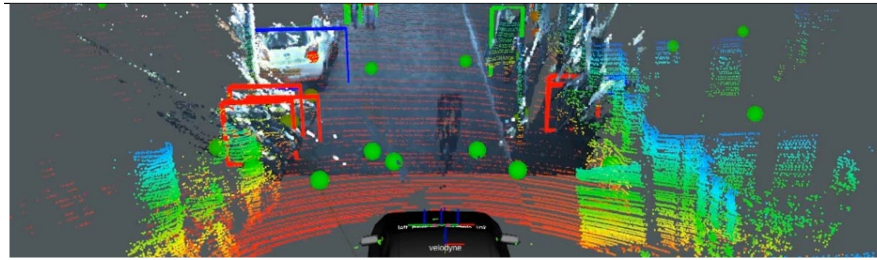


Machine Perception (RO47004, 5 EC)

Intelligent Vehicles (ME41106, 5 EC)

Lecture: Introduction

PRELIMINARY / NON-FINAL

Dariu M. Gavrila

Course Manager: Dariu M. Gavrila

2013-2014: Market introduction PRE-SAFE® brake with stereo vision-based pedestrian recognition in Mercedes-Benz S-, E- and C- Class

- Born in Cluj (Romania)
- 1990 „Doktoraal“ Degree in Computer Science at Vrije Universiteit (Amsterdam, NL)
- 1996 Ph.D. in Computer Science at Univ. of Maryland (College Park, USA)
- 1997 – 2016 Daimler R&D (Ulm, DE)
- 2016 - now Professor „Intelligent Vehicles“ at TU Delft

https://linkedin.com/in/dariu-gavrila

https://youtube.com/c/IntelligentVehiclesatTUDelft

People

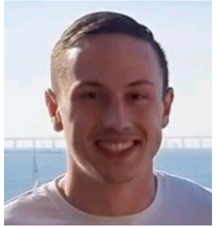
Prof. Dr. Dariu M. Gavrila
Course coordinator, lecturer

Ronald Ensing
Lab coordinator

Dr. M. Wiertlewski
Guest lecture: Tactile Sensing

A. Pálffy
Guest lecture: Radar

O. de Groot
Guest lecture: Motion Planning



S. Baratam **H. Boekema** **T. de Vries Lentsch**

Lab assistants

Machine Perception

Machine perception involves the capability of a machine to interpret data provided by environment sensors analogously to the way that humans use inputs from their senses to relate to the world around them.

Such capability is indispensable to a robot when navigating and interacting with a complex and dynamic environment.

Without machine perception, robots are “blind and deaf” (and touch-less)

Machine Perception - Applications in Robotics

Intelligent Vehicles

Service Robots

Smart Warehouse
Factory

Agriculture

Intelligent Vehicles

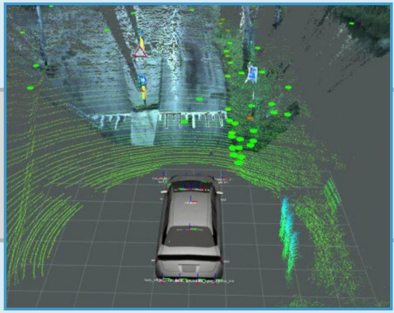
Improve safety, comfort and efficiency of transportation by automated driving.

Several levels of automation exist.

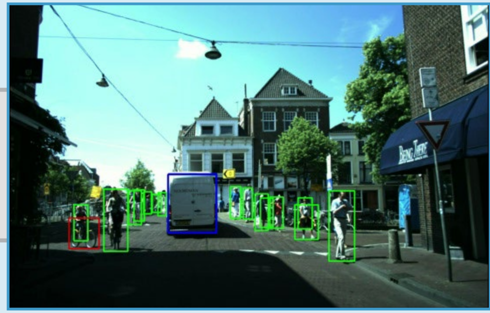
Autopilot systems that are occasionally activated by the driver to take over

Automated transport systems which drive the vehicle from source to destination

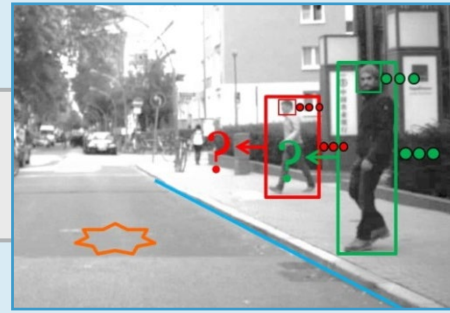
Intelligent Vehicles – System Components



