HALMSTAD UNIVERSITY

Real-Time Drone Detection and Tracking With Visible, Thermal and Acoustic Sensors

Cristofer Englund
Halmstad University, Center for Applied Intelligent Systems Research
Research Institute of Sweden (RISE), Humanized Autonomy

Fernando Alonso-Fernandez
Halmstad University, Center for Applied Intelligent Systems Research

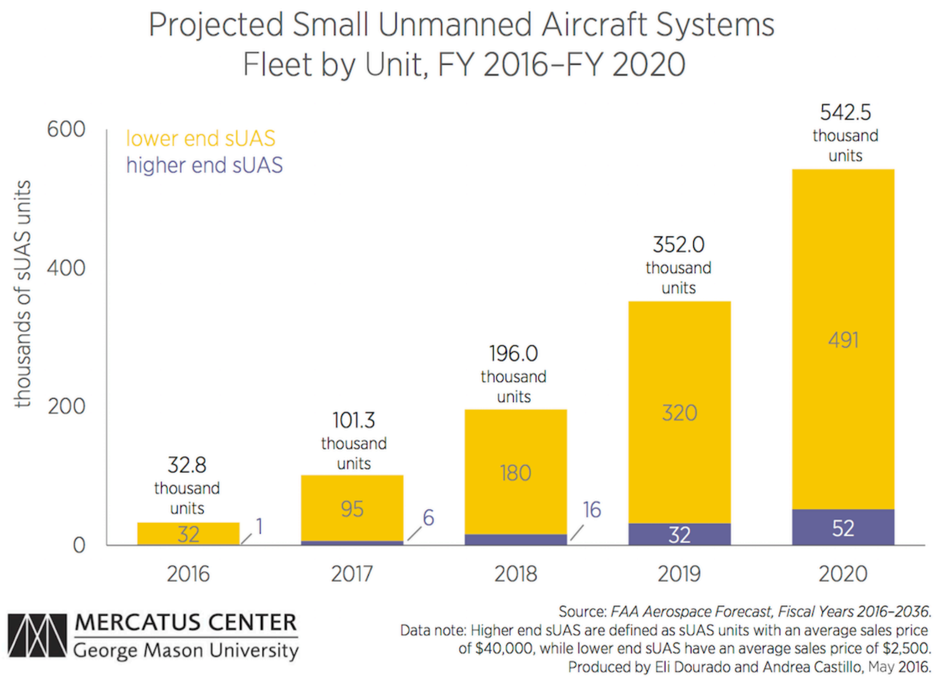
Fredrik Svanström
Air Defence Regiment. Swedish Armed Forces

Problem formulation

Both private and commercial usage of drones is increasing.

Monitoring crop, forest, powerlines, fences, photography, surveillance and delivery etc.

How can we make sure drones are not misused, intentionally or unintentionally?



HALMSTAD UNIVERSITY

Aim

This paper explores the possibilities and limitations of designing and constructing an automatic multi-sensor drone detection and tracking system building on state-of-the-art machine learning techniques.

