Class I Unmanned Aircraft Systems (UAS) tracking, classification and identification challenge

1. Introduction

NATO is currently looking at capabilities to protect people, equipment, and in general its missions against the threat of misuse of drones / Class I UAS (Unmanned Aircraft Systems). Class I UAS include unmanned aircraft with a mass lower than 150Kg; hobby drones are a typical example of Class I UAS.

The majority of the solutions developed to counter such UASs so far use a mix of sensors to detect and track drones entering in a protected flight zone. Typical sensors are radar or radio direction finding.

Results of this challenge will be presented and discussed in a special session of the Int. Conf on Military CIS (www.icmcis.eu). All participants in this data challenge are invited to take part in the special session.

2. Problem description

In this challenge, your task is to track, classify and identify Class I UAS as they fly within a defined area, from the data provided by the available sensors. The drones should be *tracked*, to show their location and velocity; they should also be *classified*, to indicate what type of object has been detected (e.g. drone, bird); and they should be *identified* and indicate which type of UAS has been observed (e.g. DJI Mavic Pro).

The challenge asks for classification of drones and tracking of their location in a range of sceanrios. Performance of classification in one scenario is provided via Kaggle. Performance of all attributes in all scenarios can be validated using ‘ground truth’ from logfiles included in the dataset. Final evaluation and ranking of challenge entries will be performed by NCIA using a scenario and dataset which is not yet public.

3. Scenarios

The measurements were conducted at a C-UAS test centre in the Netherlands. A map of the test range including the location of the sensors is depicted in Figure 1.

The RF DF sensors were located close to each other in the centre of the test range and the radars were located at a the edges of the drone flight zone. The location of the sensors is reported in most of the sensor messages and are close to the following positions:

- Diana: Lat = 51.519137 deg, Lon = 5.857951 deg
- Venus: Lat = 51.5192716 deg, Lon = 5.8579155 deg
- Alvira: Lat = 51.52126391 deg, Lon = 5.85862734 deg
- Arcus: Lat = 51.52147 deg, Lon = 5.87056833 deg

The elevation was about 31m where the sensors were deployed.

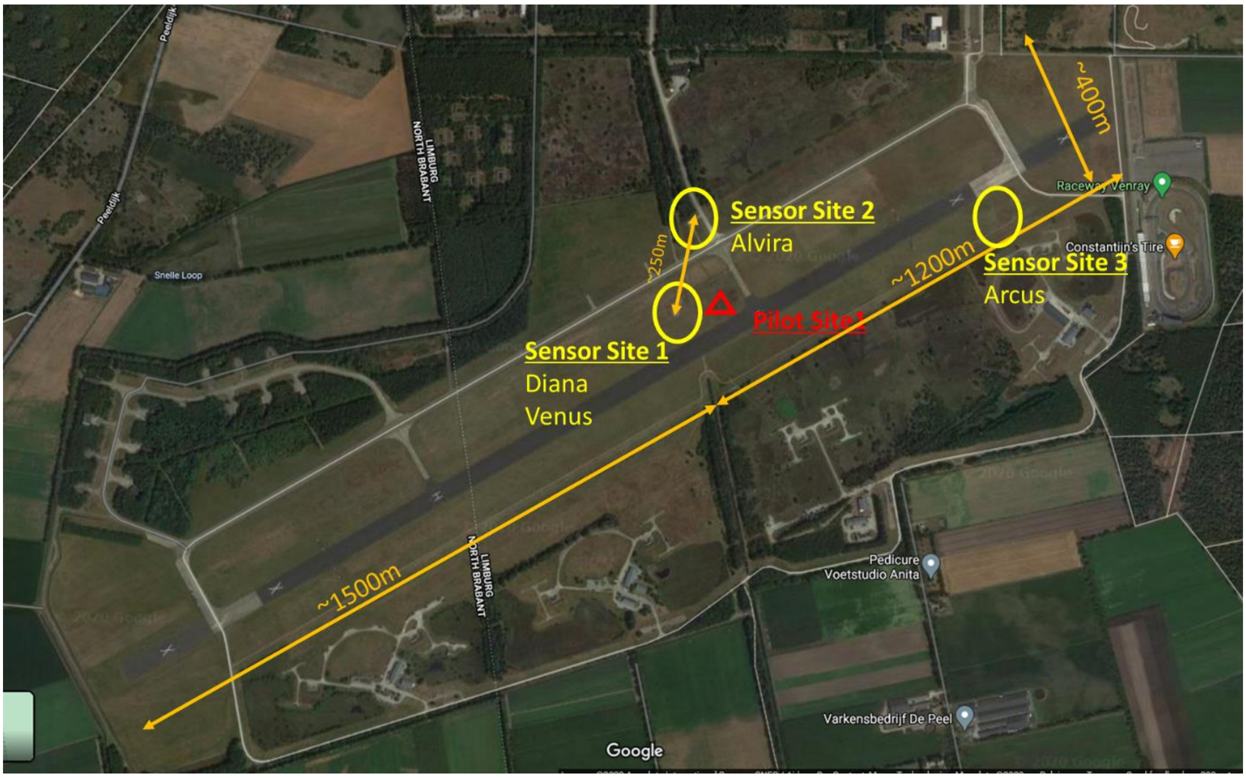

Figure 1 Sensor locations.

