Integrated Multi Sensor Multi Target Data Fusion Analysis Software - MsmtDat

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Abstract

This paper presents the features and performance of the integrated multi sensor multi target tracking and fusion software 'MsmtDat.' developed at NAL. The software is highly interactive and user friendly and has GUI based front panel for interaction. Depending on the requirement, user can tune the software for handling multi sensor single target (MSST) or multi sensor multi target (MSMT) data with or without clutter by appropriate flag setting in the GUI panel. Also provisions are made to handle maneuvering targets using interacting multiple model (IMM) technique in combination with MSST or MSMT. Software is designed keeping in view the requirements of scientists and engineers who are engaged in target tracking and radar data processing.

Key words:- Multi sensor data fusion, Multi sensor multi target tracking, Nearest neighbor Kalman filter, Probabilistic data association filter, Interacting multiple model filter.

Introduction

Data Fusion or more specifically Multi Sensor Data Fusion (MSDF) is the process to combine / integrate measured information originating from different similar / dissimilar sensors and sources (e.g. active or passive radars, EOTs, INS, GPS, etc.) to produce the most specific and comprehensive unified data / model about an event of interest. This technique achieves improved accuracies and more specific inferences than could be achieved by the use of a single sensor alone [1]. The various applications of MSDF include:

- Automated target recognition,
- Guidance for autonomous vehicles or targets tracking,
- Remote sensing,
- Battlefield surveillance,
- Automatic threat recognition,
- Monitoring of manufacturing processes, robotics and in medical applications.

At the Flight Mechanics and Control Division, NAL, many algorithms have been developed / implemented[1-5] for tracking single target with multiple sensors, multi target with multiple sensors including maneuvering targets in the presence of clutter. All these algorithms have been integrated into a single software package called 'MsmtDat' for tracking multiple airborne targets such as missile, aircraft, helicopter, using data from multiple tracking sensors like ground based radars, electro optic transducers (EOTs), INS and GPS. The integrated software is developed in 'C' and implemented on digital UNIX platform (DEC Alpha OSF 1).

The features of the integrated software package include:

- Online bias estimation and correction using GPS data as reference for all the sensor data
- Measurement noise covariance estimation using GPS data as reference
- Conversion of all data to a common Earth centered earth fixed (ECEF) reference frame
- Least squares based algorithm for target position computation using EOT data
- UD factorization based Kalman Filter / IMM (Interacting Multiple Model) filter for target state estimation
- Reference time signal generation starting with the time stamp of the sensor data that arrives first.
- Dynamic textual message display
- Filter performance evaluation
- Measurement fusion for similar sensors
- State vector fusion with range based priority for dissimilar sensors
- State estimation using the computed positions of target using EOTs data

Also following additional features are provided for multi sensor multi target (MSMT) tracking:

- Multi rate measurement mixing
- Gating for measurement screening

- o Data association using nearest neighborhood Kalman filter (NNKF) and Probabilistic data association filter (PDAF)
- o Track/Target oriented tracking

The integrated software package is interactive and user friendly. The front end GUI panel (developed using X-MOTIF) is shown in the Figure 1. The panel includes provision to input sensor location, their noise variances, sensor data format, selection of algorithms required for a given scenario. Also flags are provided to select online computations of measurement noise covariance and also to check the filter performance. Performance check includes plotting of autocorrelation of innovation sequence with theoretical bounds, estimated state error with theoretical bounds and root sum square position error (RSSPE). The flow chart of the integrated software is shown in Figure 2.

Validation Results

The software has been validated with different sets of simulated as well as real data obtained under different situations (viz. multi sensor single maneuvering target with clutter, multi sensor multiple maneuvering targets, etc.). Because of space constraints one typical validation result of multisensor multitarget simulated data is presented.

Simulation is carried out to generate 3D positions of 25 maneuvering targets tracked by two asynchronous ground based radars with varying sampling time. The measured data supplied consists of range, azimuth and elevation of targets, validity bit, time stamp and sensor identification number. IMMPDAF module of the integrated software is chosen to track this multi sensor multi target data. The characteristic parameters of the scenario for IMMPDAF algorithm [6] are predefined as follows:

- Initial mode probability μ = [0.9 0.1]
- Markov chain transition probability = p_{12} = 0.12
- Probability of true detection = 0.9
- Probability of false alarms = 0.1
- Gate threshold = 50 meters
- The ratio of the process noise covariances for the constant acceleration and constant velocity models used for tracking is chosen as 80

For achieving time synchronization of the two sensor measurements, reference time is initiated with the track time of the sensor from which the data is received first. All the measurements arriving within every 100ms are used for track to measurement association and subsequently to update the states.