Recovery of the 3D spatial enviroment

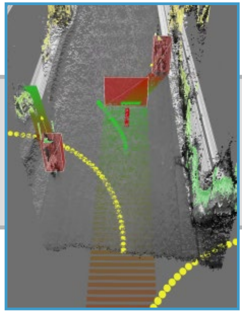


Adding semantics: scene labeling and object detection



Extraction of intent-relevant cues, predictive motion models

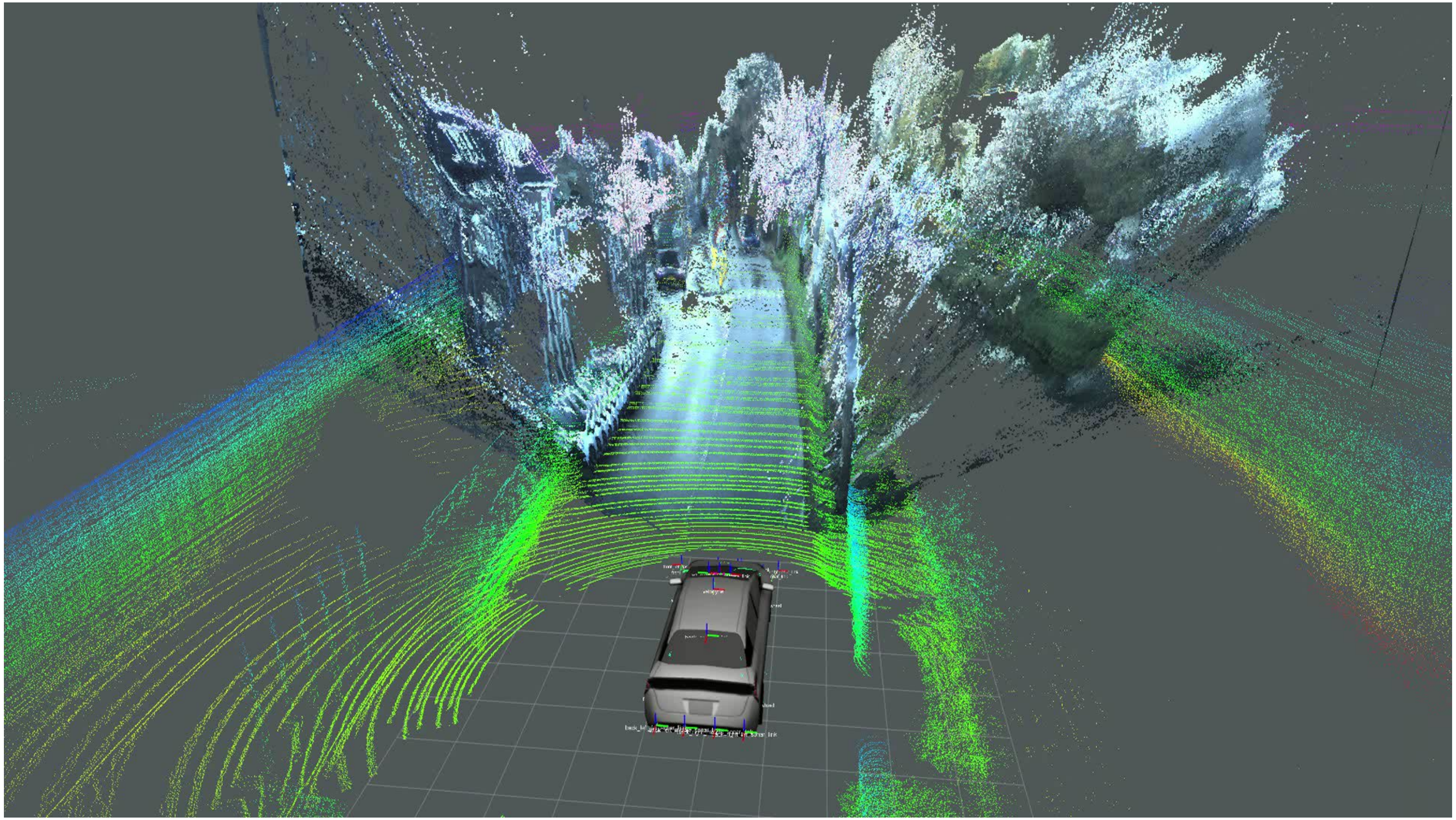
Machine Perception



Situation Analysis & Motion Planning

Vehicle Dynamics & Control

Joint Stereo Vision, Radar and LiDAR Data Visualisation



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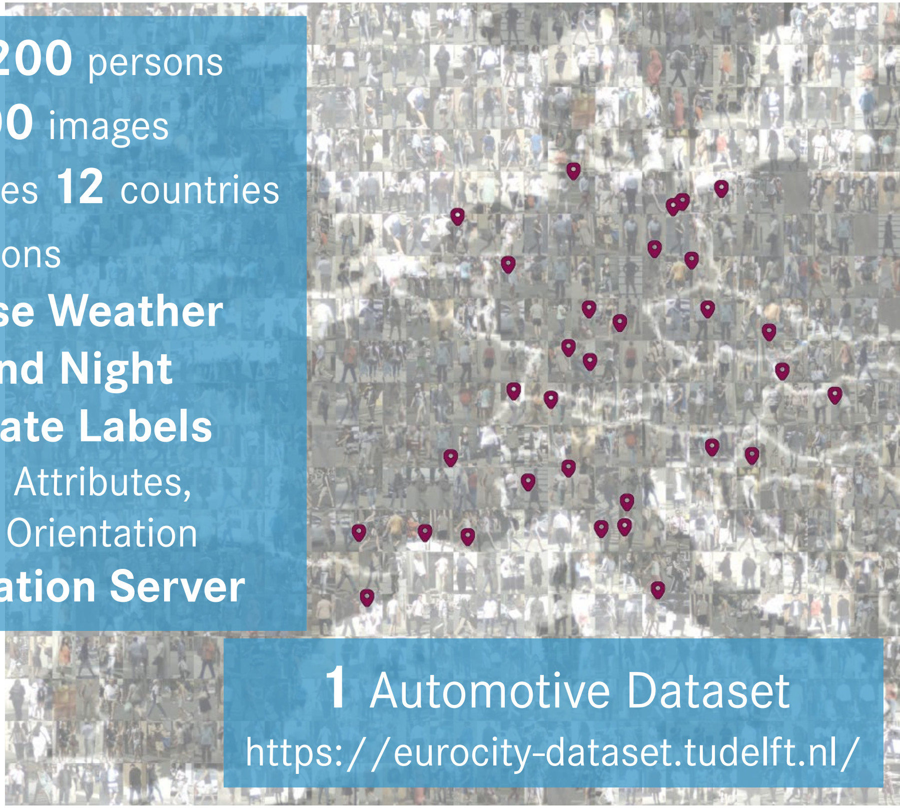
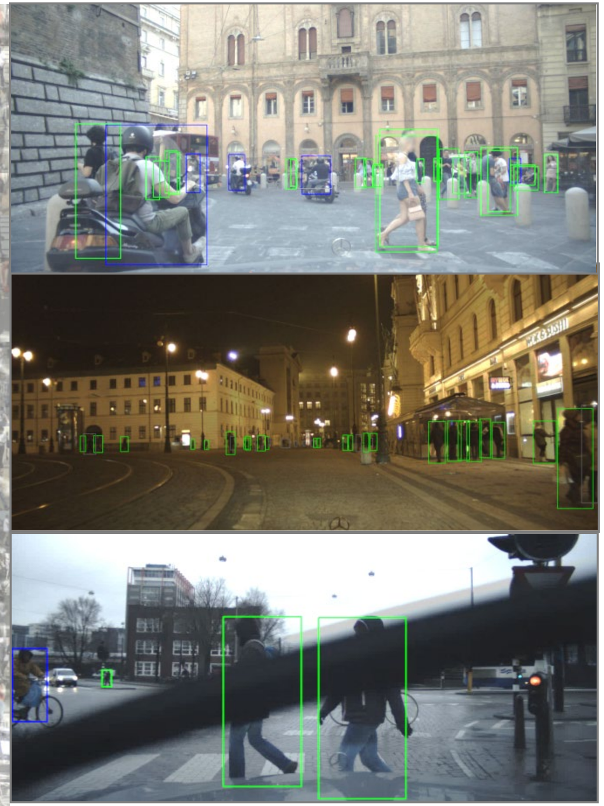
Introducing the EuroCity Person (ECP) Detection Dataset

238.200 persons
47.300 images
31 cities **12** countries
4 seasons
Diverse Weather
Day and Night
Accurate Labels
Class, Attributes,
Bbox, Orientation
Evaluation Server



1 Automotive Dataset
https://eurocity-dataset.tudelft.nl/