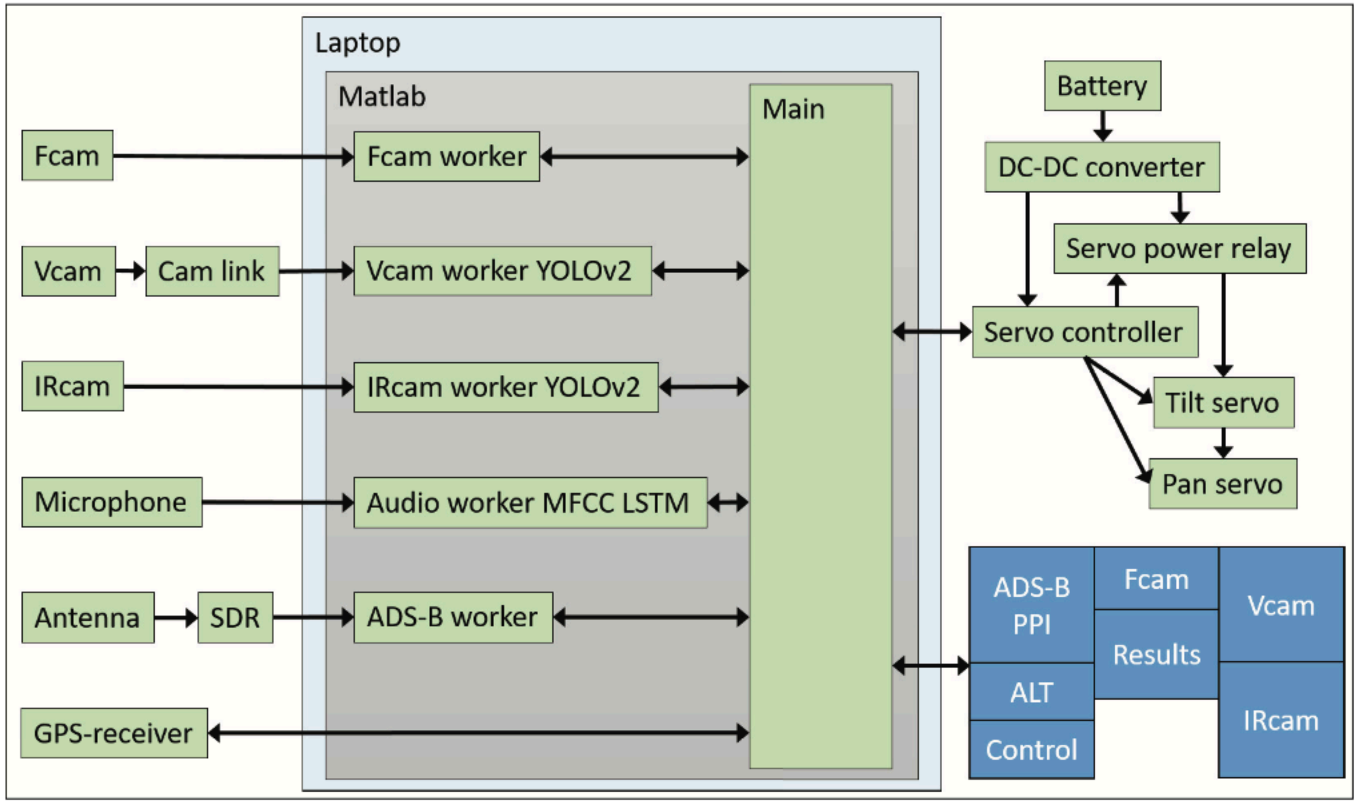
Solution - Hardware

Thermal infrared camera (IRcam) and a
Video camera in visible range (Vcam)
ADS-B antenna.
Microphone
Fish-eye lens camera (Fcam) covering 180°
horizontally and 90° vertically.

