Localization of Aircraft using ADS-B

Robin Forsling (robin.forsling@liu.se)

Background

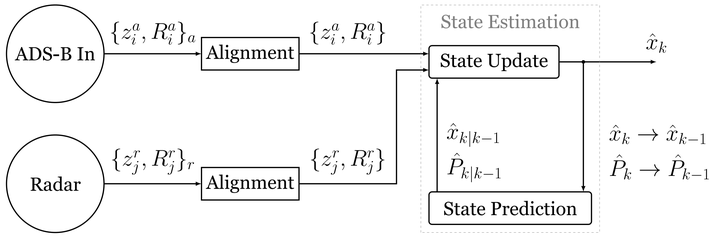
The relatively new surveillance technique ADS-B (Automatic Dependent Surveillance - Broadcast) is able to increase the situational awareness for pilots and simultaneously solve the ATC airspace surveillance problem. ADS-B is dependent in the sense that it requires GNSS (Global Navigation Satellite System) derived state estimates which are then automatically broadcasted periodically.

Components of ADS-B

- ADS-B Out – The functions for generating the ADS-B messages and broadcasting them.
- ADS-B In – The part for receiving the ADS-B messages and displaying the useful information for the operator.
- TIS-B – Traffic Information Service - Broadcast. Enables ATC to broadcast information about non-ADS-B capable objects detected by for example a ground based radar. TIS-B is received via ADS-B In.

Fusion of ADS-B data

Typically aircraft also have some radar capability and datalink capability. Therefore there is a need to fuse ADS-B data with sensor data from other sensors. A scheme for fusion of ADS-B data and radar data can look like below.



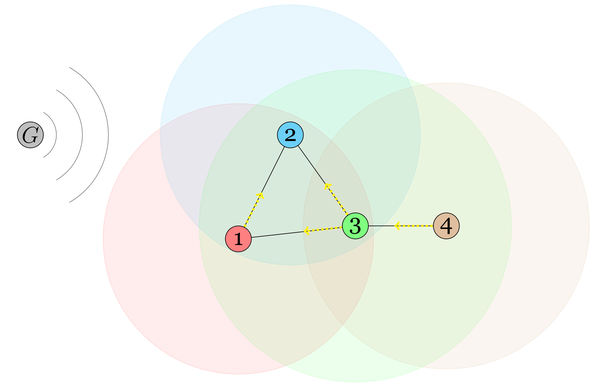
However, from a sensor fusion point of view ADS-B introduces some imperfections and other issues.

Issues concerning fusion of ADS-B data

- The complete state vector is not transmitted as a single unit in a single message
- Different ADS-B messages are transmitted at different rates
- The state estimates are given in the temporal frame of the transmitting aircraft

Problem Formulation

The figure below shows a network with multiple aircraft (1, 2, 3 and 4) and a ground station G resembling ATC. The colored circles illustrates ADS-B coverage, the yellow arrows illustrates radar coverage and the black lines illustrates a datalink.



The problem is to construct a sensor fusion scheme for a topology like the one above when ADS-B and radar measurements respectively are given by

$$z_i^a(t_a) \subseteq \{\mathbf{x}_H, \mathbf{x}_{Alt}, \mathbf{v}_H, \mathbf{v}_V\} \qquad R_i^a(t_a) \subseteq \{e_{\mathbf{x}_H}, e_{Alt}, e_{\mathbf{v}_H}\}$$
$$z_j^r(t_r) = \{\mathbf{x}, \mathbf{v}\} \qquad R_i^r(t_r) = \{e_{\mathbf{x},\mathbf{v}}\}$$

where temporal reference of t_a and t_r cannot be assumed being synchronized and the different subsets of z_i^a and R_i^a are communicated at different rates.

Questions to Answer

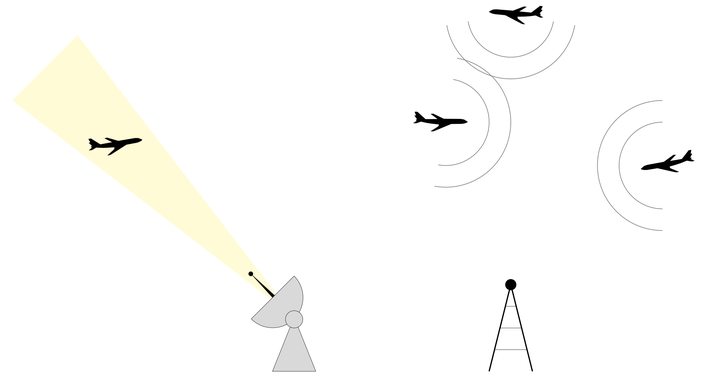
- Incomplete data – How shall the sensor fusion algorithm handle the incomplete state vectors transmitted in an ADS-B Out message?
- Multi rate – How shall the sensor fusion algorithm handle the fact that different sets of ADS-B data is transmitted at different rates?
- Not synchronized sensors – How shall the distributed estimates received via ADS-B In and estimates from own radar be fused?
- Fusion architecture – What effect has the architecture (centralized, distributed etc) on the fusion of ADS-B data?
- Consensus – How can consensus in a network with heterogenous agents be achieved?

Modelling

The problem will be modelled with kinematics that induces a changing topology. The aircraft will be heterogenous from a capability point of view. The simulation framework shall be sufficiently modular to allow for capabilities and sensor fusion scheme to be easily added/changed/removed.

Objectives

- Construct sensor fusion algorithms of different architectures that fuses ADS-B data with other sensor data
- Analyze the algorithms with respect to fundamental bounds
- Analyze the algorithms with respect to scalability



Applications

Airspace surveillance: In continuously denser airspaces it will required that ATC can perform airspace surveillance effectively.

ATC is destroyed: In case that ATC becomes temporarily unavailable or permanently destroyed it is vital that estimations can be performed distributed and that consensus can be achieved.

Autonomous aircraft: Consensus will be very important for safe operations of autonomous aircraft. UAV:s are already often equipped with systems like ADS-B, radar and datalink.

LINKÖPING UNIVERSITY
Division of Automatic Control

LINKÖPING UNIVERSITY LINK-SIC