M. Braun, S. Krebs, F. Flohr and D. Gavrila, "EuroCity Persons: A Novel Benchmark for Person Detection in Traffic Scenes, *IEEE Trans. on Pattern Analysis and Machine Intelligence (TPAMI)*. vol. 41, nr. 8, pp. 1844-1861, 2019

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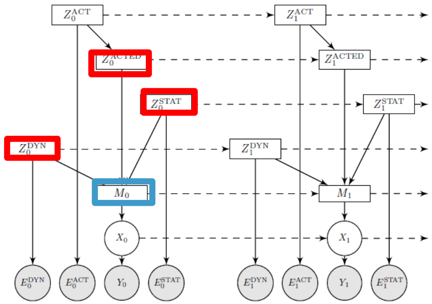
IV @ TU Delft Research: Cyclist Path Prediction



At intersection?

On collision course?

Hand gesture?

J.F.P. Kooij, F. Flohr, E.A.I. Pool and D.M. Gavrila. Context-based Path Prediction for Targets with Switching Dynamics. *Int. Journal of Computer Vision*, 2019

IV @ TU Delft Research: Semantic Scene Analysis

Semantic Scene Completion using
Local Deep Implicit Functions on LiDAR Data

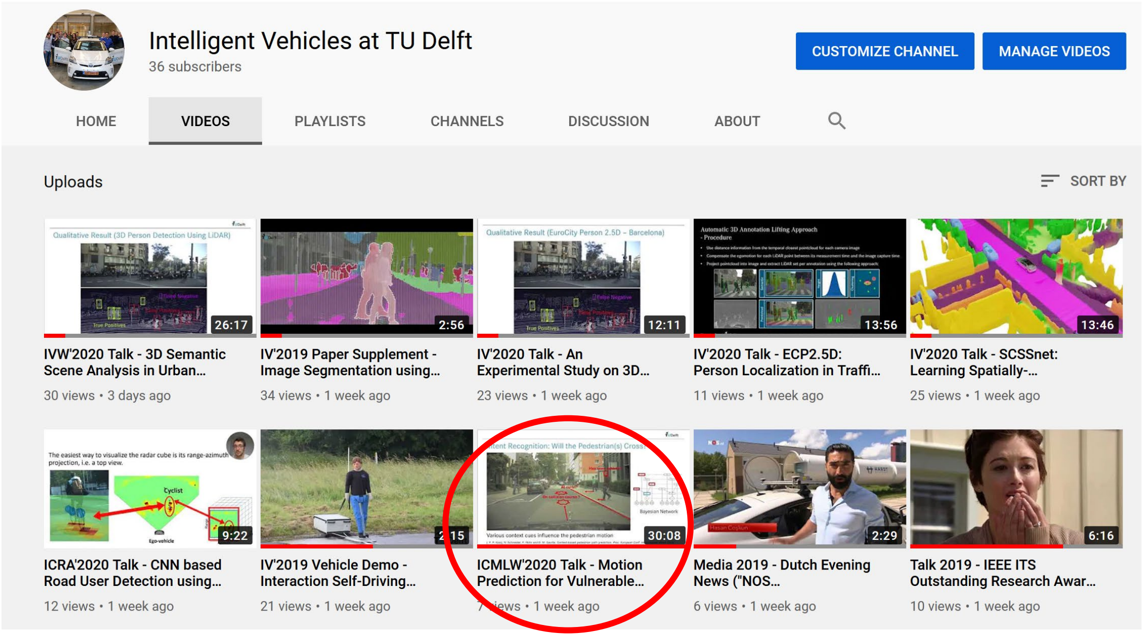
Christoph B. Rist, David Emmerichs, Markus Enzweiler and Dariu M. Gavrila