Four different drones were used to flight a number of missions. In the fog files the following mapping can be used:

- DJI MAVIC 2 – plane name = aladrian-MAVIC PRO
- DJI MAVIC PRO – plane name = djiuser_97p9AXasssb6-Mavic2
- DJI Phantom 4 Pro - plan name = kcdgc-P4 Professional V2.0
- Parrot DISCO – plane name = Parrot

Some general characteristics of these drones are listed in Table 1.

Table 1 General characteristics of the drones used in data collection.

Group	Airframe	Weight [kg]	Velocity [m/s]	RCS [m²]	Frame cross section frontal [m²]	Group/Example
A	Multi copter	1	20	0.01	0.02	DJI – Mavic DJI - Phantom
B	Fixed wing	1	20	0.005	0.1	Parrot - DISCO

Scenarios involving one drone or multiple drones were executed and the log data and sensor data recorded for further processing. Scenario 1 covers flights with one drone only and has a number of sub-scenarios where various flight pattern were used. A sketch of the flight paths for Scenario 1 is depicted in Figure 2.

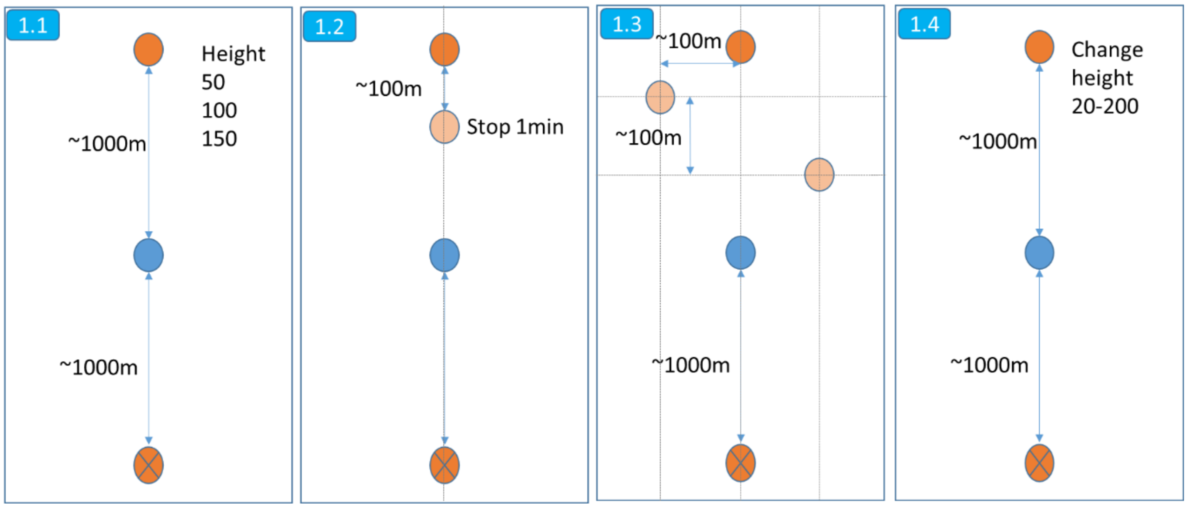

Figure 2 Scenario 1 flight paths using a single drone.

In Figure 2 the blue point represents the location of RF detection sensors, the orange represents the starting point of the mission, the crossed orange point is the end of the mission and the light orange is used to represent stop points.

Two drones were used to flight missions with intersecting paths In Scenario 2 (see Figure 3.

