DAIMLER

Building a Computer Vision Research Vehicle with ROS

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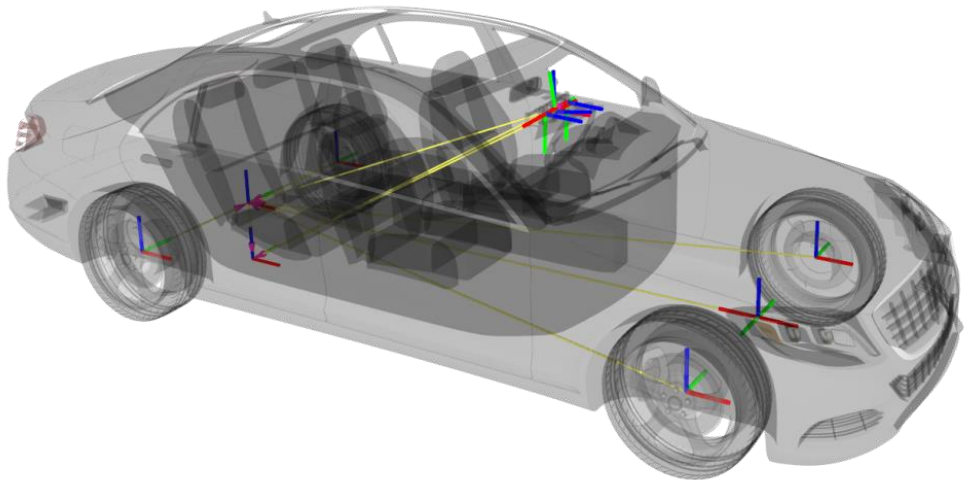

Agenda

1. Introduction
2. History
3. Triggering a Heterogeneous Sensor Setup
4. Our Calibration Solution
5. Enhancing ROS Tools / Handling Data
6. Q&A

About Us

- Daimler is the corporate parent of Mercedes-Benz.
- The authors started in team „Pattern Recognition and Cameras“ as PhDs.
- Main research topics: pedestrian intention recognition, traffic light recognition.
- Interests: object recognition from camera images, machine learning.
- Using ROS as research framework for computer vision.


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Markus Braun


Andreas Fregin


Markus Roth


Fabian Flohr

How I came to ROS

2011 / 12

- University
- RoboCup@Work

Daimler

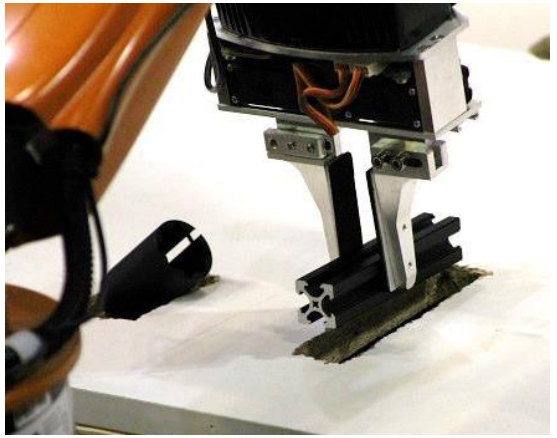
- Need for a framework
- Used est. automotive framework
- Missed simplicity, introspection and especially the doc. (wiki) of ROS

2015

- Came back to ROS

RoboCup @Work

RoboCup@Work: Basic Transportation Test



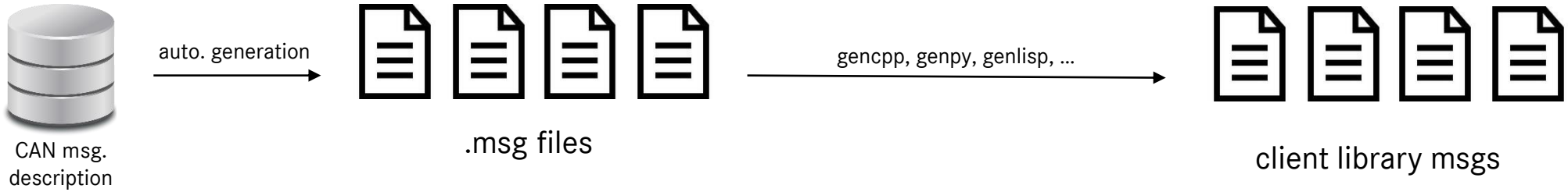
Precision Placement Test / League Winners