www.intelligent-vehicles.org

C.B. Rist, D. Emmerichs, M. Enzweiler and D.M. Gavrila. **Semantic Scene Completion using Local Deep Implicit Functions on LiDAR Data**. *IEEE Trans. on Pattern Analysis and Machine Intelligence*, 2021

NOS Journaal (Dutch Evening News), August 9-th, 2019

IV @ TU Delft Research: YouTube Channel

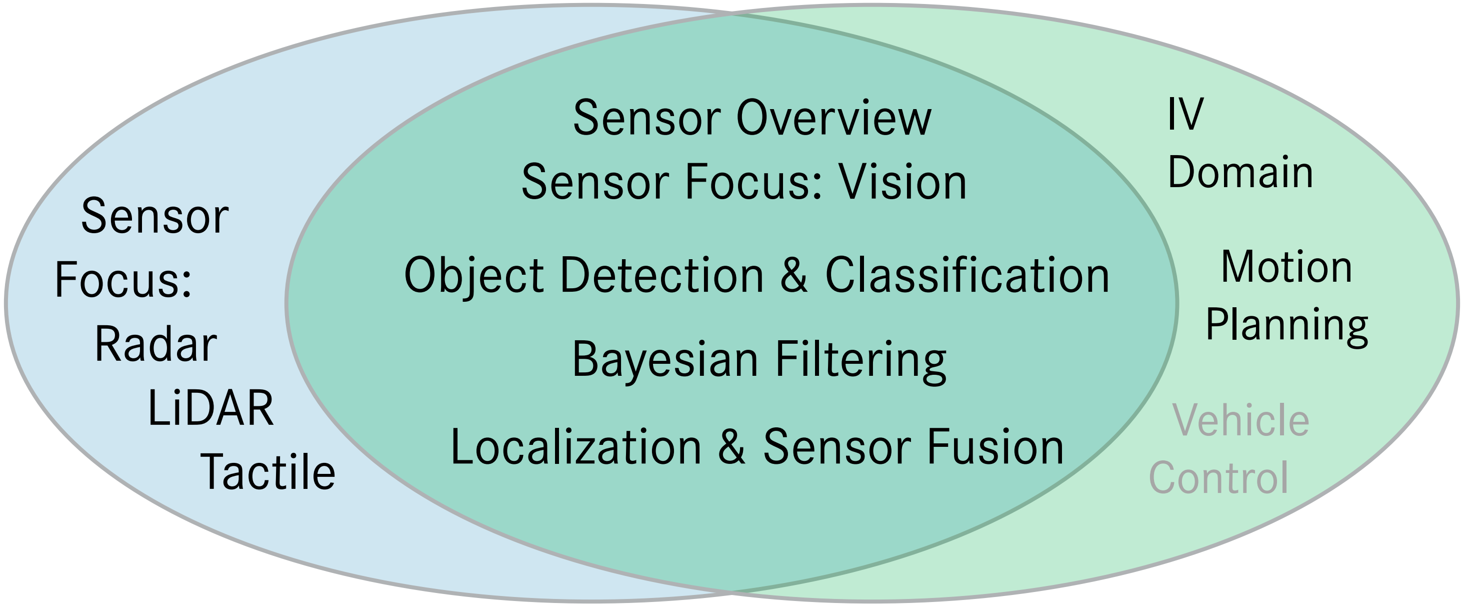


Highlighted video provides a nice illustration of our research related to topics of this course

https://youtube.com/c/IntelligentVehiclesatTUDelft

(if interested in updates, subscribe ☺)

Relation of Courses - Content



Machine Perception (RO47004, 5 EC) Intelligent Vehicles (ME41106, 5 EC)

Important: students can earn credits for only **one** of the two courses because of the overlap

Study Goals – Machine Perception, RO47004

After completing this course, students will be able to:

- explain the role of Machine Perception (MP) in Robotics, and describe applications
- explain the measurement principles of the relevant sensors
- explain the principles of well-established methods for low- to high-level sensor processing
- analyze a MP problem, consider available sensor and computational resources, and select the appropriate MP methods to apply
- perform MP experiments, evaluate the results, and draw sound conclusions
- write Python code in relevant frameworks to visualize data and implement Machine Perception methods

(extract from Study Guide)

TUDelft

Study Goals – Intelligent Vehicles, ME41106

After completing this course, students will be able to:

- understand the main methodical components of a intelligent vehicle (mobile robot)
- program basic algorithms and test these on simulated and real-world data
- express an educated opinion on the benefits and risks of automated driving, the current developments from driver assistance to driver-less cars, and the forces driving this transformation

(extract from Study Guide)

Course Prerequisites (both MP and IV)

