Sensors in Robotic Systems

How robots sense the world.

Technical details

- Meeting suggestion Tuesdays 3pm-5pm starting May 28th
- 2 presentations 30 min+ discussion, one presentation on standby.
  + review of the topic

Grading

- Grade consists of 40% presentation, rubric:
  - Organization and presentation
  - Knowledge of subject: introduction
  - Background content: adjacent papers
  - Thoroughness of information presented
  - Graphics (in PowerPoint)
  - Mechanics: typos, (grammar) errors in text
  - Length and pace: 20-22 minutes, hard cut at 23 min.

Grading

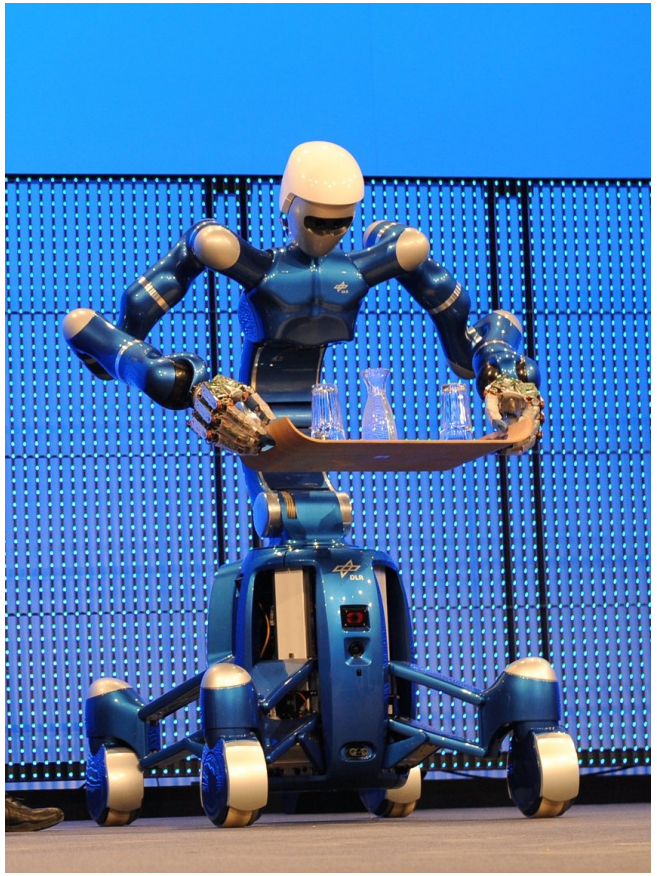
- 60% written part, rubric:
  - Based on: https://welfens.wiwi.uni-wuppertal.de/fileadmin/welfens/daten/Skripte/SS13/Bewertungskriterieneng.pdf
  - 6-8 pages IEEEconf two-column format, A4:
    https://ras.papercept.net/conferences/support/files/ieeeconf.zip
    https://ras.papercept.net/conferences/support/tex.php

- Paper Deadline:
  Monday Junly 8th, 23:59:59 CET (local time Munich) via email to
  Andrei Costinescu: andrei.costinescu@tum.de or
  Peter Gawronski: peter.gawronski@tum.de

Grading deductions

- Miss your time slot without excuse – failed grade.
- In case of sickness inform beforehand – you may present the week after (with doctor’s notice).
- Absence of up to one time is allowed if asked >1day earlier.

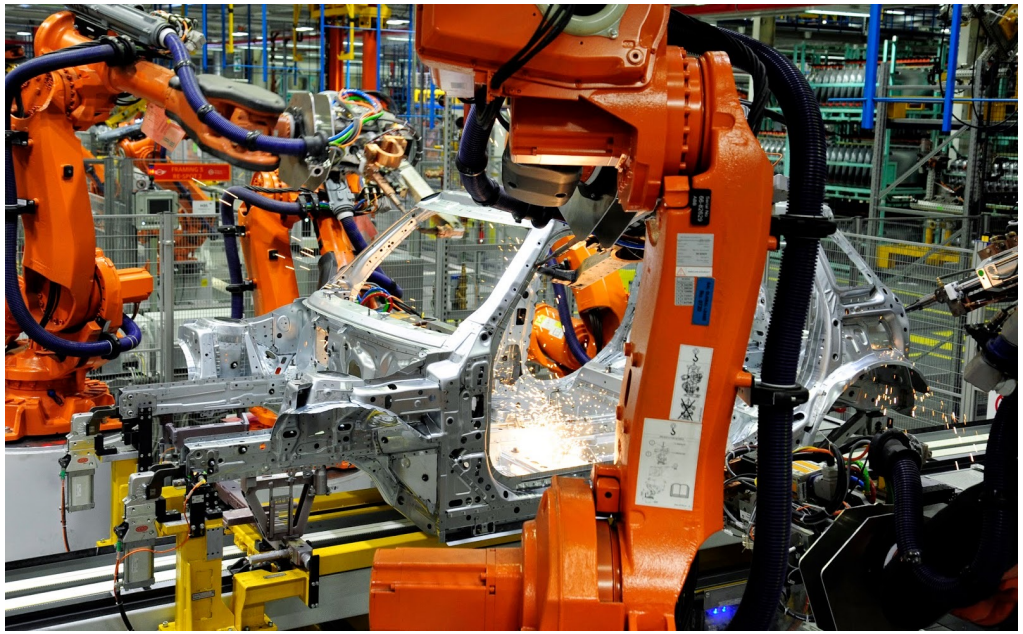
What is different in Robotics compared to Big Data Queries?



We need to know not only what is in the area around the robot, but also

- How big is the confidence in the correctness of the observation? How much of the object was visible…
- How certain is the system to see a specific object (similarity to other similar ones)?
- Where it is relative to the robot?
- What is the dynamic state of the observed object?
- What is the accuracy of the metric observation?

