FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS
UNIVERSIDAD DE CHILE

PROGRAMA DE CURSO

Código	Nombre
EL7031	Robotics, Sensing and Autonomous Systems
Nombre en Inglés	
Robotics, Sensing and Autonomous Systems	

SCT	Unidades Docentes	Horas de Cátedra	Horas Docencia Auxiliar	Horas de Trabajo Personal
6	10	3.5	1.5	5.0

Requisitos	Carácter del Curso
EL4003 Signals & Systems 2	Electivo

Resultados de Aprendizaje

At the end of the course, the student will understand:

1) The functionality of range measurement sensors in robotics.
2) The ability to derive sensor models and understand sensor uncertainty.
3) Kinematic and dynamic system models.
4) The application of linear estimation and data fusion for robotics and tracking.
5) The application of probabilistic data association in robotics.
6) Methods which implement Bayes Theorem in sensor fusion.
7) Use and application of unscented Kalman and particle filters in robotics.
8) Grid based and feature based robotic mapping.

Metodología Docente

The course will utilize the following teaching methods:

1) Lectures.
2) Exercises conducted in class.
3) Project assignments, in which the students present research papers in robotics*.

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a) Research papers and chapters are selected from the book "Probabilistic Robotics" [1].
b) All of the students will be required to read each paper/chapter before the designated class session for that paper/chapter.
c) Each student is required to select a paper or chapter and to understand, compare and demonstrate the contents. This will be carried out in the form of a "Reading discussion group". The designated student will lead the discussion, with slides, videos and research gathered from papers and the internet. All students in the class are expected to contribute to the discussions.

Evaluación General

The students will be evaluated based on the following criteria:

1) Exercises (tutorials) set in class, which they will hand in.
2) Project assignments in which they will present their interpretation of research papers in robotics.

Unidades Temáticas

Número	Nombre de la Unidad	Duración en Semanas
1	Sensors in Robotic Applications	5

Contenidos	Resultado de Aprendizaje de la Unidad	Referencias a la Bibliografía
1. Cameras - Use of Vision in Tracking and Robotics (Conjugate points, disparity, photogrammetry, correspondence problem, correlation and edge matching methods). 2. Active Triangulation Sensors including depth (Triangulation gain, accuracy trade-offs). 3. Time of Flight (TOF) Cameras. 4. LADAR - Laser Detection and Ranging Sensors (Co-axial sensing, Amplitude Modulated Continuous Wave (AMCW) range estimation, AMCW noise analysis). 5. RADAR - Radio Detection and Ranging Sensors (Radar equation, Received power vs. range spectra interpretation, Frequency Modulated Continuous Wave (FMCW) range estimation, noise sources). 6. SONAR - Sound Navigation and Ranging Sensors (Reflection of waves – Specular vs. diffuse, Time of Flight (TOF) sensing, Interpreting sonar – Regions of Constant Depth (RCDs)).	At the end of this unit, the students will: 1) Understand the physical working principles or each sensing type. 2) Learn how to derive and use sensor models. 3) Learn how noise affects each type of sensor, and how to estimate sensor uncertainty.	[2], [5]

Número	Nombre de la Unidad	Duración en Semanas
2	Probabilistic Data Fusion and Estimation in Robotics	6

Contenidos	Resultado de Aprendizaje de la Unidad	Referencias a la Bibliografía
1. Brief Review of Bayes Theorem and different notation used. 2. Tracking (Applying linear estimation to target tracking, alpha-beta trackers, dynamic target models, software implementations). 3. Conditional independence assumptions necessary for applying Bayes theorem in data fusion (definition of state for conditional independence of sensor measurements). 4. Non-parametric Bayesian methods based on the Unscented Kalman Filter (UKF) and Monte Carlo based particle filters. 5. Representing statistical uncertainty (Uncertainty ellipsoids & Monte Carlo methods). 6. System Kinematic Models (Constant velocity, acceleration models, discrete white noise acceleration systems, digitizing continuous time systems).	At the end of this unit, the students will: 1) Revise Bayes theorem and be able to apply it to discrete and continuous sensor fusion problems. 2) Understand the importance of conditional independence in data fusion systems. 3) Understand how to apply linear, non-linear and non-parametric estimation methods (e.g. Monte Carlo methods) to tracking problems. 4) Understand the meaning of statistical uncertainty and be able to represent it in a meaningful way. 5) Understand methods and issues of implementing the above in software.	[3], [4], [6], [7].