- **Basic linear algebra and probability theory**
  To refresh your knowledge on these subjects, review your textbooks or online resources. For instance, the TU Delft provides video lectures on these topics on http://math-explained.tudelft.nl (e.g. linear algebra, probability theory).
- **Intermediate Python programming skills**, e.g. Numpy, object oriented programming (classes, inheritance), modules, namespaces and scope.
  To refresh your skills, check out https://www.learnpython.org/ and https://docs.python.org/3/tutorial/
  It is possible to start the course with beginner Python skills if your aim is to take advantage of this course to also improve your programming expertise. Be aware, however, that this "catching up" will likely result in an increased study load (e.g. 1-2 EC).
- **Recommended: Pattern Recognition / Machine Learning** (RO47002, CSE2510, or equivalent)

Session Types & Materials

Session types

- Lectures
- Practicum Sessions: Q&A on current practicum (group-wise)
- Interactive Lectures: Discussion of past practicums

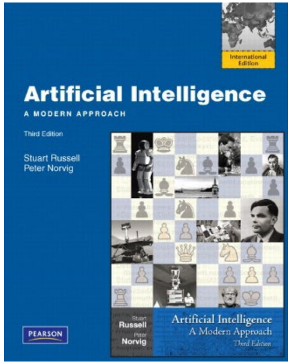
Concepts / Breadth (Lectures)

Practice / Depth (Practicum Sessions, Interactive Lectures)

Lectures will be recorded (but not the interactive lectures & practicum sessions)

Materials

- Lecture slides
- Documentation associated with practicum assignments
- Other hand-outs that will be supplied on Brightspace
- Recommended for IV: Artificial Intelligence: A Modern Approach (Russel and Norvig) 3rd edition freely available as PDF



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Feedback & Assessment

	Practicum (3x)	Final Assignment	Final Exam
Feedback type[1]	Formative	Summative	Summative
Modality	Programming/Written	Programming/Written	Written (Closed Book)
Student Size	Groups of 2 (alternating, random)	Individual	Individual
Allowed Cooperation	Within group	None	None
Grading Type	PASS/FAIL	Numeric (1.0-10.0)	Numeric (1.0-10.0)
Grading Weight	0% (but see knock-out)	50%	50%
Late Policy[2]	None (late submissions = FAIL)	-1 grade pt./day (max 2 days)	N/A
Knock-out	At least 2 of 3 need to be PASS	5.0	5.0
Transfer Result to Next Acad. Year	Yes, upon request	Yes, upon request	Yes, upon request

1. "Formative": Help students to learn and practice, "Summative": Assess student performance
2. Exceptions only for medical reasons with doctor's notice (technical/internet malfunctions are no valid reasons)

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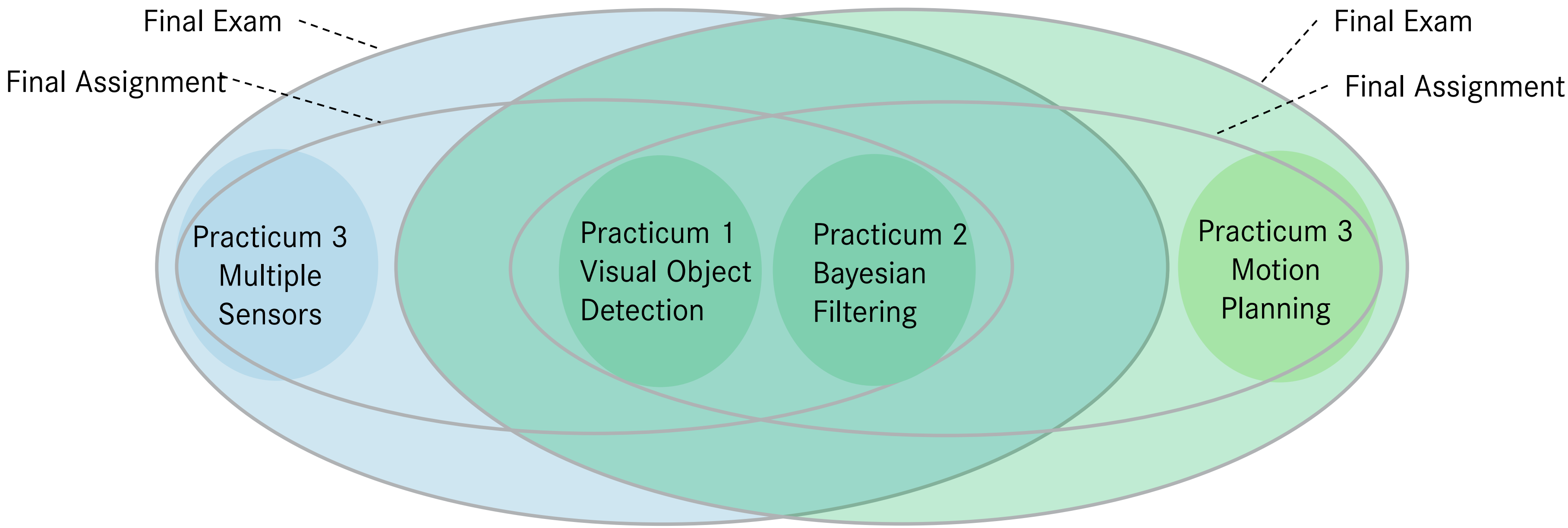
Relation of Courses - Assessment



Machine Perception (RO47004, 5 EC) Intelligent Vehicles (ME41106, 5 EC)

Practice your methodical understanding/implementation skills on the Practicums to be well prepared for the Final Assignment. The latter will incorporate additional lecture concepts and will allow more freedom to make own choices.