Computational Challenges in Robotics Applications

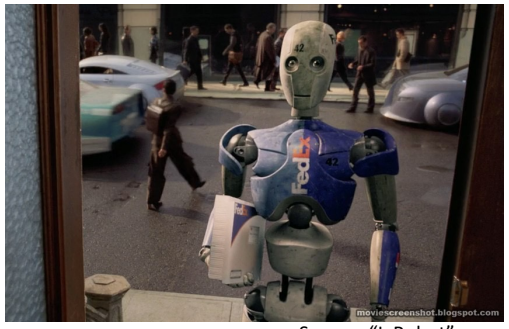


Source: Aytoindustry Newsletter

Complete knowledge about the environment –early adoption of robots in industrial apps

Geriatrics: Garmi Robot (MSRM)

Human-Robot Interaction: understanding human gestures, predictable behavior for acceptance



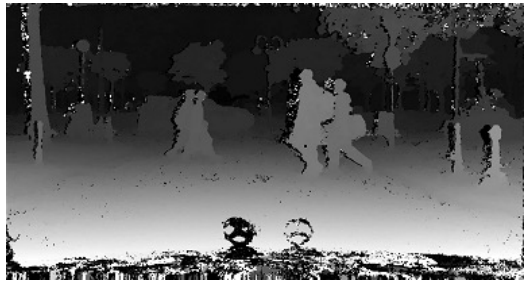
Source: "I, Robot"

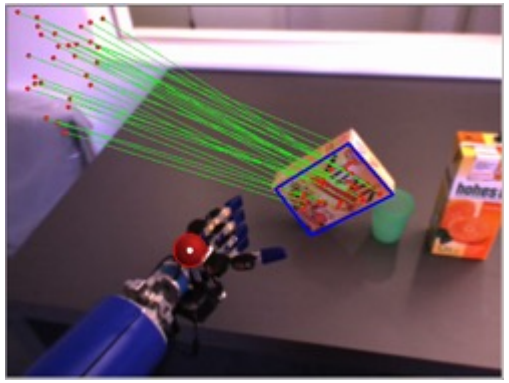
Understanding and Acting in Dynamic Environments: understanding human actions/behaviors, collision avoidance

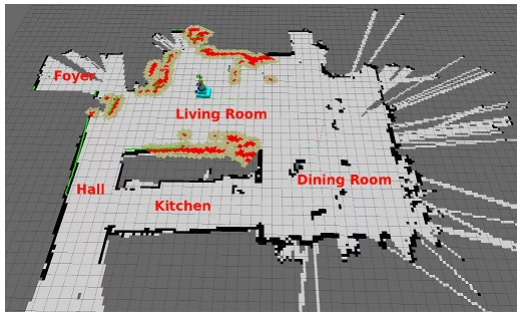
Inherent Safety to Humans: Understanding injury parameters

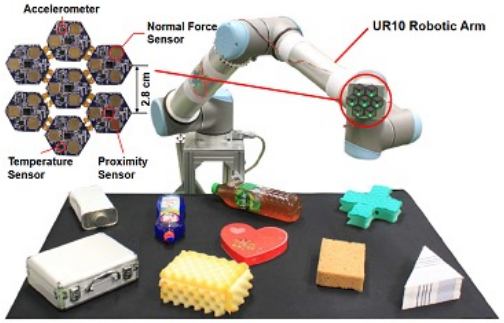
Semantic Labeling of Scenes: Knowledge about functions of scene geometry

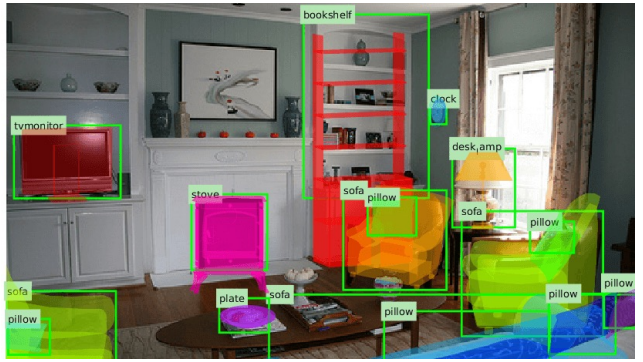
Robot Perception

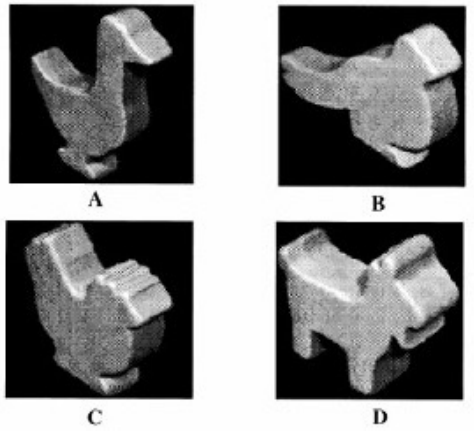












What Information is in Images?

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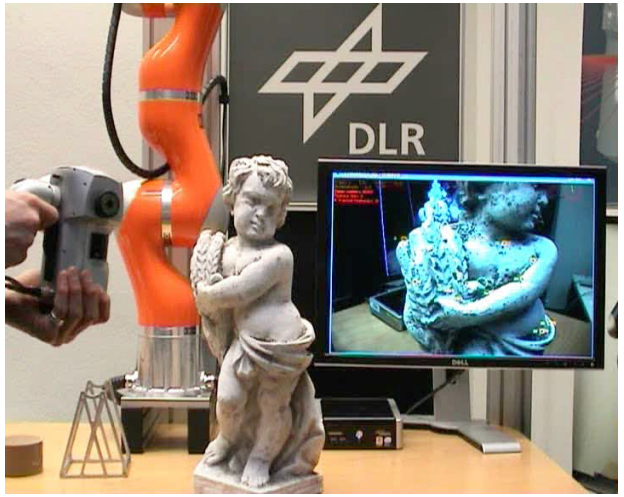
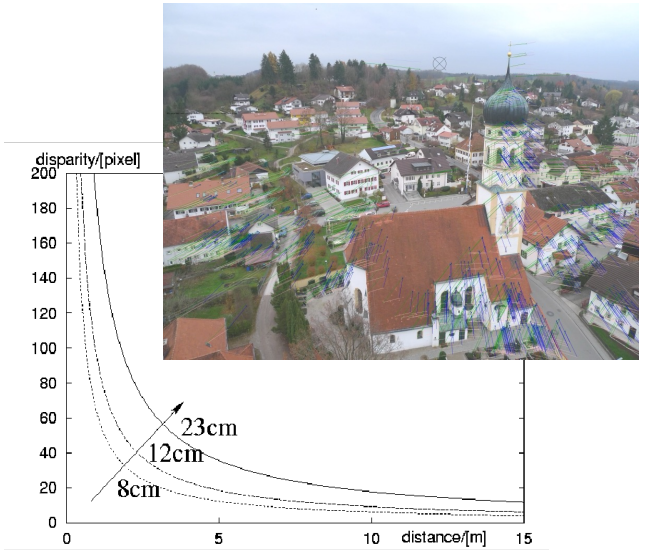
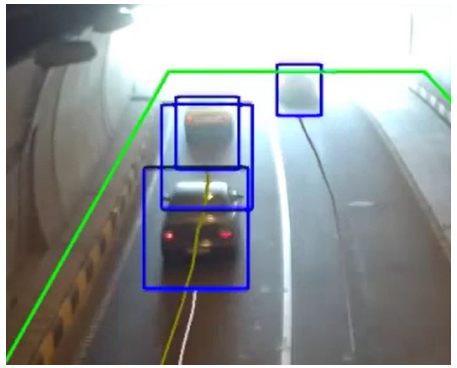
Problems with camera-based Measurement for Control