Daimlers History in ADAS & Autonomous Driving Research

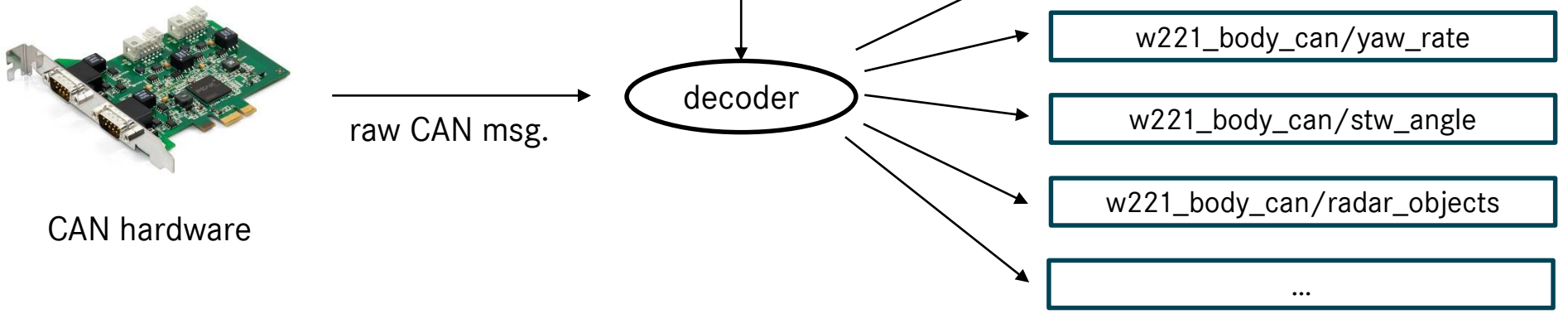
Our ROSified Research Vehicles

Universal CAN Message Decoder

- Message generator for CAN-bus messages



- Decoding/Publishing



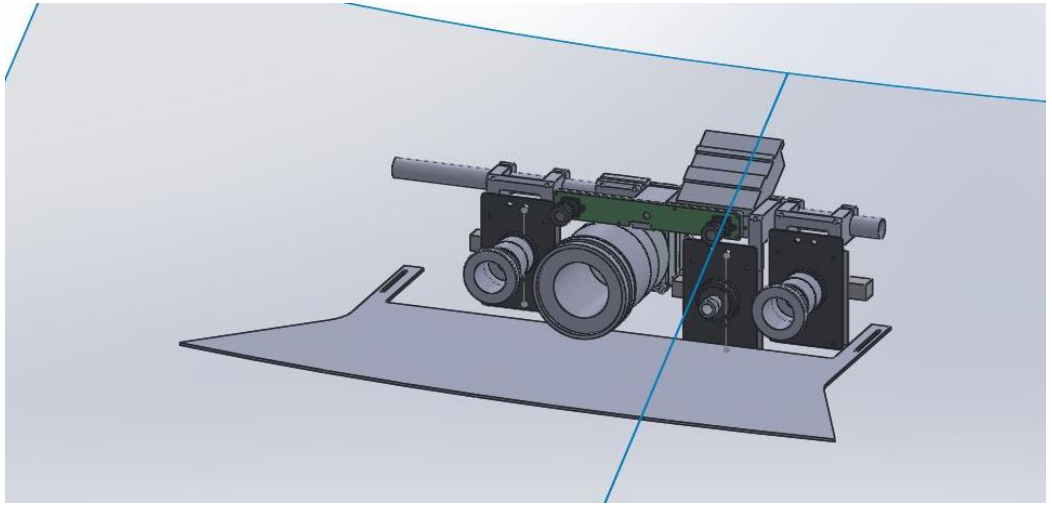
Enabling Low-Level Sensor Fusion

Target

- Capture surrounding at the same moment in time
- … across different sensors
- Precisely time-stamp sensor-readings