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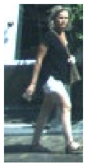
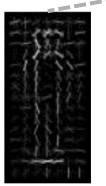
Preview Practicum 1 (MP/IV): Visual Pedestrian Detection

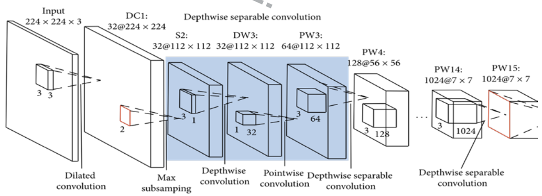
Proposal Generation → Feature Extraction → Classification



Feature Extraction: or

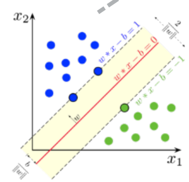


HOG features

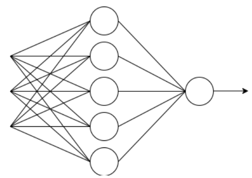


Convolutional Neural Net features

Classification: or



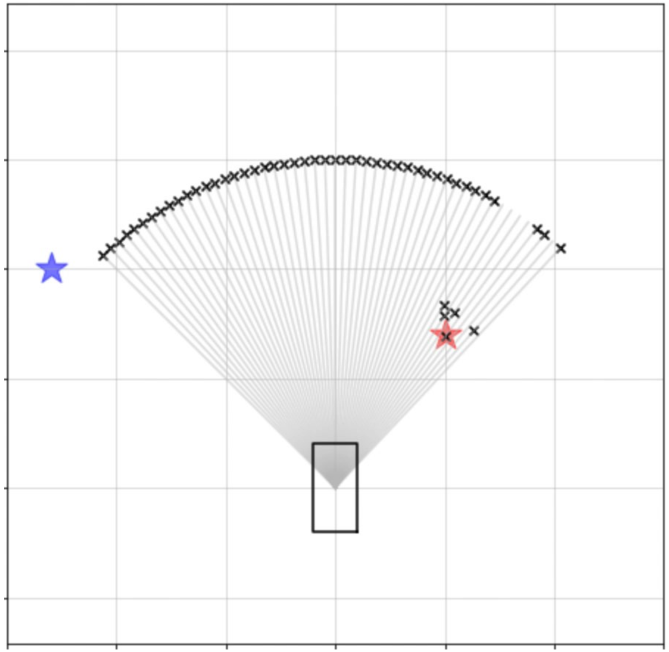
SVM



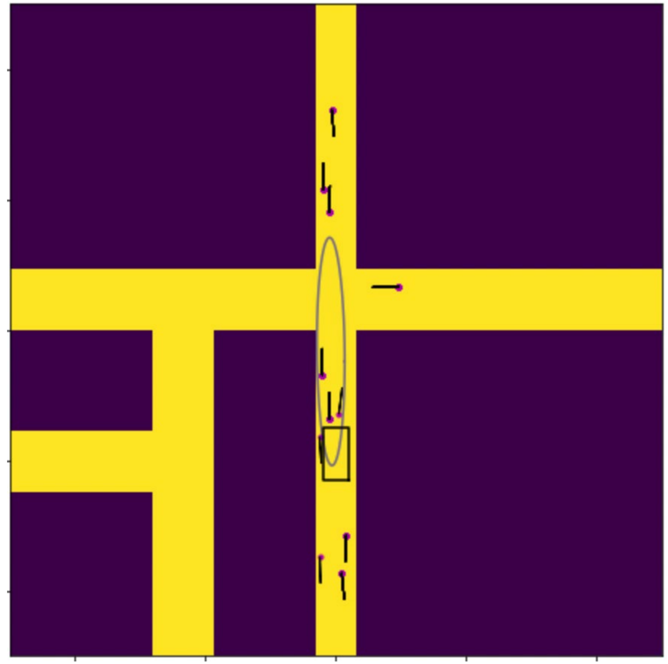
FFN

Apply Machine Learning methods for feature extraction and classification to detect pedestrians in real-world video images. Perform quantitative performance analysis.