At the first scan, each measurement is used to initiate a track. At each subsequent scans, track to measurement correlation (TMCR) table [6,7] is formed between all the existing tracks and present measurements for each sensor separately using gating and data association technique. Based on the entries in the TMCR table (see Table 1) the tracks are either updated, predicted, initiated or deleted. All the measurements that are falling within the gate of a particular track are chosen for updating that track using PDAF algorithm. If any of the measurements do not fall within the gate of any of the track, then that particular measurement is not associated with any of the existing tracks. Instead a new track is initiated with that measurement as initial condition. If no measurements fall within the gate of the particular track, that track is predicted to the next instant through time propagation of states. If the track does not get any measurement(s) within its gate for update continuously for more than 4sec, then that particular track will be deleted. Tracks, which are close to each other (determined based on distance threshold) are fused together using state vector fusion in order to avoid redundant tracks.

Figure 3 shows the comparison of 25 estimated tracks and the corresponding measured trajectories. Figure 4 illustrates the RSSPE of one of the tracks. From the figure it is clear that position error is within the acceptable limits. Figure 5 shows the auto-correlation of the innovation sequence with corresponding theoretical bounds. Since the autocorrelation is well within their bounds, it is clear that filter is able to extract nearly full information from noisy measurements and estimate the target states.

Conclusion

Different techniques / algorithms for multi sensor single target (MSST) tracking and multi sensor multi target (MSMT) tracking including maneuvering targets in the presence of clutter are integrated into a single software package with user friendly interactive features. A case study of twenty five targets tracked by two ground based radars is presented to show the performance of the integrated software.

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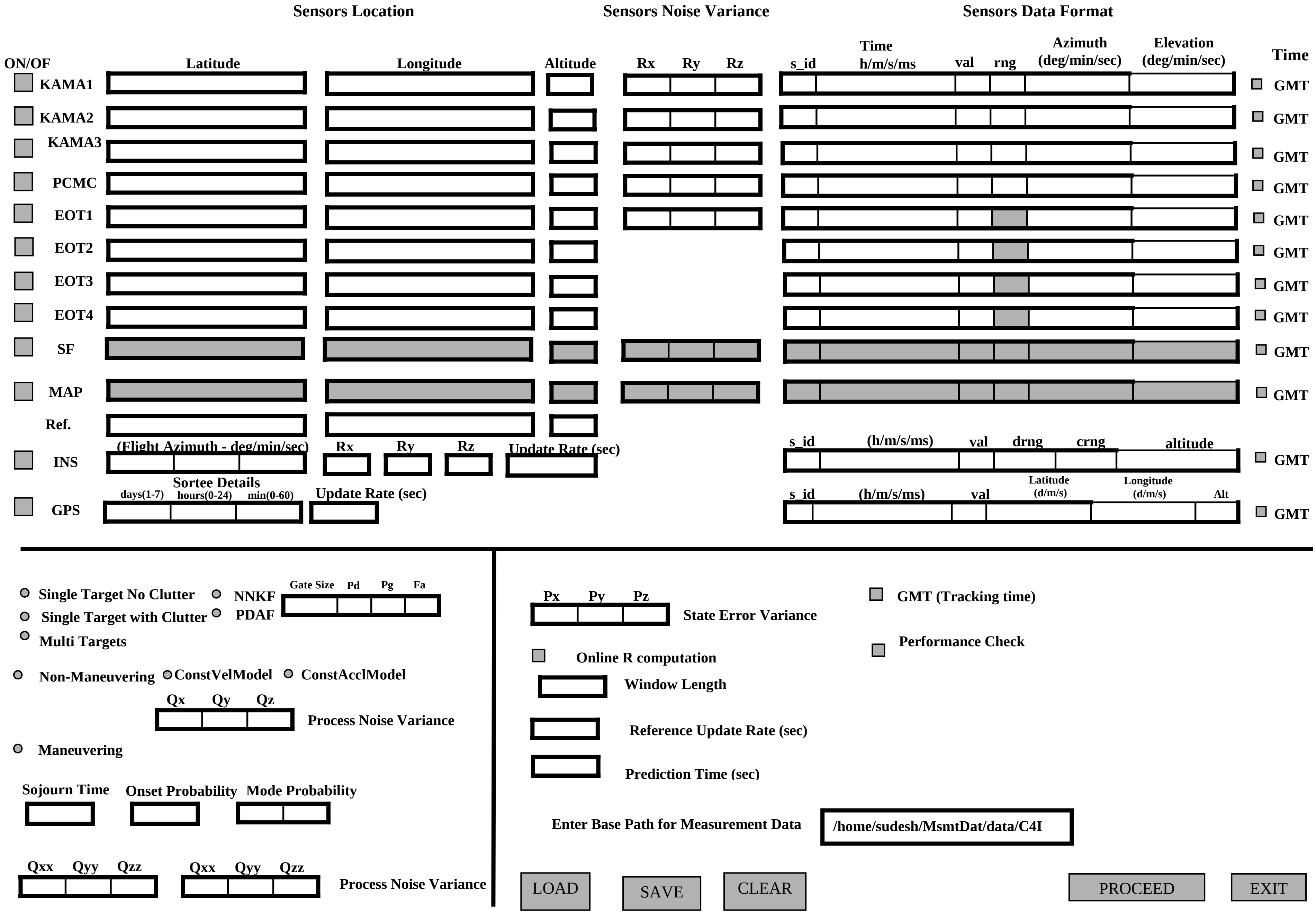