Solution - Software

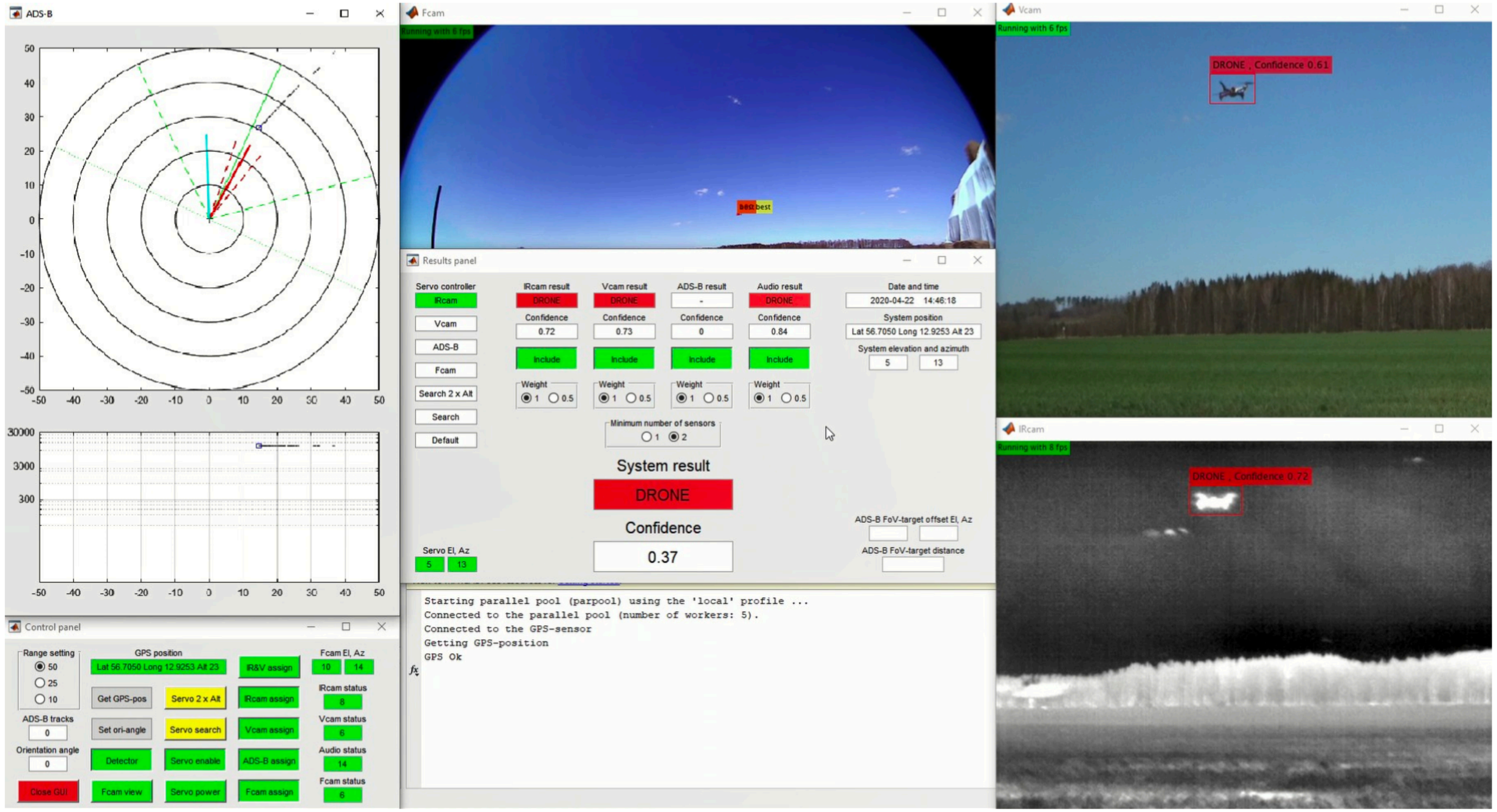
Five workers – functions

- Fcam
  - ELP 8 megapixel 180° fish-eye lens 1024×768
  - Gaussian mixture model (foreground/background)
  - Multi-object Kalman filter tracker
- Vcam
  - CNN (YOLO v2)
  - Sony HDR- CX405 video camera
    - Elgato Cam Link 4K frame grabber 1280×720
- IRcam
  - CNN (YOLO v2)
  - FLIR Breach PTQ-136 using the Boson 320×256 pixels detector
- Audio
  - MFCC Features feed into LSTM
- ADS-B
  - Antenna and a NooElec Nano 2+ Software Defined Radio receiver



Solution - GUI

Results of the different sensors/workers, and
Possibility of controlling the system.



HALMSTAD UNIVERSITY

Drone Detection Dataset

Dataset captured at three airports in Sweden:

- Halmstad Airport (IATA/ICAO code: HAD/ESMT),
- Gothenburg City Airport (GSE/ESGP) and
- Malmö Airport (MMX/ESMS).

Three different drones are used:

- Hubsan H107D+, a small-sized first-person-view(FPV);
- DJI Phantom 4 Pro;
- DJI Flame Wheel. Quadcopter (F450) Hexacopter (F550).

Ten-second clips

- 90 audio clips and 650 videos (365 IR and 285 visible)
- 203328 annotated image (!)

https://github.com/DroneDetectionThesis/Drone-detection-dataset

Fig. 4. Examples of varying weather conditions in the dataset.

Fig. 3. The three drones of our dataset. Left: Hubsan H107D+. Middle: DJI Phantom 4 Pro. Right: DJI Flame Wheel F450.

Results – individual sensors

- Evaluation individual sensors
  - precision,
  - recall and
  - F1-score
    - 2 x ((precision x recall) / (precision+recall))
- CLOSE: 0 m – 15 px in IRcam
- MEDIUM: 15 px-5 px in IRcam
- DISTANT: 5 px- 1 px in IRcam

	drone	helicopter	background	average
Precision	0.9694	0.8482	0.9885	0.9354
Recall	0.9596	0.9596	0.8687	0.9293
F1-score				0.9323

TABLE V
RESULTS WITH THE AUDIO DETECTOR.

distance bin: CLOSE	airplane	bird	drone	helicopter	average
Precision	0.9197	0.7591	0.9159	0.9993	0.8985
Recall	0.87367	0.85087	0.87907	0.87927	0.8706
F1-score					0.88447

distance bin: MEDIUM	airplane	bird	drone	helicopter	average
Precision	0.82817	0.50637	0.89517	0.95547	0.7962
Recall	0.70397	0.70337	0.80347	0.83557	0.7615
F1-score					0.77857

distance bin: DISTANT	airplane	bird	drone	helicopter	average
Precision	0.78227	0.61617	0.82787	0.79827	0.7561
Recall	0.40437	0.74317	0.48367	0.45647	0.5218
F1-score					0.61757

