SHAKE THE FUTURE.

CENTRALE NANTES

ENGINEERING PROGRAMME

SPECIALISATION

ROBOTICS

AUTUMN SEMESTER

Établissement public sous tutelle du
ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation

GROUPE **CENTRALE**

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MANIPULATOR ROBOT MODELLING

ROBOTICS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Abdelhamid CHRIETTE

Objectives

This course's main objective is to study and implement mathematical tools to develop models (geometric, kinematic and dynamic) dedicated to robot manipulators.

Course contents

Part 1: Introduction to robotics
Part 2: Background on geometry, kinematics and dynamics of solids
Part 3: direct and inverse geometrical modeling of manipulator arms
Part 4: direct and inverse kinematics modeling of manipulator arms
Part 5: direct and inverse dynamic modeling of manipulator arms

Labs:
LAB 1: Introduction to tools and methods for modeling
LAB 2: Complete modeling of a robot manipulator with 6 degrees of freedom

Course material

- W. Khalil, and E. Dombre, Modelling, identification and control of robots, Hermes Penton, London, 2002.
- J. Angeles, Fundamentals of Robotic Mechanical Systems, Springer-Verlag, New York, 2002.

Keywords

Manipulator robot. Manipulator arms. Direct and inverse geometrical modeling. Direct and inverse kinematics modeling. Direct and inverse dynamic modeling

Links with other programmes

Robot design. Robot Control.

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	5	20 hrs	4 hrs	8 hrs	0 hrs

ROBOT DESIGN

ROBOTICS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Sébastien BRIOT

Objectives

This course is about the optimum design of serial and parallel robots. Some performance indices will be provided and the design problems will be formulated as optimization problems. Those optimization problems may be mono- or multi-objective and subject to constraints. The geometric, kinematic, kinetostatic, elastostatic and dynamic performances of the robots will be considered in those design problems. Moreover, some optimization routines will be taught to solve the optimization problems at hand.

Course contents

Part 1: Geometric, kinematic, kinetostatic, elastostatic and dynamic modeling of robots
Part 2: Performance indices: maximal regular workspace, dexterity indices, transmission factors for velocities and wrenches, elastostatic and elastodynamic indices (considering actuator stiffness only), accuracy / resolution, maximal torque value, energy, etc.
Part 3: Problem of the non-homogeneity of Jacobian matrices
Pare 4: Sensitivity analysis of serial and parallel manipulators to geometric errors and joint clearances.
Part 5: Static Balancing: use of counterweights or springs
Part 6: Trajectory planning
Part 7: Optimal task placement
Part 8: Optimal and robust design

Course material

- W. Khalil, E. Dombre, Modelling, identification and control of robots, Hermes Penton, London, 2002.
- C. Germain, S. Caro, S. Briot and P. Wenger; Optimal Design of the IRSBot-2 Based on an Optimized Test Trajectory; Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2013, August 4-7, 2013, Portland, Oregon, USA.
- S. Briot, A. Pashkevich and D. Chablat; Optimal Technology-Oriented Design of Parallel Robots for High-Speed Machining Applications; Proceedings of the 2010 IEEE International Conference on Robotics and Automation (ICRA 2010), 3-8 May, 2010, Anchorage, Alaska, USA
- Caro, S., Bennis, F. and Wenger, P., 2005, Tolerance Synthesis of Mechanisms: A Robust Design Approach, ASME Journal of Mechanical Design, Vol.127, pp. 86-94, January 2005. hal-00463707
- Wu, G., Bai, S., Kepler, J.A., and Caro, S., 2012, Error Modeling and Experimental Validation of a Planar 3-PPR Parallel Manipulator With Joint Clearances, ASME Journal of Mechanisms and Robotics, Vol. 4(4), pp. 041008-1-041008-12. hal-00832640
- Binaud, N., Cardou, P., Caro, S. and Wenger, P., The Kinematic Sensitivity of Robotic Manipulators to Joint Clearances, Proceedings of ASME Design Engineering Technical Conferences, August 15-18, 2010, Montreal, QC., Canada.

Keywords

Parallel robots, Geometric, kinematic, kinetostatic, Elastostatic, Workspace, Dexterity indices, Trajectory planning, Optimal and robust design.

Links with other programmes

Manipulator robot modeling

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	**3**	**20 hrs**	**0 hrs**	**12 hrs**	**0 hrs**

ADVANCED PROGRAMMING

ROBOTICS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Abdelhamid CHRIETTE

Objectives

C ++ has become essential in robotics, it is used among others in the ROS library (Robot Operating System).

The purpose of this course is to introduce the C ++ language through educational examples. Teaching will alternate between lectures, tutorials, and lab sessions for programming.

On completion of the module, the student will master the use of a C ++ toolchain and will have acquired sound knowledge of the C ++ language features, such as the programming class, exceptions, templates and redefining operators.