Camera by itself is too slow with 25-30Hz to stabilize a robot or monitor high dynamic motion



The quality of the reconstructed pose varies with the distance to the observed objects



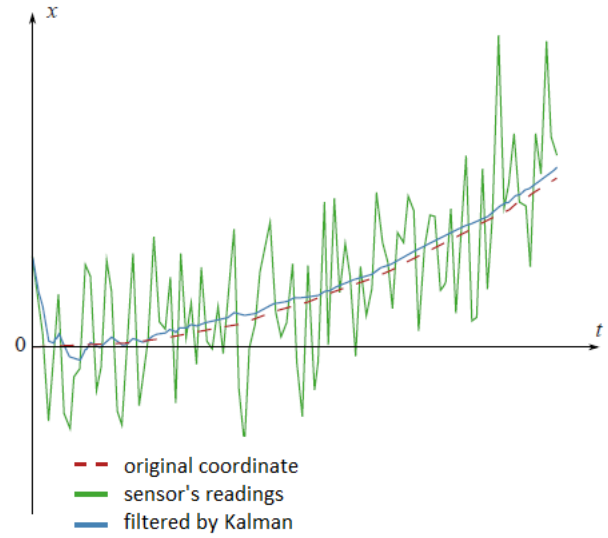
Camera can be blinded for multiple seconds in tunnels, etc.

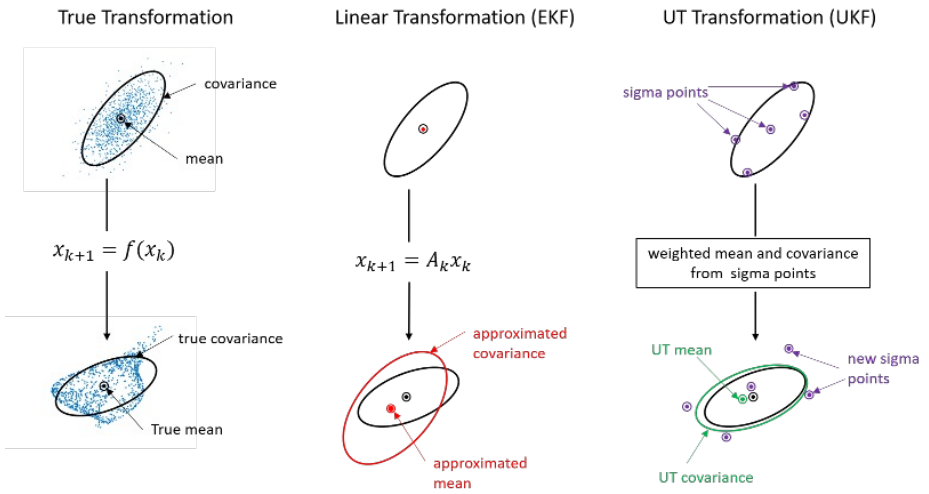
Introduction to robot sensing

- Sensors are the only way to interact with environment
  - Needed for any kind of autonomous behavior
- Sensors are not ideal: Noisy, offset, biased, …
- Moving robots need to learn about their world
  - Odometry, Localization, Servoing, Exploration, Mapping
- Different sensors must be merged
- Objects need to be recognized to be interacted with

Input filtering

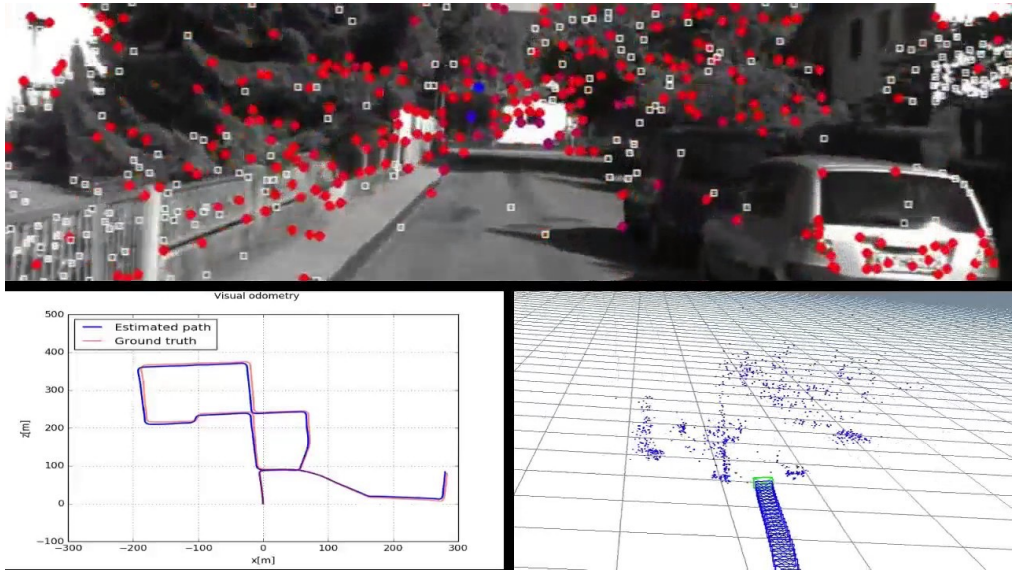
- Input is noisy. Very noisy.
- Filtering techniques from 1960s to modern times
- T01 (Extended) Kalman Filter
- T02 Unscented Kalman Filter
  Particle filters