Preview Practicum 2 (MP/IV): Bayesian Filtering

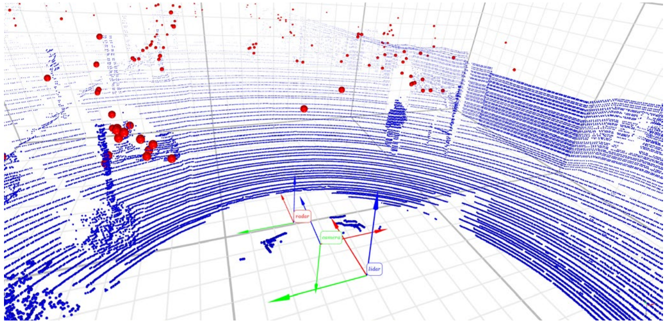


Multi-Target Tracking
with the Kalman Filter

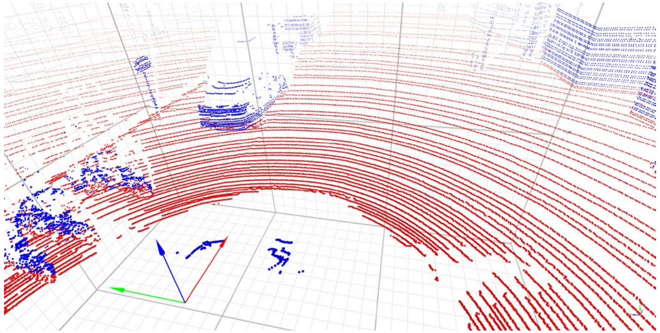


Ego Localization
with Particle Filter

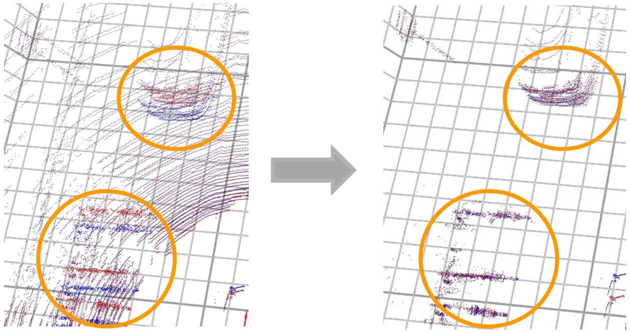
Preview Practicum 3 (MP): Multiple Sensors



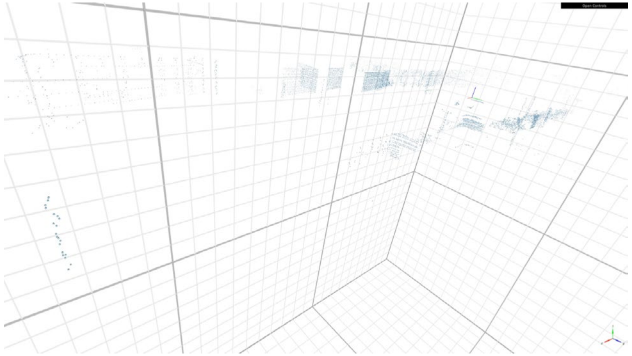
Visualize radar and LiDAR data (and stereo data)



Ground Plane Estimation



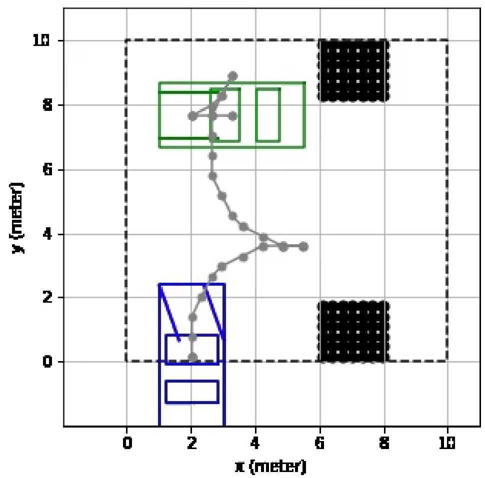
3D point cloud alignment using ICP algorithm

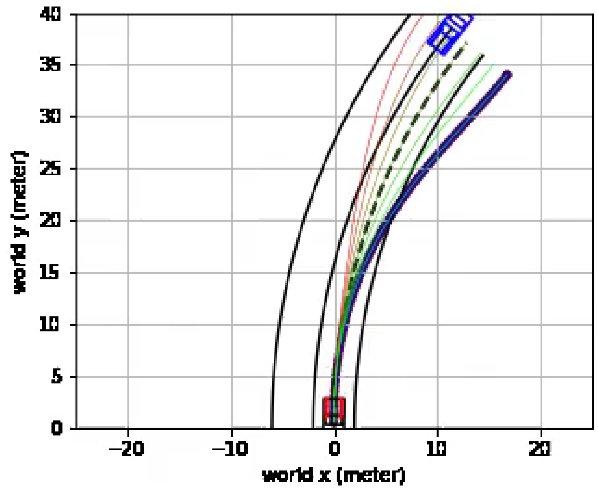


Building 3D point cloud maps

... and more!

Preview Practicum 3 (IV) – Motion Planning





Have the self-driving car park itself with the A* algorithm

Plan safe motions for a self-driving vehicle

- Formulate candidate trajectories
- Select best trajectory based on simple goal completion and collision-avoidance considerations

Practicum / Final Assignment – Note

Academic integrity is a high good at TU Delft.

It is not permitted

- to use solution concepts/code from others for the final assignment (or from outside of your group for the practicums). *Passing the work of others as one own's constitutes scientific fraud - even if it is just one line of code.*
- to make your own solution concepts/code available to others for the final assignment (or outside your group for the practicums) - this includes dissemination via the internet, social media or WhatsApp groups. *Unauthorized sharing of solution concepts/code is considered as abetting scientific fraud.*

Cases with a suspicion of (abetting) scientific fraud will *always* be forwarded to the Examination Board. Penalties include exclusion from the course, inclusion in an academic dishonesty registry, and even removal from the MSc program.