Course contents

- Development chain installation
- C, separate compilation
- Mixing C and C++
- C +: C ++ without classes (argument passed by reference)
- The class structure, constructor and destructor, method
- Redefining operators
- Pointers
- Controlling copy
- Inheritance and virtual functions;
- Abstract classes;
- Dynamic allocation;
- Templates;
- Exceptions.

Course material

Christine EBERHARDT, Tout sur le C++, Editions Dunod, 2009, 224 pages, EAN13: 9782100531899.

Scott Meyer, Effective C++: 55 Specific Ways to Improve Your Programs and Designs (3rd Edition), Addison-Wesley

Keywords

C++

Links with other programmes

First Year Course in Algorithms and Programming

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	16 hrs	4 hrs	16 hrs	0 hrs

VISION FOR ROBOTICS

ROBOTICS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Olivier KERMORGANT

Objectives

This course's main objective is to present the basic principles of vision (image, image processing, and visual geometry). The themes concern the formation of images, vision sensors, low salaries, detectors and descriptors, calibration, pose estimation, the multi-view monitoring and visual geometry.

Course contents

Part 1: Introduction to vision
Part 2: Image processing
Part 3: Visual Geometry
Part 4: Follow Visual
Part 5: Multi-view Geometry

Labs:
LAB1: Low level image processing
LAB2: Extraction points of interest
LAB3: classic camera calibration and fisheye

Course material

- I. Pitas, Digital Image Processing Algorithms, Prentice Hall, New York, 1993.
- O. Faugeras, Three-dimensional computer vision. A geometric viewpoint, The MIT Press. Cambridge, Mass. 1993, ISBN: 0262061589
- Richard Hartley, Andrew Zisserman, Multiple View Geometry in Computer Vision, Barnes & Noble, 2nd edition 2004 , ISBN-10: 0521540518
- Quang-Tuan Luong, Olivier Faugeras, The Geometry of Multiple Images- The Laws That Govern the Formation of Multiple Images of a Scene, MIT Press, March 2001, ISBN: 0-262-06220-8
- T S Huang, Multiple Calibration and Orientation of Cameras in Computer Vision, Springer, 2001, ISBN: 3 540 65283 3
- Yi MA, Stefano Soatto, Jana Kosecka, S. Shankar Sastry, An invitation to 3D vision: from images to geometric models, Springer, 2004, ISBN 978-0-387-00893-6
- Gari Bradski, Adfrian Kaebler, Learning OpenCV: Computer vision with openCV library, OReilly Media, 2008, ISBN: 978-0-596-51613-0

Keywords

Image processing, Visual geometry. Calibration. Pose estimation.

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	20 hrs	0 hrs	12 hrs	0 hrs

NON-LINEAR CONTROL AND OBSERVATION

ROBOTICS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Guy LEBRET

Objectives

This courses main objective is to introduce the basic tools for the analysis and control of linear and non-linear systems in the state approach.

Course contents

Linear systems
Part 1: systems analysis (controllability, observability)
Part 2: Synthesis controllers (state feedback, observers, reconstructed state feedback)
Part 3: Robust stability.

Nonlinear systems
Part 4: systems analysis (accessibility, observability)
Part 5: synthesis regulators (input-output linearization, robust control).

Labs:
LAB1: inverted pendulum (linear version)
LAB2: inverted pendulum (non-linear version)

Course material

- Phlippe de Larminat, Commande des systèmes linéaires, Hermès science, 2002, 288 p.
- Hassan K. Khalil, Nonlinear Systems, Prentice Hall PTR, 2002 - 750 pages

Keywords

Linear systems controllability, observability, feedback status, robust stability, accessibility, input-output linearization, robust control.

Links with other programmes

Advanced control of linear systems, Embedded Control and Power Grids Specialisation

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	20 hrs	4 hrs	8 hrs	0 hrs

INTELLIGENT VEHICLE AND TRANSPORT

ROBOTICS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Gaetan GARCIA

Objectives

The first part of the course aims to give students an overview of the applications of mobile robots. This part also covers the basics of their kinematic modelling, together with the mathematical tools used in vehicle localization algorithms.

The second part of the course aims to address some of the issues related to human-computer interaction in the field of transportation. It presents a multidisciplinary approach to system design, at the crossroads between cognitive ergonomics and engineering. The illustrations mainly concern the automatic assistance for vehicular control, in a car or an aircraft.

Course contents

- Constraint equations of wheeled mobile robots.
- Mobile robot mobility depending on the types of wheels.
- Kinematic modelling of wheeled mobile robots.
- The localization function in mobile robotics, with a focus on odometry and Kalman filtering tools.
- Psychology and ergonomics applied to human-machine systems.
- Perception for the control of vehicular motion.
- Human-machine cooperation in driving.
- Spatial disorientation in aeronautics.