Figure 1: Layout of front end GUI panel (created using x-motif in ‘C’ on DEC-Alpha)

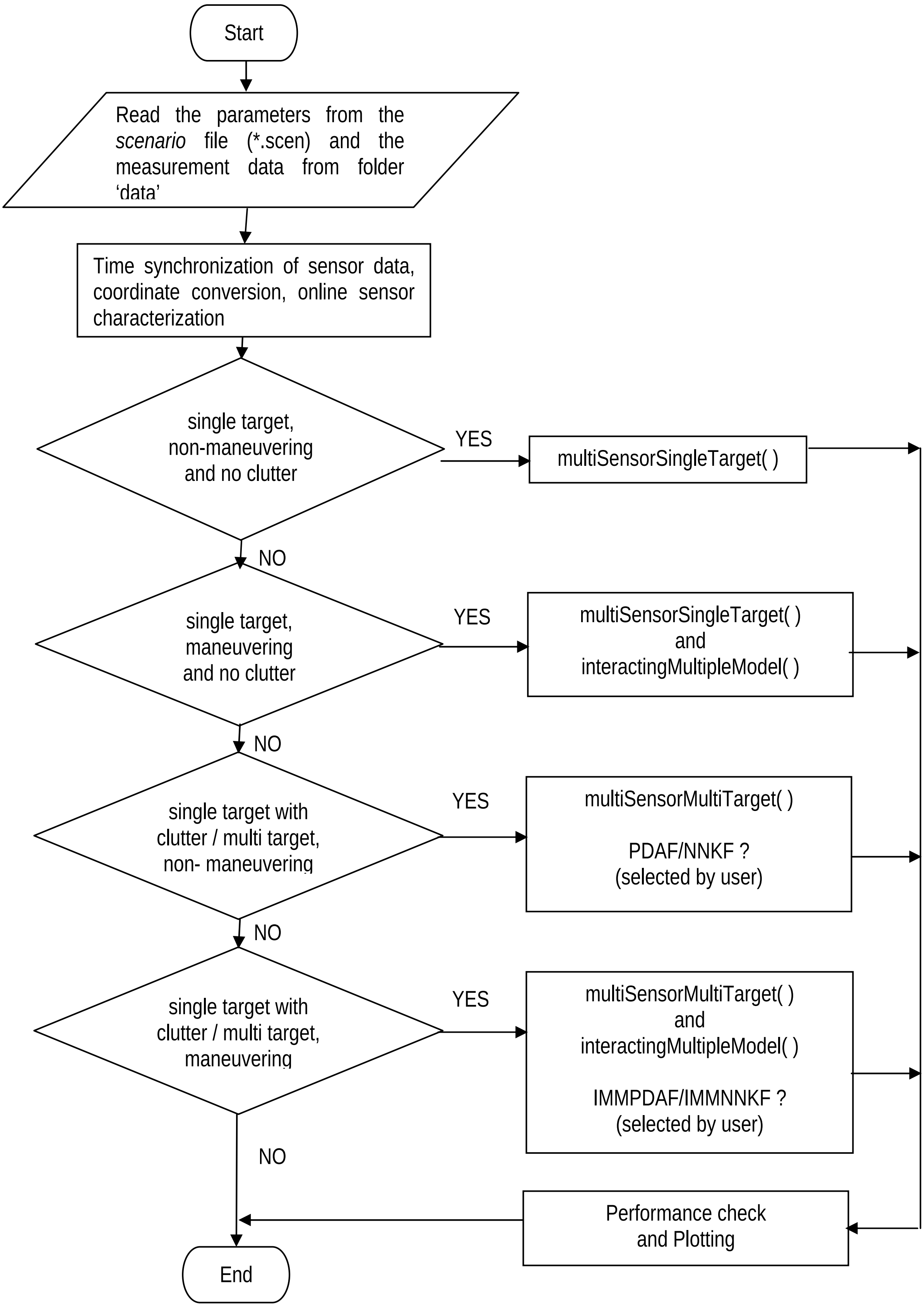

Figure 2: Flowchart of integrated interactive 'MsmtDat' software

Table 1 : TMCR at 10th scan

		Current Measurements		
		M1	M2	M3
Existing tracks	T1	1000	1000	1000
	T2	1000	1000	1000
	T3	1000	1000	1000
	T4	45.2	1000	1000
	T5	1000	45.1	1000
	T6	1000	1000	45.1
	T7	1000	1000	1000
	T8	1000	1000	1000
	T9	1000	1000	1000