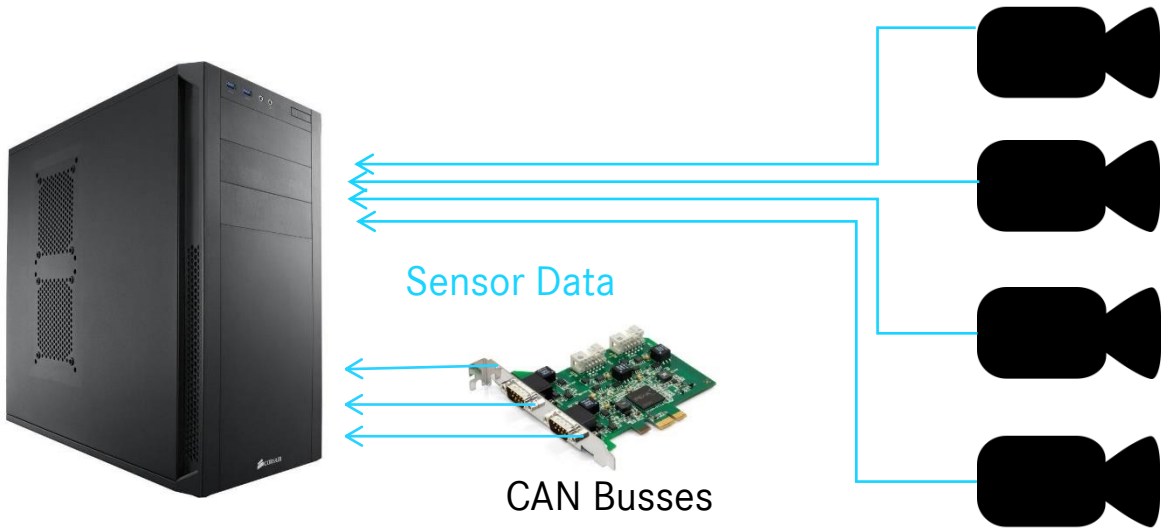
Constraints

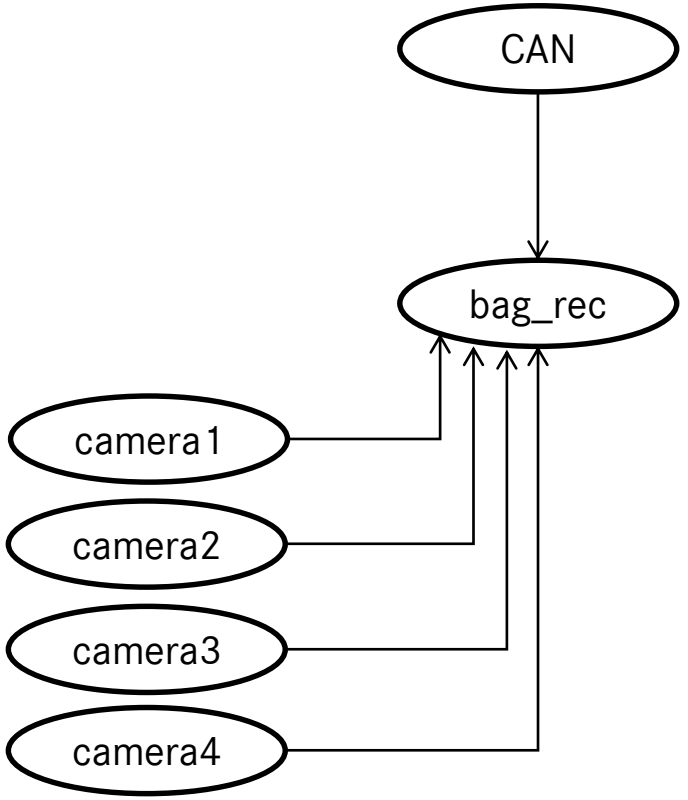
- Heterogeneous sensors
- Different sensor nodes
- Maybe different cycle rates
- Unstamped sensor data from CAN-bus



