Course Syllabus for
DAUSY National Ph.D. Program in Autonomous Systems
(year 2022-23)

Course title	Linear and nonlinear Kalman filtering: theory and applications
Scientific discipline sector	ING-INF/04
Hours of instruction	15hours
CFU	1,5CFU
Semester, period	February2023
Practical information	Link to download didactic material https://drive.google.com/drive/folders/1UJCR-gTf3qSy1T__-6wkxPe4vFOAXcPZ?usp=share_link Link to register to the course https://docs.google.com/spreadsheets/d/1xReNg2UQBDCnZuy4AypIwBkbqQ_Lwy2e8P7AqYH1dSQ/edit?usp=share_link
Goal	This course aims to provide both theoretical and practical tools to tackle estimation problems encountered in several areas of engineering and science. In particular, it is shown how to formulate such estimation problems as instances of a general dynamical system state estimation problem and how to derive the mathematical solution of the latter problem. Then it is shown that, for a linear Gaussian system, such a solution yields the well-known Kalman filter. Further, approximate techniques (e.g. extended and unscented Kalman filters, particle filter, etc.) are presented for the case of nonlinear and/or non-Gaussian systems, for which an exact closed-form solution cannot be found. To conclude the theoretical part, theoretical limitations (i.e. the Cramer-Rao lower bound) on the quality of estimation are discussed. In the second part of the course, we illustrate some applications of linear/nonlinear Kalman filtering (e.g., tracking, robotic navigation, environmental data assimilation)and new frontiers of research concerning multi-agent and/or multi-object estimation.

Syllabus	· A general dynamic estimation problem in state-space form · Recursive Bayesian filtering · Kalman filter asrecursive Bayesian filter in the linear Gaussian case · Beyond the Kalman filter: nonlinear filters for nonlinear and/or non-Gaussian estimation problems (extended Kalman filter, unscented Kalman filter, particle filter, Gaussian sum · filter). · Theoretical limits on the quality of estimation · Applications to surveillance, robotic navigation and environmental data assimilation. · Research on multi-agent and/or multi-object estimation.
Bibliography	Handouts provided by the teacher. · B.D.O. Anderson, J.B. Moore: Optimal filtering, Prentice Hall, 1979. · 7 Y. Bar-Shalom, X.R. Li, T. Kirubarajan: Estimation with applications to tracking and navigation, J. Wiley & Sons, 2001. · 8 B. Ristic, S. Arulampalam, N. Gordon: Beyond the Kalman filter: particle filters fortracking applications, Artech House, 2004.
Examination method	Final examination by written test (if necessary)