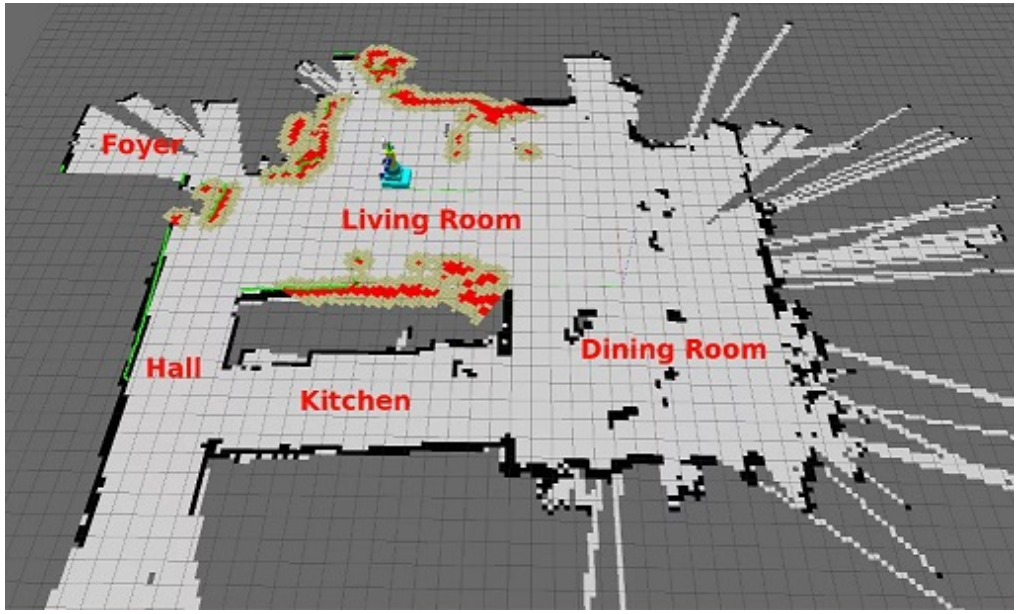


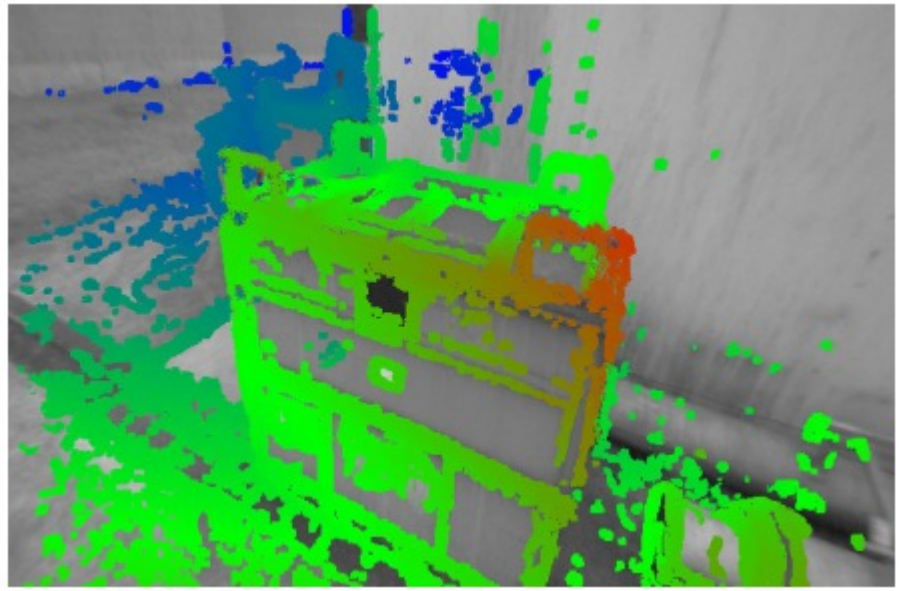


SLAM

- Simultaneous Localization and Mapping
- Visual SLAM
  - T03 Feature-based
  - T04 Featureless

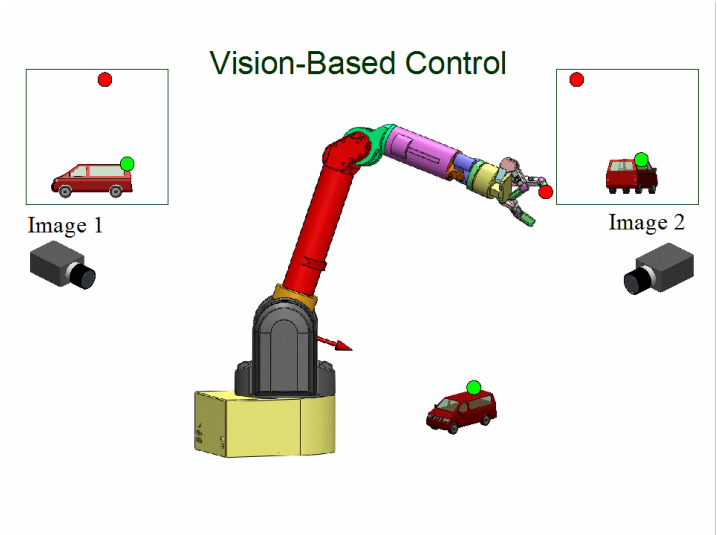




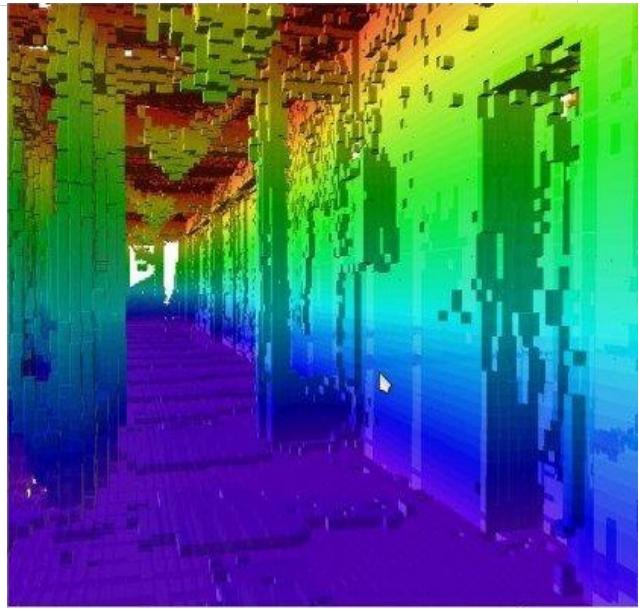


Visual control/mapping

- T05 Visual control: Robot is controlled by where the object should be from cameras view
  - No 3D reconstruction or similar

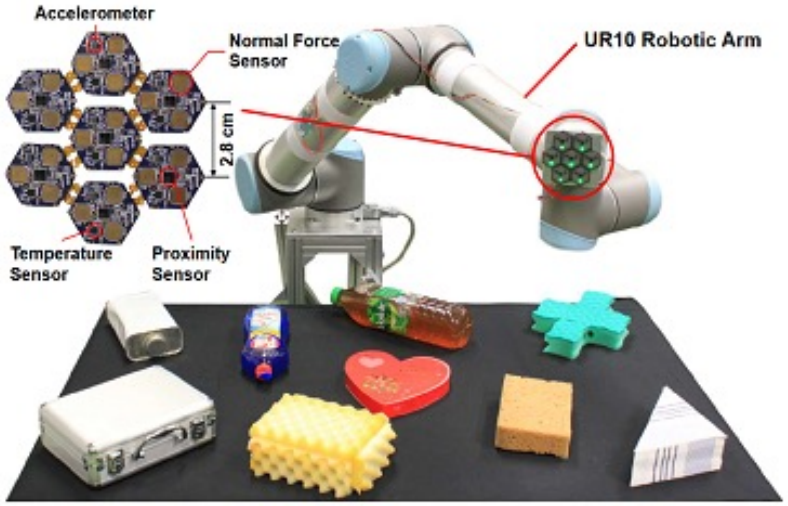


- T06 Visual mapping: How is data from SLAM stored?
  - Feature points can be saved raw, clustered, keyframe-based…



