

# Tracking and Data Fusion

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This tutorial is a thorough overview of tracking and data fusion for surveillance systems with applications to defence and civilian systems. The tutorial is divided in 9 sections. *Section 1* presents a historical survey and introduces the basics of target tracking and data fusion. *Section 2* deals with the state estimation for stochastic dynamic systems; in particular the following topics are covered: optimal Bayesian estimator, linear filters (including Kalman filter), nonlinear filters (including the extended Kalman filter, the unscented Kalman filter and the particle filter), hybrid state estimation (including target dynamic models, multiple model filter, and interactive multiple model filter). Data association is the theme of *Section 3*. In more details, the topics tackled in the section are: gating, global nearest neighbour algorithm, joint probabilistic data association, multiple hypotheses tracking, multidimensional assignment, and mixture reduction data association. In *Section 4* we review the tracking system design issues with particular emphasis on: management of track life stages (track initiation & confirmation, track quality indicators, track deletion), choice of tracking coordinate system (Cartesian, polar, spherical, geodetic, Earth-centred & Earth-fixed), performance prediction and evaluation (Cramer-Rao lower Bounds and measures of effectiveness) and electronic counter-counter measures. Multiple sensor tracking and fusion is described in *Section 5*. We present various system architectures (centralised, distributed, hybrid) with their pros & cons. We also explain track-to-track association & fusion algorithms (for active tracks, passive and active tracks, and also the fusion of synthetic aperture – SAR - images). Two additional topics of *Section 5* are: handling out-of-sequence data, and registration of multiple sensors. The fusion of attribute data for track identification and measurement to track association is covered in *Section 6*. Here we describe what are the typical attributes, the goals of attribute data fusion and several automated reasoning schemes (voting, Bayesian probabilistic, evidential, possibilistic, etc). An emerging technology is the application of knowledge based techniques to tracking: it is briefly outlined in *Section 7*. *Section 8* is fully dedicated to several applications, such as: ballistic missile tracking, A-SMGCS (Advanced Surface Movement Guidance and Control System), GMTI (Ground Moving Target Indicator), track-before-detect, and bistatic radar tracking. The tutorial ends (*section 9*) with a comprehensive list of textbooks and papers for further reading.

## Short biography of Branko RISTIC

Branko Ristic has some 20 years of R&D experience related to signal processing, estimation, tracking and data fusion. He began his Career in 1984 at the Vinca Institute in Belgrade, Serbia, where his job was to develop and implement DSP algorithms for HF radiocommunications. From 1989 to 1994 he was with two universities in Brisbane, Australia: the University of Queensland and the Queensland University of Technology (QUT), doing research related to automatic placement and routing of integrated circuits and the design and analysis of time-frequency and time-scale distributions. In 1995 he was with GEC Marconi Systems in Sydney, Australia, developing a concept demonstrator for noise cancellation in towed arrays. Since 1996, he has been with DSTO, where his role has been to develop and analyse the performance of algorithms for target tracking and multisensor integration. From August 2003 he is on a study leave at IRIDIA, Universite libre de Bruxelles (Belgium).

Dr. Ristic received all his degrees in electrical engineering: a Ph.D. from QUT in 1995, an M.Sc. from Belgrade University in 1991, and a B.Eng. from the University of Novi Sad in 1984. During his career, he has published over 70 technical papers and co-authored a recent book “Beyond the Kalman filter: Particle filters for tracking applications”, Artech House, 2004.

## Short biography of Alfonso FARINA (September 2003)

**Alfonso FARINA** (Fellow of IEEE and Fellow of IEE) received his doctor degree in electronic engineering from the University of Rome (I) in 1973. In 1974 he joined Selenia, now Alenia Marconi Systems, where he is a manager (since May 1988); since one year he is a member of the Chief Technical Office. Recently he has been appointed Scientific Director. In his professional life Alfonso

has provided technical contributions to detection, signal, data & fusion, image processing for radar systems. He has provided leadership in many projects – also conducted in the international arena – in surveillance for ground and naval applications, in airborne early warning and in imaging radar. Since 1979, he has also been Professore Incaricato of Radar Techniques at the University of Naples; in 1985 he was appointed Associate Professor. He is the author of more than 270 peer reviewed publications and the author of books and monographs: *Radar Data Processing (Vol. 1 and 2) (translated in Russian and Chinese)*, 1985-1986 ; *Optimised Radar Processors*, 1987 ; *Antenna Based Signal Processing Techniques for Radar Systems*, 1992. He has written the Chapter 9 on “ECCM techniques” in the Radar Handbook (2<sup>nd</sup> Edition 1990), edited by Dr. M. I. Skolnik of Naval Research Laboratory. He has been session chairman at many international radar conferences. He uses to lecture at universities and research centres in Italy and abroad; He also frequently gives tutorials at the Intl. Radar Conferences on signal, data and image processing for radar; in particular on multi-sensor fusion, adaptive signal processing, space time adaptive processing (STAP) and detection. In the 1987 He received the Radar Systems Panel Award of IEEE-AESS *for development of radar data processing techniques*. He is the Italian representative at the International Radar Systems Panel of IEEE-AESS. He has been the Italian industrial representative at the SET (Sensor and Electronic Technology) of RTO (Research Technology Organisation) of NATO. He has been in the BoD of the International Society for Information Fusion (ISIF). He has been nominated Fellow of IEEE with the following citation: "For development and application of adaptive signal processing methods for radar systems." He is a referee of numerous publications submitted to several Journals of IEEE, IEE, Elsevier, etc., He has also cooperated with the editorial board of ECEJ (Electronics & Communication Engineering Journal) of IEE. More recently, Alfonso serves as a member in the Editorial Board of Signal Processing (Elsevier). He is the co-recipient of the prestigious best paper award, entitled to Mr. B. Carlton, of IEEE Trans. on Aerospace and Electronic Systems for the year 2001. Alfonso has been the leader of the team that received the 2002 AMS CEO award for Innovation Technology. Alfonso has recently been the co-recipient of the AMS Radar Division award for Innovation Technology in 2003.

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