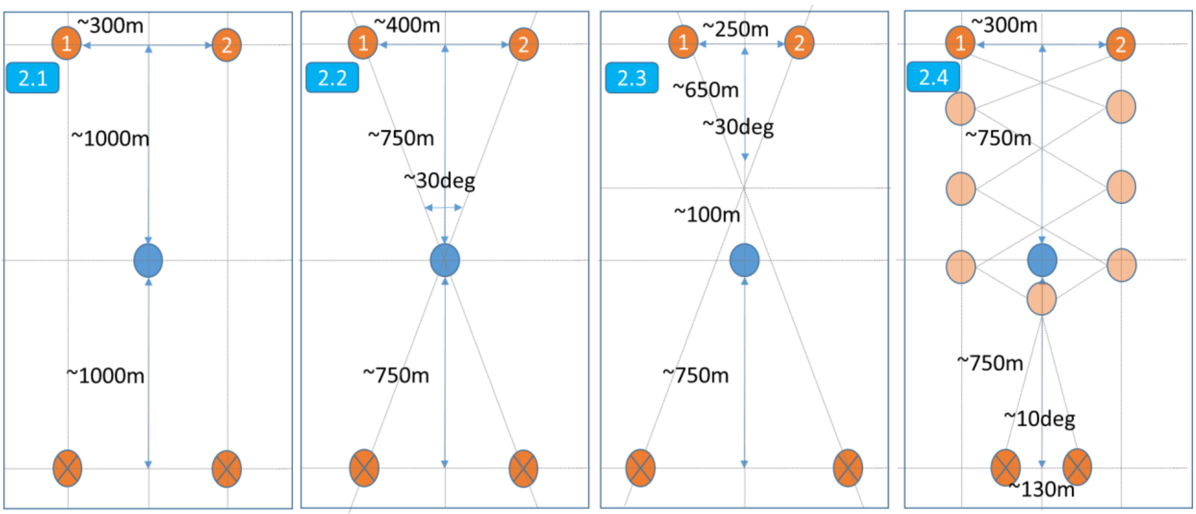

Figure 3 Scenario 2 flight paths.

4. Data

The data consists of:

a) Log files, giving the exact tracks which each UAS flew. This data can be considered as the ‘true’ record of the location of the UAS at any given time, velocity information is included in this data. As each UAS generates a unique log file, these files also provide the true classification of each type of UAS. Log files are available for all flights and can be used to label data or as inputs for training in case a supervised method is used.
Log files are generated for each flight, by each UAS. Where multiple UAS flew at the same time multiple log files can be correlated from the time stamps, to identify the true picture of which UAS were flying where.

b) Radar sensor data, these files give the outputs from different radar systems which detected the UAS during flights. These files provide location information (latitude, longitude, altitude) as well as the bearing and range detected for UAS by the radar system during UAS flights.
Radar data timestamps can be correlated with log file timestamps to test the accuracy of radar data. Classification information is included in the radar reports as well and can be used to consolidate the object class across multiple sensors. Two radar systems (fictitious names Alvira and Arcus) were used to record the data: Alvira a 2D radar and Arcus a 3D radar. Despite the 2D or 3D operation mode both radars report altitude of the target. In the radar the field containing TracksTrack information shall be used as measurements reported by the sensor.

c) Radiofrequency (RF) direction finding (DF) sensor data, these files give the outputs from different radio direction finding systems. These systems give a bearing for any radio transmissions detected, such transmissions may come from the UAS itself or from the UAS controller.
Radio direction finding data timestamps can be correlated with log file timestamps to test the accuracy of this sensor data. While radar sensor can provide classification information based on kinematic and radar reflectivity characteristics, the RF DF sensors can go one step further and identify the UAS and the controller based on the RF signature. Two RF DF systems were used fictitiously referred as: Diana and Venus. Diana provides range information based on power level of the received signal but this information has high uncertainty due to various effects such as multipath and variations in the array antenna pattern. Diana uses a linear array antenna to estimate the bearing of an intercept and this introduces an ambiguity: Diana only reports detections in a 180 deg sector even if the target is located in the opposite sector. Venus uses a circular array antenna with no bearing ambiguity and provides no range information. Both RF sensors report UAS and controller detections, however for the purpose of this challenge only UASs will be tracked.

Log data and sensor data is provided as comma separated files with self-explanatory column names.

5. Evaluation

The evaluation will be based on how closely the results of algorithms developed during this challenge match the ‘true’ position and velocity of a UAS, as given by the log files.

For evaluation an additional set of sensor data files (not currently released) will be used, outputs will be compared to the corresponding log files from the UAS flights.

Scoring will be :

a) 70% for accuracy of the position;
b) 15% for classification of the UAS. Classification of the track is only expected into one of three categories (drone, fixed_wing, unknown).
c) 15% for identification of the UAS. Four rotary drones and one fix drone were used during the data collection.

Results of the multi sensor tracking, classification algorithms shall be provided as csv file with the following minimum set of columns:

- TrackDateTime(utc),
- TrackID
- TrackPositionLatitude
- TrackPositionLongitude
- TrackPositionAltitude
- TrackVelocityAzimuth
- TrackVelocityElevation
- TrackVelocitySpeed
- TrackClassification
- TrackIdentification
- TrackSource (list of sensor/detections used to establish the reported track state)

6. Data licensing

Data can be used for this challenge without further approval. The data set can also be used by participants in NATO's Science and Technology Organisation's 'IST-184' group.

NATO may grant approval for the data set to be used by government and academic bodies for other purposes, please contact NCIA regarding use of the data set outside this challenge or IST-184.

7. Submissions

Submissions shall be subject to review and inspection by the challenge organisers, but will not be made open source. Intellectual Property Rights (IPR) within challenge submissions shall remain with the team.

8. Conference

The ICMCIS will include a special session on machine learning techniques for drone detection and counter-UAS techniques, based on the activities in this challenge. Teams are invited to submit a short description of their approach and to give a short presentation within the special session. More details on this special session will be added to the challenge in March.