Tactile exploration

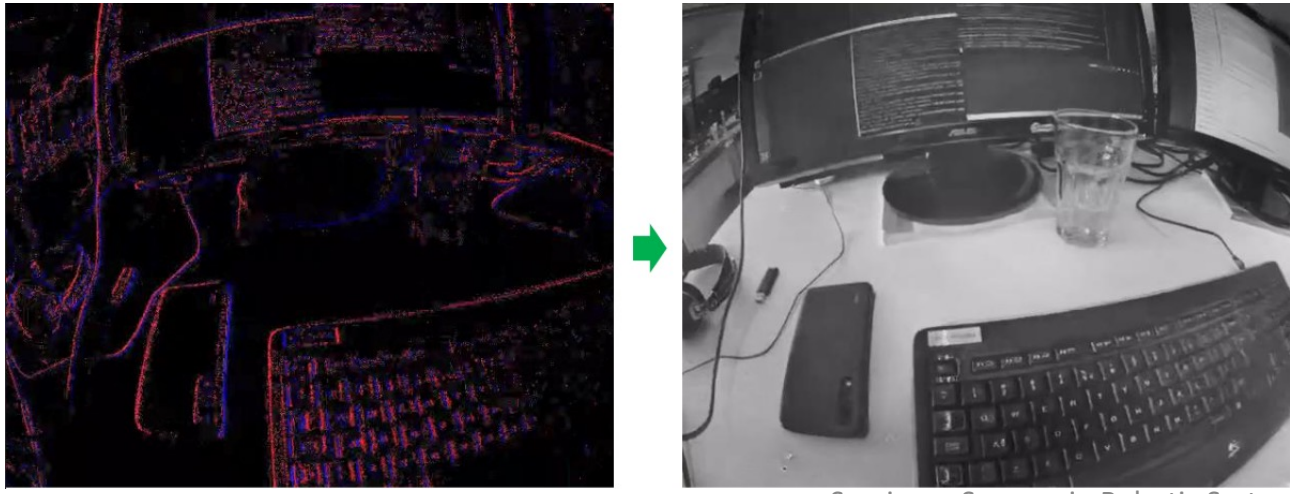
- T07 Tactile exploration

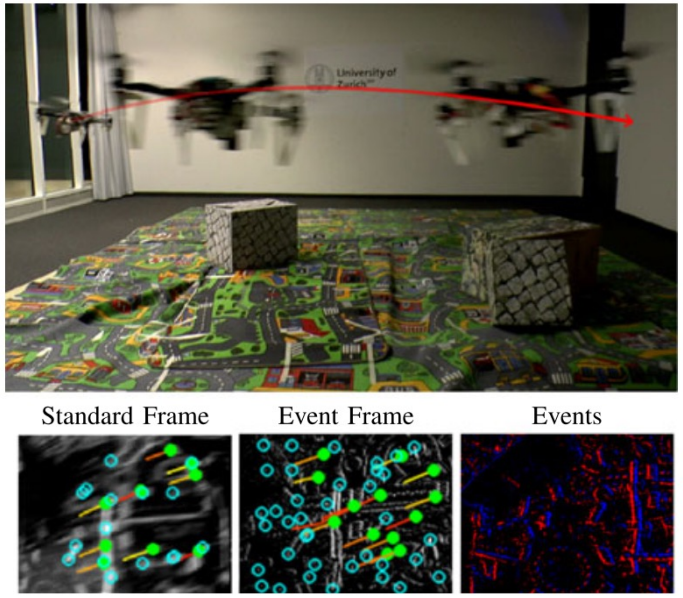


- T08 Tactile material classification

Event cameras

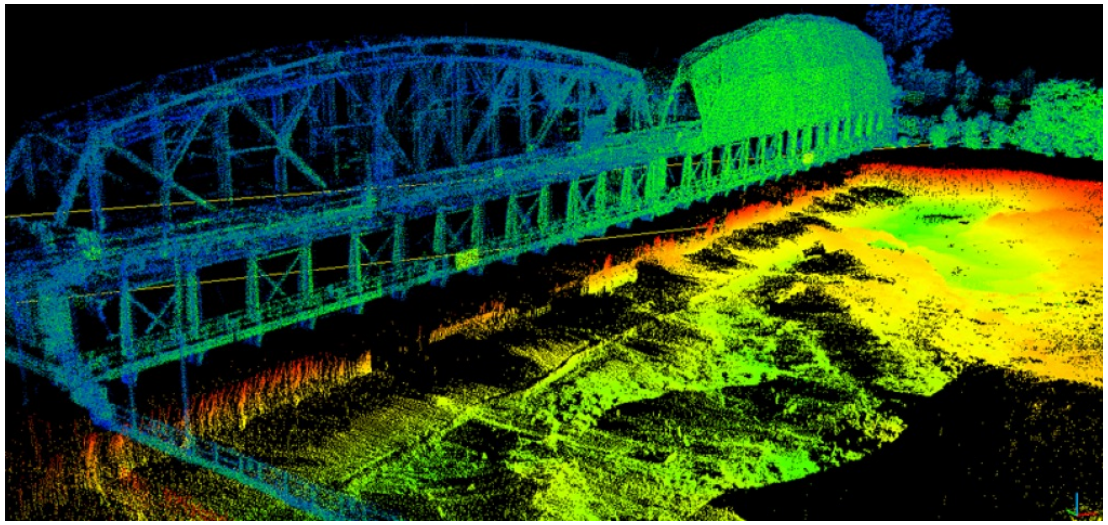
- Register changes in brightness per pixel
  - Superfast! Expensive! (new!)
- Completely different approaches than traditional cameras
- T09 Reconstruct “classical” image and video from event camera
- T10 Robot control with event cameras