TABLE III
RESULTS WITH THE THERMAL INFRARED SENSOR. THE AVERAGE OF THE THREE F1-SCORES IS 0.7601

distance bin: CLOSE	airplane	bird	drone	helicopter	average
Precision	0.8989	0.8284	0.8283	0.9225	0.8695
Recall	0.7355	0.7949	0.9536	0.9832	0.8668
F1-score					0.8682

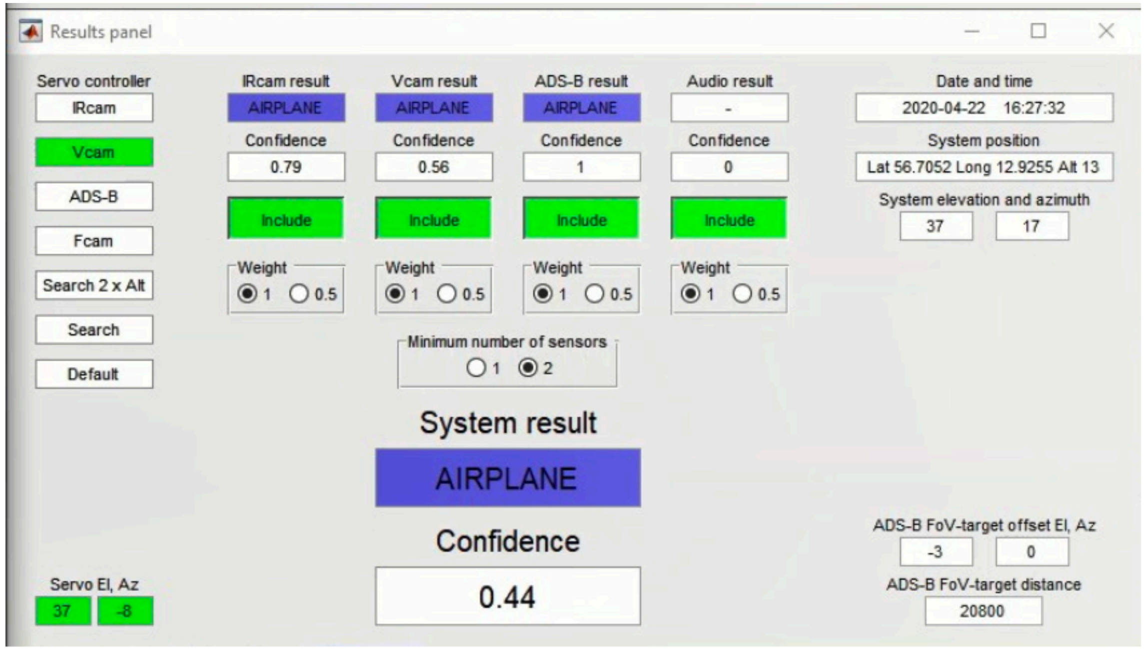
distance bin: MEDIUM	airplane	bird	drone	helicopter	average
Precision	0.8391	0.7186	0.7710	0.9680	0.8242
Recall	0.7306	0.7830	0.7987	0.7526	0.7662
F1-score					0.7942

distance bin: DISTANT	airplane	bird	drone	helicopter	average
Precision	0.7726	0.6479	0.8378	0.6631	0.7303
Recall	0.7785	0.7841	0.5519	0.5171	0.6579
F1-score					0.6922

TABLE IV
RESULTS WITH THE VISIBLE CAMERA. THE AVERAGE OF THE THREE F1-SCORES IS 0.7849

Results – sensor fusion

- Weight on selected sensors
- Averaging between frames



HALMSTAD UNIVERSITY

Conclusions

- We explored the possibility to design and build a **multi-sensor drone detection system** utilizing state-of-the-art machine learning techniques and sensor fusion,
- The system incorporates common **video** and **audio** sensors, and a thermal **infrared** camera,
- A **fish-eye** lens camera with a wider field-of-view is used to steer the sensors in any direction,
- An **ADS-B** receiver allows to keep track of cooperative aircrafts in the surrounding airspace,
- Results confirm that machine learning techniques can be applied to input data from infrared sensors, making them well suited for the drone detection task,
- The **infrared detector achieves a F1-score of 0.76**, showing similar performance as the **visible video detector with a F1- score of 0.78,**
- The **audio classifier achieves a F1-score of 0.93,**
- A multiclass dataset is published for other researchers to use and compare results with.

Cristofer.Englund@hh.se / Cristofer.Englund@ri.se

A center of knowledge on the west coast

Cristofer.Englund@hh.se / Cristofer.Englund@ri.se

HALMSTAD UNIVERSITY