Número	Nombre de la Unidad	Duración en Semanas
3	Autonomous Robot Navigation	4

Contenidos	Resultado de Aprendizaje de la Unidad	Referencias a la Bibliografía
Scientific articles which present recent advances in: 1. Definitions of complete and hybrid states and Markov transition kinematics and dynamics. 2. Robot motion (odometric and velocity based kinematic models, Markov assumptions, sources of uncertainty). 3. Sensor measurement models (Definition of a sensor model, Forward sensor models, random, false and missed detections, range uncertainty). 4. Robot localization (algorithmic issues in implementing extended Kalman Filter (EKF) and Monte-Carlo methods). 5. Grid based localization and mapping (Uncertainty grid concepts, grid cell independence assumptions, inverse measurement models, occupancy grid mapping with forward sensor models). 6. Graphical Simultaneous Localisation and Map (SLAM) building methods (GraphSLAM, scan matching, relation to mass-spring constraint systems, estimation in information space, factorizing the posterior estimates). 7. Particle filtering and Rao-Blackwellisation (A factored solution to the SLAM problem, conditionally independent robot maps, importance sampling, maximum a-posteriori (MAP) and expected a-posteriori (EAP) maps). 8. Random Finite Set (RFS) based SLAM and advanced	At the end of this unit, the students will: 1) Learn how to apply probabilistic techniques to non-linear robotic systems. 2) Learn how to derive and use non-linear measurement models. 3) Learn robot localization techniques based on the extended Kalman filter (EKF) and Monte-Carlo methods. 4) Learn Grid-based robot localization and mapping. 5) Understand the joint probabilistic estimation concept of Simultaneous Localisation and Map (SLAM) building. 6) Learn graphical methods for solving the SLAM problem. 7) Learn particle filter and Rao-Blackwellisation methods for solving SLAM. 8) Learn new methods of statistical representations based on set theory.	[1], [8], [9], [10], [11].

methods (Introduction to Finite Set Statistics (FISST) and Bernoulli representations of uncertainty).		

Bibliografía General

Bibliografía Básica

[1] S. Thrun, W. Burgard & D. Fox, "Probabilistic Robotics", MIT Press, 2005.

[2] M.D. Adams, *"Sensor Modelling, Design & Data Processing for Autonomous Navigation"*, World Scientific Publications 1999.

[3] Peter S. Maybeck, *"Stochastic Models, Estimation and Control"*, Volume 1, Academic Press, 1979.

[4] James V. Candy, *"Bayesian Signal Processing - Classical, Modern and Particle Filtering Methods*", John Wiley & Sons, 2009.

Bibliografía Complementaria

[5] Mongi A. Abidi & Rafael C. Gonzales, *"Data Fusion in Robotics & Machine Intelligence"*, Academic Press 1992.

[6] Y. Bar-Shalom, X. Rong Li, T. Kirubarajan, *"Estimation with Applications to Tracking and Navigation"*, John Wiley & Sons, 2001.

[7] J.K. Uhlmann, *"Dynamic Map Building and Localisation: New Theoretical Foundations"* PhD thesis, University of Oxford, 1995.

[8] M.W.M.G. Dissanayake, P. Newman, S. Clark, H.F. Durrant-Whyte and M. Csorba, "*A Solution to the Simultaneous Localistaion and Map Building (SLAM) Problem*", IEEE Transactions on Robotics and Automation, Vol. 17, No. 3, June 2001.

[9] M. Montemerlo, S. Thrun, D. Koller, and B. Wegbreit, "*FastSLAM: A factored solution to the Simultaneous Localization and Mapping problem*", Proceedings of the AAAI National Conference on Artificial Intelligence, Edmonton, Canada, 2002.

[10] M. Montemerlo, S. Thrun, D. Koller, and B. Wegbreit, "FastSLAM 2.0: An Improved Particle Filtering Algorithm for Simultaneous Localization and Mapping that Provably Converges", Proceedings of the 18th International Joint Conference on Artificial intelligence (IJCAI), Acapulco, Mexico, 2003.

[11] J.S. Mullane, B.N. Vo, M.D. Adams, B.T. Vo, "*Random Finite Sets for Robot Mapping and SLAM - New Concepts in Autonomous Robotic Map Representations*", Springer Tracts in Advanced Robotics No. 72, May 2011.

Vigencia desde:	
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