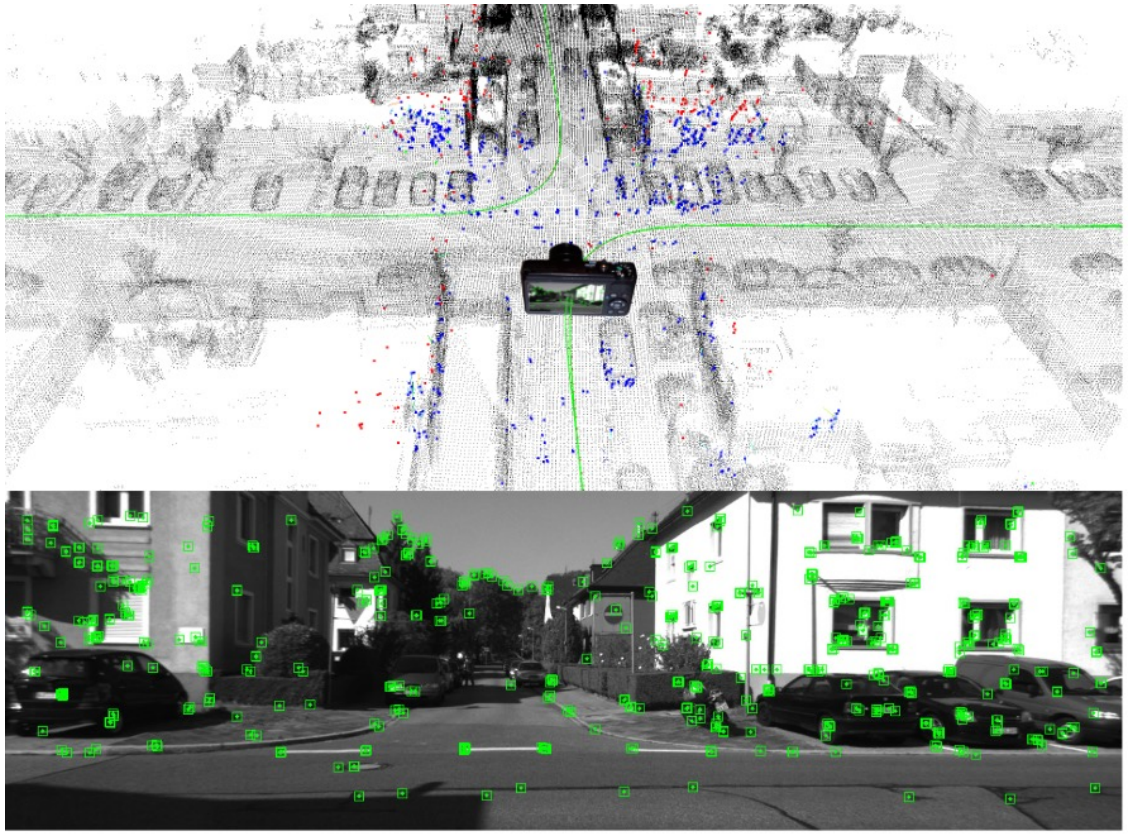




Localization in LIDAR/Camera data

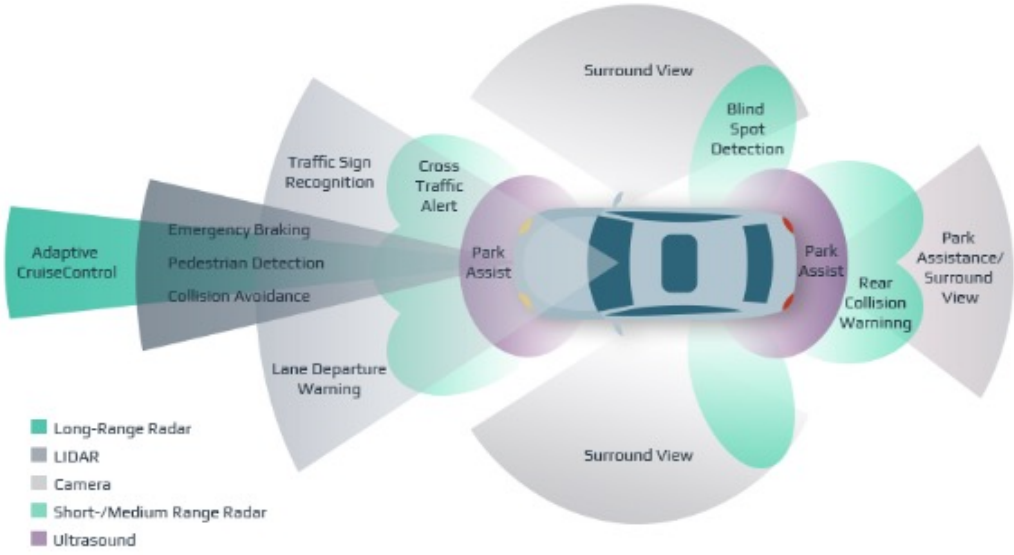
- Localization can be done from different sensors
- T11 LIDAR
- T12 Camera





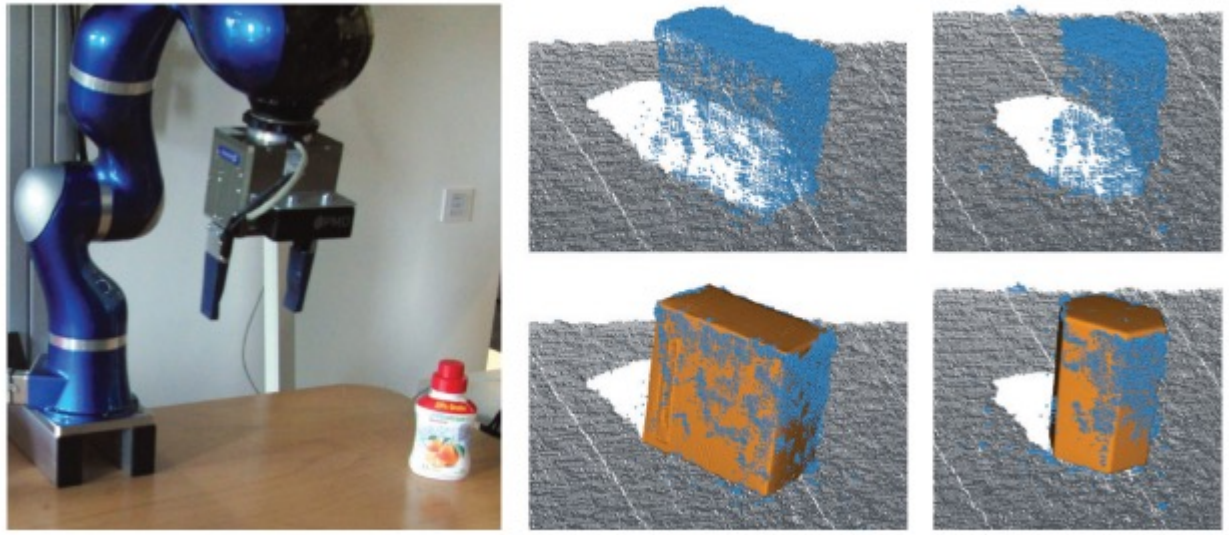
Sensor Fusion

- Two main problems:
- T13 Match proprio- to exterioceptive sensors (E.g. IMU to camera)
- T14 Handle time delay between sensors