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Subject to change

Schedule: Machine Perception (MP) & Intelligent Vehicles (IV)

Lectures Tue,Th@15:45-17:30; Practica Th@10:45-12:30

Week	*Date*	*Type & Course*	*Description*	*Instructors*
1	Tue. 15 Nov.	Lecture MP/IV + IV	Introduction (MP/IV) *1st hour* / Intelligent Vehicles Overview (IV) *2nd hour*	Gavrila
	Th.17 Nov.	Lecture MP/IV	Sensor Overview *1st hour* / Live Vehicle Demo / 3D Vision *2nd hour*	Gavrila & Ensing
	Th. 17 Nov.	Practicum MP/IV	Practicum: Getting Started	Ensing & Boekema
2	Tue. 22 Nov.	Lecture MP/IV	Visual Object Detection: Proposals, Features & Classifiers	Gavrila
	Th. 24 Nov.	Lecture MP/IV	Visual Object Detection: Neural Networks & Performance Metrics	Gavrila
	Th. 24 Nov	Practicum MP/IV	Practicum 1	Ensing & Boekema
3	Tue. 29 Nov.	Lecture MP/IV	State Estimation: Bayesian/Kalman Filtering	Gavrila
	Th. 1 Dec.	Lecture MP/IV	State Estimation: Particle Filtering – Data Association	Gavrila
	Th. 1 Dec.	Practicum MP/IV	Practicum 1 & 2 (**Fri, 2 Dec. @ 18:00, Deadline Practicum 1**)	Ensing & Boekema & Baratam
4	Tue, 6 Dec.	Interactive Lecture MP/IV	Discussion: Practicum 1	Ensing & Boekema
	Th. 8 Dec.	Lecture MP/IV	Ego-Localization & Sensor Fusion (MP/IV)	Gavrila
	Th. 8 Dec	Practicum MP/IV	Practicum 2 (**Mon, 12 Dec. @ 18:00, Deadline Practicum 2**)	Ensing & Baratam
5	Tue. 13 Dec.	Lecture IV	Motion Planning / Planning as Graph Search (pre-recorded) *2nd hour*	De Groot & Gavrila
	Th. 15 Dec.	Interactive Lecture MP/IV	Discussion: Practicum 2	Ensing & Baratam
	Th. 15 Dec	Practicum MP/IV	Practicum 3	Ensing & DeVriesLentsch
6	Tue. 20 Dec.	Lecture MP	Tactile Sensing *1st hour* / Radar Sensing *2nd hour*	Wiertlewski & Palffy
	Th, 22 Dec	Lecture MP	*To be determined*	*To be determined*
	Th, 22 Dec.	Practicum MP/IV	Practicum 3 & Start Final Assignment (**Fri. 23 Dec @ 18:00, Deadline Practicum 3**)	Ensing&DeVriesLentsch&Groot
7	Tue.10 Jan.	Interactive Lecture IV	Discussion: Practicum 3 IV	Ensing & De Groot
	Th. 12 Jan.	Interactive Lecture MP	Discussion: Practicum 3 MP	Ensing & De Vries Lentsch & De Groot
	Th. 12 Jan.			
8	Tue. 17 Jan.	Lecture MP+IV	Wrap-Up (MP) *1st hour* / Wrap-up (IV) 2nd hour	Gavrila
	Th. 19 Jan.			
	Th. 19 Jan.		**(Fr, 20 Jan @ 18:00 Deadline Final Assignment)**	
10	Tue, 31 Jan.	**Final Exam MP/IV**	Tue, 11 Apr. **Resit Final Exam MP/IV**	

Time Management

5 EC x 28 hours/EC = 140 hours of study

Breakdown in contact and self-study
- 36 hours contact (16 hrs lectures, 8 hrs interactive lectures & 12 hrs practicum sessions)
- 104 hours self-study

Breakdown of self-study
- ~48 hours for Practicums (18 + 14 + 16 hours)
- ~36 hours for Final Assignment
- ~20 hours for Final Exam

Breakdown of normal week
- 140 hours / 8 weeks = 17.5 hours per week
- 36 contact hours / 8 weeks = ~4.5 contact hours per week

→ **~13 hours self-study per normal week**

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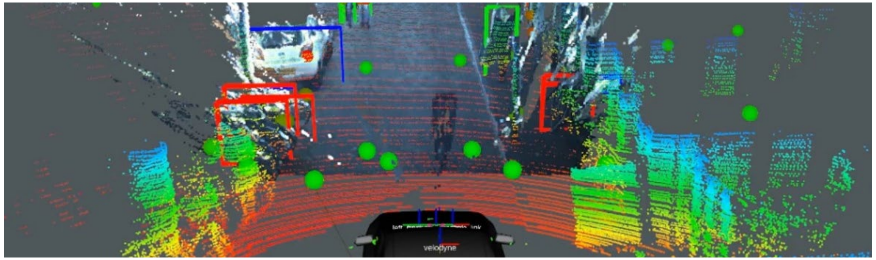
Related Courses - Machine Perception / Intelligent Vehicles

Q1	• RO47002 Machine Learning for Robotics • RO47003 Robot Software Practicals • IN4010 Artificial Intelligence Techniques (6 EC over Q3 & Q4)
Q2	• **RO47004 Machine Perception** • **ME41106 Intelligent Vehicle**
Q3	• CS4240 Deep Learning *strongly recommended* • ET4169 Radar I: From Basic Principles to Applications • CS4230 Machine Learning 2 (in Q3 & Q4) • EE4685 Machine Learning, a Bayesian Perspective • EE5020 Sensor Signal and Data Processing (4 EC)
Q4	• CS4245 Seminar Computer Vision by Deep Learning • EE4675 Object Classification with Radar (4 EC) • GEO1016 Photogrammetry and 3D Computer Vision • AESB2440 Geostatistics & Remote Sensing

All courses are 5 EC unless otherwise noted



Machine Perception (RO47004, 5 EC)

Intelligent Vehicles (ME41106, 5 EC)

Best wishes for a worthwhile and enjoyable learning experience!

Dariu Gavrila and Ronald Ensing