Radar Tracking and Data Fusion

Date: TBD **Time:** TBD
Instructor: Dr. James K Beard **Course Number:** ECE.09.402.04
Credits: 3

This graduate ECE course considers radar trackers from three points of view. Requirements and estimation provide a basis and context, and the main part of the course is on tracker functions. For the requirements perspective, radars are presented as sensor assets on a network that may be placed on the ground or on moving platforms such as ships, aircraft, or spacecraft. The second topic is estimation theory as applied to radar trackers, including requirements analysis in addition to track file update. The third area addresses the base tracker functions of data association and track file update and maintenance and forms the main body of the course.

Requirements: The Radar as a Networked Sensor

The use of radar data is thus often a data fusion problem, particularly when the radar data processor is a note on a network. The Joint Directors of Laboratories (JDL) Data Fusion Process Model is a context that underlies much of the coordinated work for most network sensor applications, and it provides a structure for understanding the function and hierarchy of most data fusion functions. The JDL process model defines six levels of information fusion processing:

- Level 0: Source data preprocessing, such as signal processing.
- Level 1: Object refinement, such as data alignment, association and correlation, and estimation of position, velocity, and identity.
- Level 2: Situation refinement, such as event or activity detection.
- Level 3: Impact assessment, such as damage assessment and estimation of aggregate force capabilities.
- Level 4: Resource management, such as computation of measures of performance, optimization of resource utilization, and sensor and resource tasking.
- Level 5: Cognitive refinement, which monitors and manages the interface between the data fusion system and the human operator and decision makers.

We will present thumbnails of each of these processing levels, with Levels 0 through 2 in the context of networked sensors, present and future. Level 1 and Level 2 techniques will include Dempster-Shafer and Bayesian inference methods. Levels 3 through 5 will be presented from the viewpoint of air traffic control.

Enabling Technologies: Estimation Theory

Estimation is the principal enabling technology applied to tracking and data fusion. Simple examples are used to illustrate basic methods and show how probability and statistics underlie simple algebraic descriptions of well-known estimation techniques, which we use as a basis for showing the estimation theory basis of the Kalman filter.

The method of maximum likelihood is the methodology for designing estimators that use the Maximum Likelihood Estimators (MLEs), which are known to provide estimates which have the smallest mean square errors that can be provided from a given set of data. The classical basis for maximum likelihood is presented and extended to the vector case, such as estimating aircraft position in two or three dimensions from radar data. We show how the Kalman filter is related to MLEs.

The classical estimation methods of maximum likelihood, maximum a priori (MAP), and Bayesian estimates are presented and compared. We discuss the practical issues with application and use of these estimators, such as biased estimates and how to remove biases.

This topic concludes with formulation of the Kalman filter from estimation theory and application of estimation theory to design of experiments, data analysis and requirements analysis.

Core Data Processing Functions: Data Association and Track Update

Radar trackers are the data processing blocks between raw detections and data for synthetic displays. The tracker is where the radar detection information is combined with the transponder data to provide information for the display graphics such as target identification. The base tracker function is to provide and maintain a data base of radar contact information as a set of track files. These track files provide the data for alerting functions such as collision alerts and altitude warnings as well as for synthetic displays.

Radar tracker technologies vary from traditional coast-and-update methods to state-of-the-art track-before-detect methods. The methods used by FAA radars in the past and present are used as a basis for describing the advantages and disadvantages of the technologies for FAA and other radars for present and future radars. The high traffic density seen in many FAA and other radar installations builds on this basis to describe the concept and design of a multiple hypothesis tracker (MHT) for ground based radars, and the practical considerations in the design and implementation of these trackers and in the function of sharing data between radars or merging data from multiple radars at a central facility such as an air traffic control center.

Other topics will be presented, including a review of probability and statistics as applied in relevant radar tracker technologies, interactive multiple models (IMM) in radar trackers, radar tracking from moving and airborne platforms, and basic considerations in data sharing between radars.

Who should attend: The primary audience is the engineer who needs to understand the requirements, interpretation, design, development, and use of trackers and the use of tracker data in facilities that use data from multiple radars such as C4I networks. The engineer who plans to be involved with projects that include integration data from radar trackers, or who will be involved in writing or interpreting data fusion requirements, or in development, design, and maintenance of systems that perform tracking and data fusion.

Prerequisites: A degree in EcE, computer science, software engineering, or the equivalent. Undergraduate courses in underlying mathematics such as analytic geometry, differential equations, and advanced calculus are recommended.

Texts: David L. Hall and Sonya A.H. McMullen, Mathematical Techniques in Multisensor Data Fusion, Artech, 2004, ISBN 1-58053-335-3; A. Gelb, Ed., Applied Optimal Estimation, MIT Press (1974), ISBN 0-262-57048-3, Instructor-developed materials.