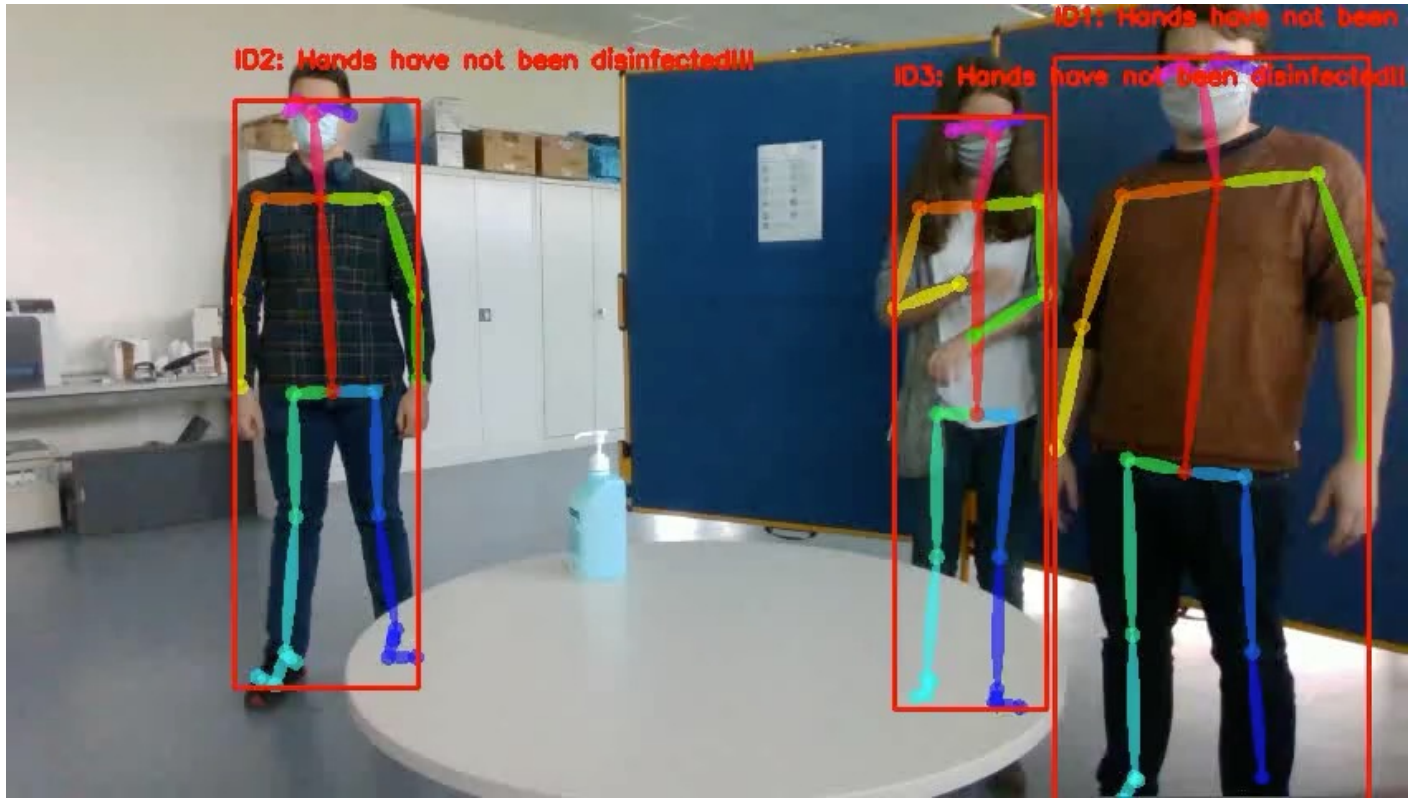


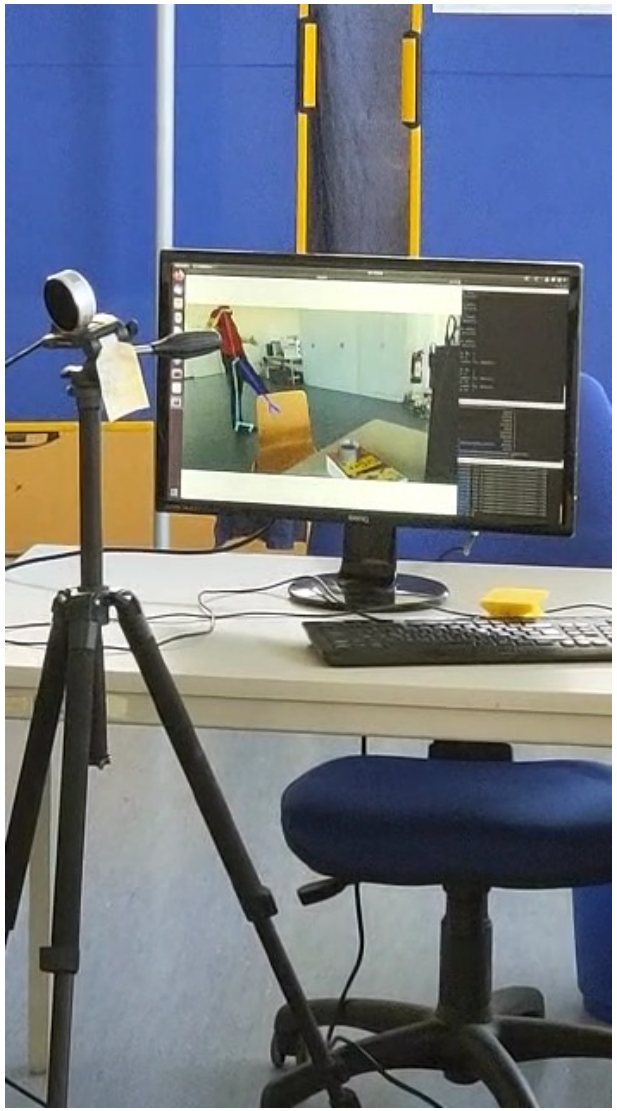
Object recognition

- For objects to be manipulated they need to be identified
- T15 Find objects in 3D point clouds
- T16 Find Objects by their appearance



Pure DL Skeleton Detector





Pick Topics (https://mvp.in.tum.de/link.html)

