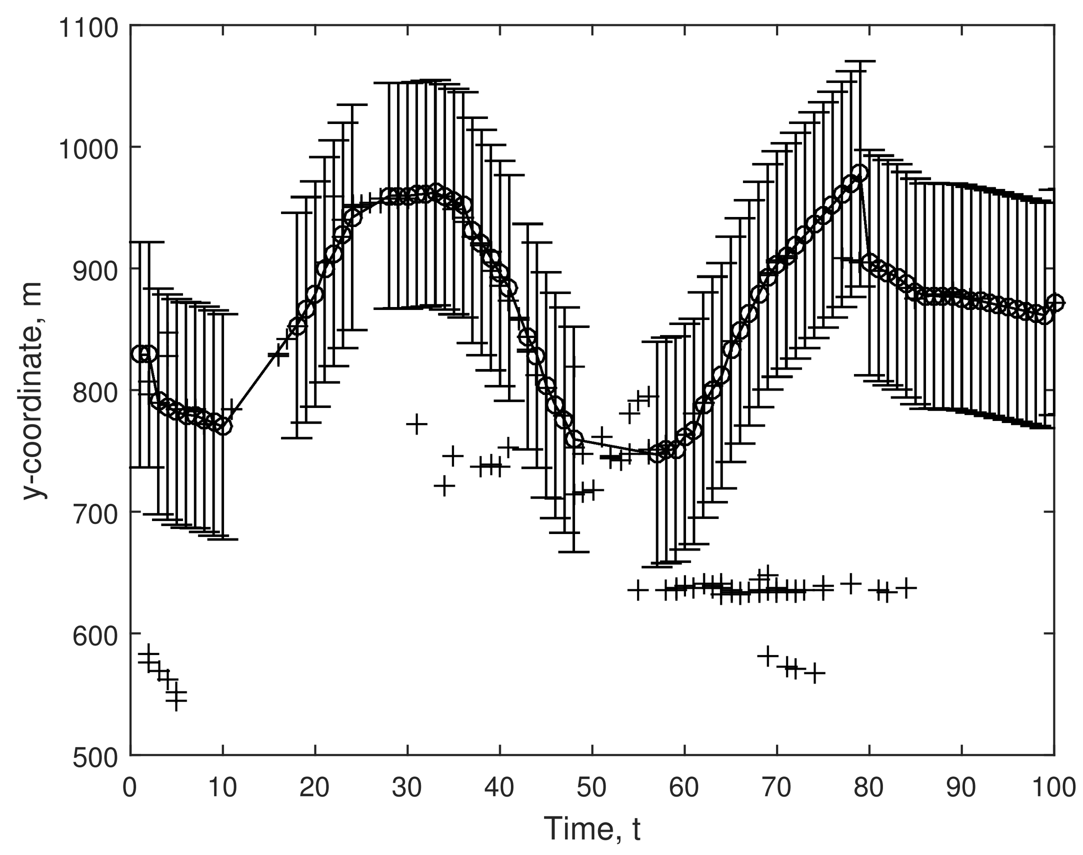

Figure 7: Y coordinates of detections and estimates plotted over time. '+' symbols represent radar detections, 'o' symbols represent filter estimates with a $\pm\sigma$ uncertainty.

Conclusions

The Bernoulli Gaussian Sum filter has successfully given sensible estimates of the UAV's position and tracked it over time. The filter has managed to deal with the false alarms that have been generated at close range.