Autonomous Racing Cars

Course Number & Title	**Autonomous Racing Cars**
Credit Units	6 ECTS VU (VO + Lab)
Class/Laboratory Schedule	Lecture and lab: 2 x 3 hours/week. Tuesday and Thursday 9-12am, CPS Library
Instructor	Radu Grosu, radu.grosu@tuwien.ac.at
Prerequisites	C++ and Python programming, Matrix algebra, Differential equations, Signals and Systems
Text(s)/Required Materials	Recommended (but not required): *Planning Algorithms* (by LaValle), *Computer Vision: A Modern Approach* (by Forsyth and Ponce), *Modern Control Engineering* (by Ogata). Additional readings from the literature will be provided as appropriate.
Catalog Description	This hands-on, lab-centered course is for master students interested in the fields of artificial perception, motion planning, control theory, and applied machine learning. It is also for students interested in the burgeoning field of autonomous driving. This course introduces the students to the hardware, software and algorithms involved in building and racing an autonomous race car. Every week, students take two lectures and complete an extensive hands-on lab. By Week 6, the students will have built, programmed and driven a 1/10th scale autonomous race car. By Week 10, the students will have learned fundamental principles in perception, planning and control and will race using map-based approaches. In the last 6 weeks, they develop and implement advanced racing strategies, computer vision and machine learning algorithms that will give their team the edge in the race that concludes the course.
Topics Covered	The course has five learning modules that build on each other and include three races for evaluation: 1. *Introduction to ROS, F1/10 & the Simulator:* Introduction to self-driving hardware and full autonomous vehicle software stack, automatic emergency braking, LiDAR, rigid body transformation, Laplace domain dynamics, PID control for wall following. 2. Driving using Reactive Methods & RACE!: Build vehicle, tune electronic speed controller, and implement reactive driving methods such as follow the gap and complete Race 1. 3. AV Mapping & Localization: Foundations of SLAM with scan matching and particle filters, Google Cartographer SLAM, implement pure pursuit driving, and complete Race 2 using maps. 4. AV Planning: Moral Decision Making for autonomous systems, raceline optimization, planning with rapidly exploring random trees (RRT) and understanding model-predictive control (MPC). 5. Learning & Vision: Design and implement algorithms for detection and pose estimation, reinforcement learning and visual feature extraction. 6. F1/10 Grand Prix! Race 3 will include a project to implement planning and control race strategies.
Course Objectives and Relationship to Program Education Objectives	The goal of this course is to give students an up-to-date foundation in the technologies being deployed and tested on self-driving cars, and more general mobile autonomous systems.
Contribution towards Program Outcomes	Multidisciplinary Ability – High Problem Solving Approach – High Problem Solving Methods – High Experimentation – High Design – Med Professional Orientation – High
Contribution towards Professional Component	100% Engineering science
Weekly/Session Schedule	Week 1 Introduction, using the F1/10 simulator. Lab 1: Intro to ROS Week 2 Systems: Automatic Emergency Braking and notions of safety. Lab 2: Safety Co-Pilot Week 3 Sensing: LiDAR and rigid body transformations

	Week 4 Sensing and Actuation: Reference tracking, Laplace domain dynamics, PID. Lab 3: Wall Following robot lab Week 5 Actuation: Electronic Speed Control tuning and Lab 4: Follow the Gap Week 6 Race preparation and **Race 1**. Week 7 Perception I: Localization by scan matching Week 8 Perception II: Mapping the world: SLAM and particle filters Week 9 Planning I: Pure pursuit Week 10 Planning II: Racing lines. **Mid-semester Race** 2 with navigation maps. Week 11 Ethics: Moral decision making and student debate Week 12 Advanced topics: Rapidly exploring random trees (RRT) and Model-Predictive Control (MPC) Week 13 Computer vision: detection, pose estimation and visual feature extraction Week 14 Machine Learning: Neural network auto-pilots: can a machine learn to drive? Week 15 Guest lectures: Reinforcement Learning and Autonomous vehicles research prototypes Week 16 **End-of-semester race**
Grading Details	50% Directed Labs 30% Competition and public communication 5% Competition documentation 5% Peer review 10% Participation and instructor/TA evaluation
Prepared By/Date	Radu Grosu / October 18 2019