- 01 (Extended) Kalman filter
- 02 UKF & particle filters

- 03 Featureless/direct SLAM(LSDSLAM)
- 04 Feature-based SLAM (ORBSLAM)

- 05 Visual servo control
- 06 Visual maps

- 07 Tactile exploration
- 08 Tactile material classification

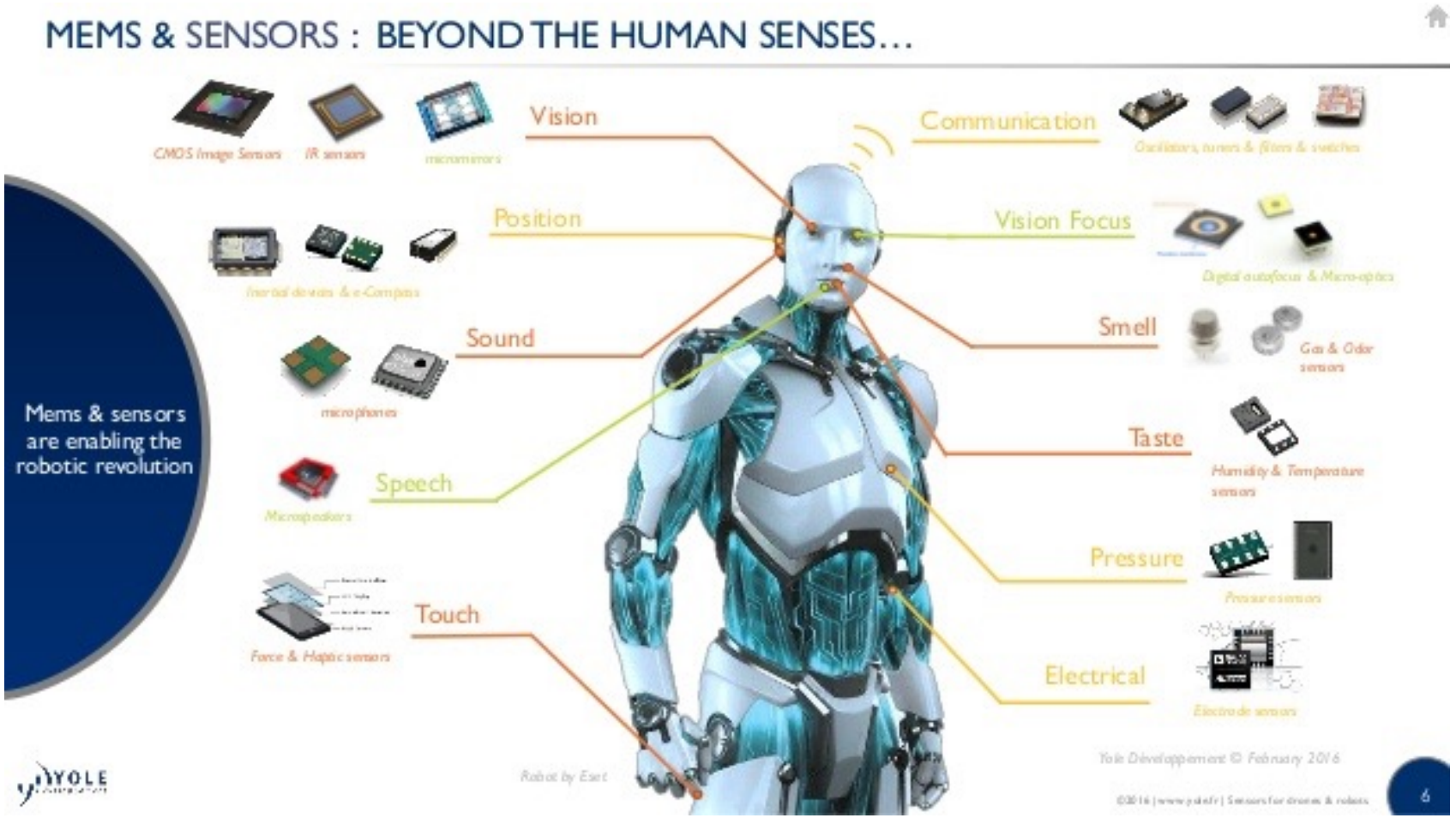
- 09 Event cam: Image reconstruction
- 10 Event camera: Robot control

- 11 Localization LIDAR in LIDAR
- 12 Localization Visual in LIDAR

- 13 Fusion: proprio-&exterioceptive
- 14 Fusion: Handling of time delay

- 15 Object recognition 3D
- 16 Obj. rec. Appearance-based

Thank you!


MEMS & SENSORS : BEYOND THE HUMAN SENSES…
Mems & sensors are enabling the robotic revolution
Vision
Position
Sound
Speech
Touch
Communication
Vision Focus
Smell
Taste
Pressure
Electrical
CMOS Image Sensors
IR sensors
microphones
Inertial devices & e-Compass
Digital autofocus & Micro-optics
Gas & Odor sensors
Humidity & Temperature sensors
Pressure sensors
Electrode sensors
Force & Haptic sensors
Robot by Eset
Yole Développement © February 2016

Sources

- P1: https://arstechnica.com/cars/2018/09/this-lidarcamera-hybrid-could-be-a-powerful-addition-to-driverless-cars/
- P8: bostondynamics.com, https://www.kurokesu.com/main/2017/05/08/3d-scanning-like-a-pro/, https://www.sifsof.com/clinical-apps/simultaneous-localization-and-mapping-slam/, https://mediatum.ub.tum.de/doc/1375631/1375631.pdf, neurohive.io,
- P10: https://habr.com/en/post/436248/, https://de.mathworks.com/help/fusion/ug/introduction-to-estimation-filters.html
- P11: https://www.youtube.com/watch?v=tP1GFapGalQ, https://vision.in.tum.de/research/vslam/lsdslam, “Robot carthography: ROS+SLAM”
- P12: “Uncalibrated Visual Servoing” Azad Shademan et al., https://sourceforge.net/projects/octomap/
- P13: https://dlr-alr.github.io/dlr-tactmat/, https://mediatum.ub.tum.de/doc/1375631/1375631.pdf
- P14: “Tutorial on Event Cameras“ Davide Scaramuzza,
- P15: https://vrroom.buzz/vr-news/products/arvizio-optimizes-lidar-point-clouds-hololens, http://www.lifelong-navigation.eu/files/caselitz16iros.pdf
- P16: https://www.intellias.com/sensor-fusion-autonomous-cars-helps-avoid-deaths-road/
- P17: papers T13+T14
- P19: https://www.slideshare.net/Yole_Developpement/sensors-for-drones-and-robots-market-opportunities-and-technology-revolution-2016-report-by-yole-developpement