Course material

- C.Canudas, B. Siciliano, G.Bastin (editors), Theory of Robot Control, Springer-Verlag, second edition 1999, Chapters 7,8 & 9.
- B.Siciliano, O.Khatib, (editors), Robots Handbook, Springer-Verlag 2008, Chapters 17, 34, 35.
- Pierre Dauchez (editor), Applications non manufacturières de la robotique, traité I2S, Hermès Science Publications 2000, ISBN 2-7462-0165-8.
- Berthoz, A. (1997) Le sens du mouvement, Odile Jacob
- Cacciabue, PC (2007) Modelling Driver Behaviour in Automotive Environments: Critical Issues in Driver Interactions with Intelligent Transport Systems, Springer
- Jagacinski & Flach (2002). Control Theory for Humans, Quantitative Approaches to Modeling Performance. Lawrence Erlbaum Associates.

Keywords

Mobile robots, localization, kinematic model, human factors, perception, sensorimotor control, cognition, driving assistance systems

Links with other programmes

Robot Control, Manipulator robot modeling

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	20 hrs	0 hrs	12 hrs	0 hrs

Robotics Project 1

Robotics, Engineering programme specialisation
Autumn Semester

Professor: Abdelhamid CHRIETTE

Objectives

Introduce students to robotics engineering tools (modeling, identification and control) through the projects proposed by teachers of the specialisation.

Course contents

Continuous project.

Course material

Depending on the project.

Keywords

Robotics, control, parallel robots, ROS, underwater robots, drones.

Links with other programmes

All courses of the specialisation.

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	1	0 hrs	0 hrs	0 hrs	32 hrs

Modelling and Control of Unmanned Systems (Aerial/Submarine)

Robotics, Engineering programme specialisation
Autumn Semester

Professor: Abdelhamid CHRIETTE

Objectives

This course's main objective is to inform engineering students about the problems associated with modeling, perception, navigation and control stand-alone systems like aerial drones and submarines.

Course contents

Part 1a: Unmanned Aerial Systems (UAS)
Part 1b: Fixed Wing (General Introduction & Basics of Aerodynamics, Stability and Derivation of a Dynamic Model, Control, Aspects of Flight Dynamics & Autopilot Design)
Rotary Wing (Introduction to Rotorcraft, Dynamic Modeling of Rotorcraft, Control of Rotorcraft).
Part 2: Unmanned Submarine Vehicles (USV)
Introduction to Submarine Systems, Dynamic Modeling of Submarine Systems, Control of Submarine Systems

Lab Work:
LAB1: Fixed Wing UAS Model and Control
LAB2: Modeling and control of a Quadrotors
LAB3: State Estimation & Control

Course material

- Unmanned Aerial Vehicles: Embedded Control, Rogelio Lozano (Editor), February 2013, Wiley-ISTE.
- Advances in Unmanned Aerial Vehicles State of the Art and the Road to Autonomy. Series: Intelligent Systems, Control and Automation: Science and Engineering, Vol. 33, Valavanis, Kimon P. (Ed.), 2007, XXIV, 543 p.
- Autonomous Underwater Vehicles: Modeling, Control Design, and Simulation, Pushkin Kachroo, Sabiha Wadoo. CRC Press Inc, 14 December 2010.

Keywords

Unmanned Aerial Systems, Aerodynamics, Stability, Dynamic Model, Control, Rotary Wing, Unmanned Submarine Vehicles.

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	20 hrs	0 hrs	12 hrs	0 hrs

MIDDLEWARE

ROBOTICS, ENGINEERING PROGRAMME SPECIALISATION
AUTUMN SEMESTER

Professor: Gaetan GARCIA

Objectives

The goal of this course is to discover the ROS framework (Robot Operating System). This framework allows for the design of a whole robotic architecture with several elementary programs that communicate together, which is a common situation in robotics.

Course contents

1: General architecture: nodes, topics and services
2: Low-level tools for assisted development
3: Higher-level tools

Labs: The labs will be using the Baxter robot from Rethink Robotics
LAB1: Using nodes and topics, writing launch files to run several nodes
LAB2: Message reading an writing
LAB3: Using the TF topic (frame transformation) and services
LAB4: Using image topics

Course material

Quigley, M., Conley, K., Gerkey, B., Faust, J., Foote, T., Leibs, J., ... & Ng, A. Y. (2009, May). ROS: an open-source Robot Operating System. In ICRA workshop on open source software (Vol. 3, No. 3.2, p. 5).
http://wiki.ros.org/ROS/Tutorials

Keywords

ROS (Robot Operating System), Real Time Systems

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	6 hrs	0 hrs	16 hrs	0 hrs