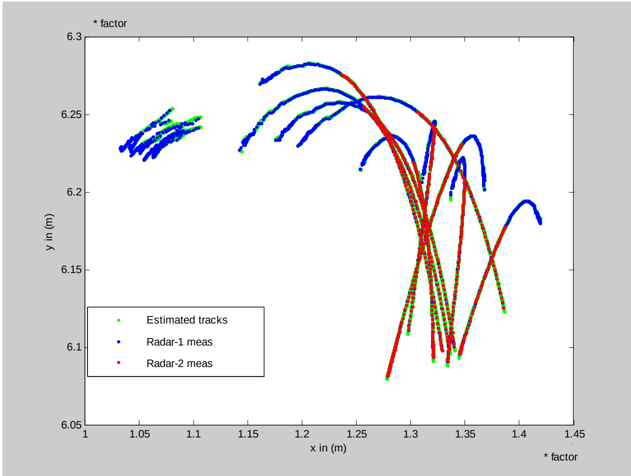

Figure 3: Measured and Estimated trajectories (in X-Y plane) of 25 targets tracked by 2 radars (simulated data)

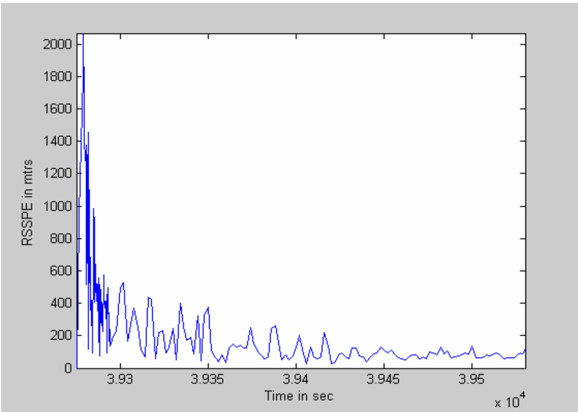

Figure 4: RSS Position Error (of track no. 11)

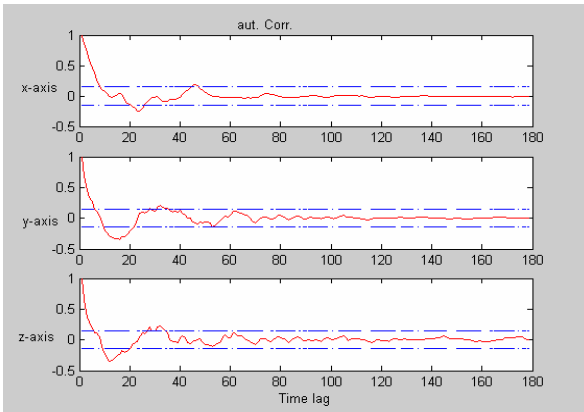

Figure 5: Autocorrelation of residual (of track no. 11)

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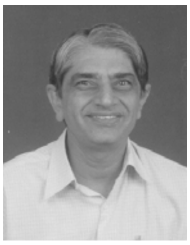
Dr. (Mrs.) Girija G, received her Ph.D. from Bangalore University in 1996. She is presently working as Scientist at National Aerospace Laboratories (NAL), Bangalore. Her areas of research are: modeling, parameter estimation of aerospace vehicles and multi sensor data fusion. She is a recipient of NAL Foundation Day Award for Research in the year 1995. She has published about 50 research papers. She is a member of Aeronautical Society of India.



Dr. J. R. Raol was born in 1947 in Gujarat. He obtained BE and ME degrees from MS university of Baroda in 1971 & 1974 and PhD from McMaster University, Canada in 1986. Worked in National Aerospace laboratories, Bangalore from 1975 to 1981 and was actively involved in the multidisciplinary control group's activities on human pilot modelling in fixed- and motion-based research simulators. He re-joined NAL in 1986 and is currently Head of the Flight Mechanics and Control Division of NAL. Current activities includes modeling, identification, multisensor data fusion, fuzzy systems, genetic algorithms and neural networks He is a senior member of the IEEE (USA), Fellow of IEE, Fellow of the Aeronautical Society of India, and Life Member of System Society of India. He has authored (jointly with Dr. Giriga G. and Dr. Jatinder Singh) a book on “Modeling and Parameter Estimation of Dynamic System”, published by IEE, UK in 2004. He has 100 publications to his credit.