Software Triggering

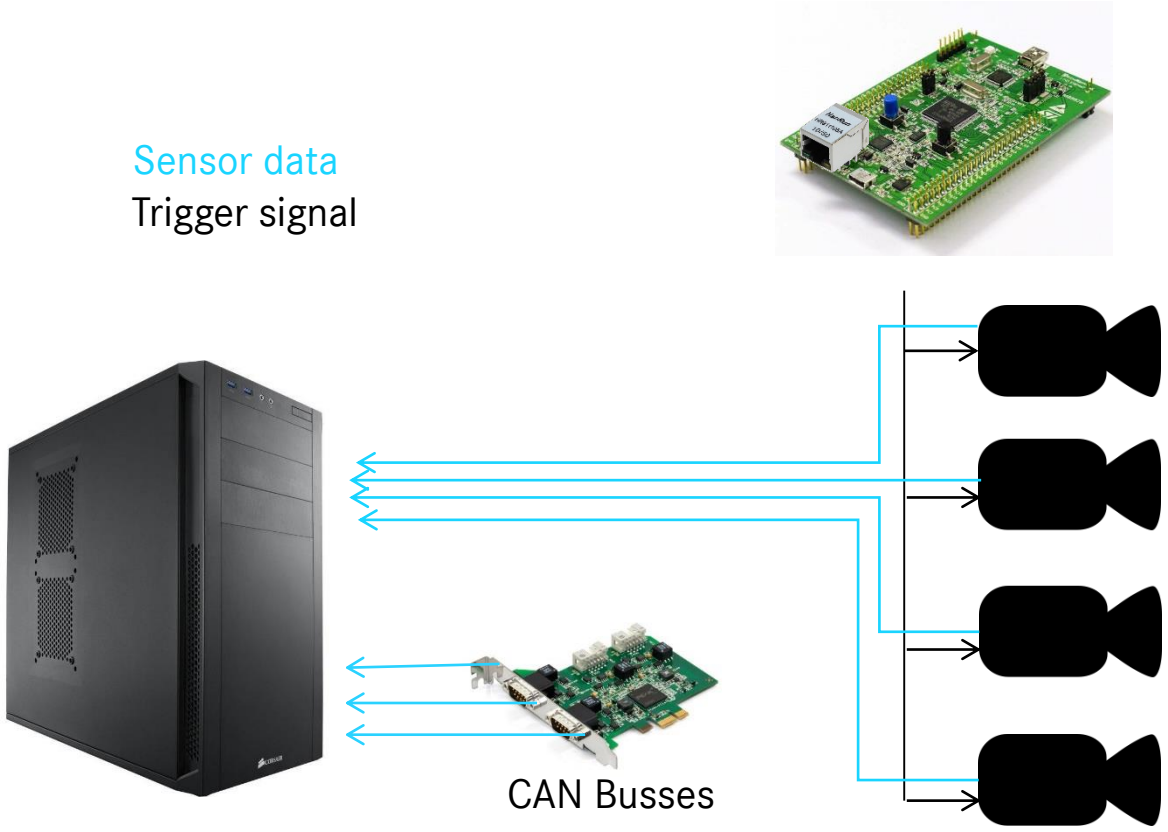
- Use the host PC to software-trigger all sensors

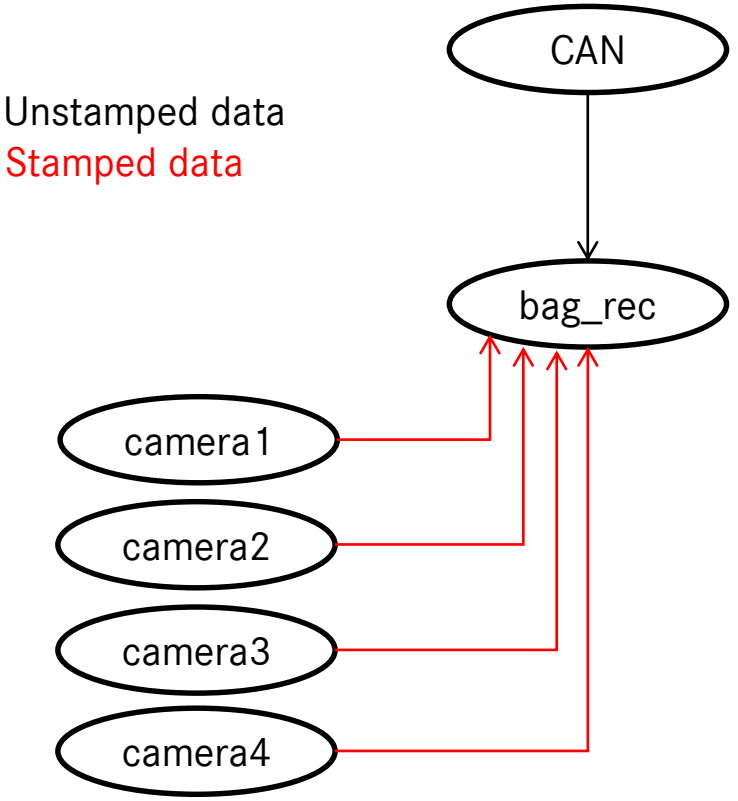




Hardware Triggering

- Use a trigger generator to hardware-trigger all sensors
- Same acquisition time – but when?





Sensors do not know about reference time

- The exposure was triggered at the exact same moment, so the data (images) show the same content
- Processing time of heterogeneous setups will vary ->data (images) arrive at different moments in time
- Timestamping using ros::Time::now() will result in different timestamps
- Timestamping using ros::Time::now() is not correct (arrival vs. acquisition!)
- We need to know the moment of triggering in reference time

PTP Time-Sync (Precision Time Protocol, IEEE1588)

- Trigger (Microcontroller) does not know about reference time
- Time-Synchronization: STM32F4 + LWIP + ROSUDP + PTPd

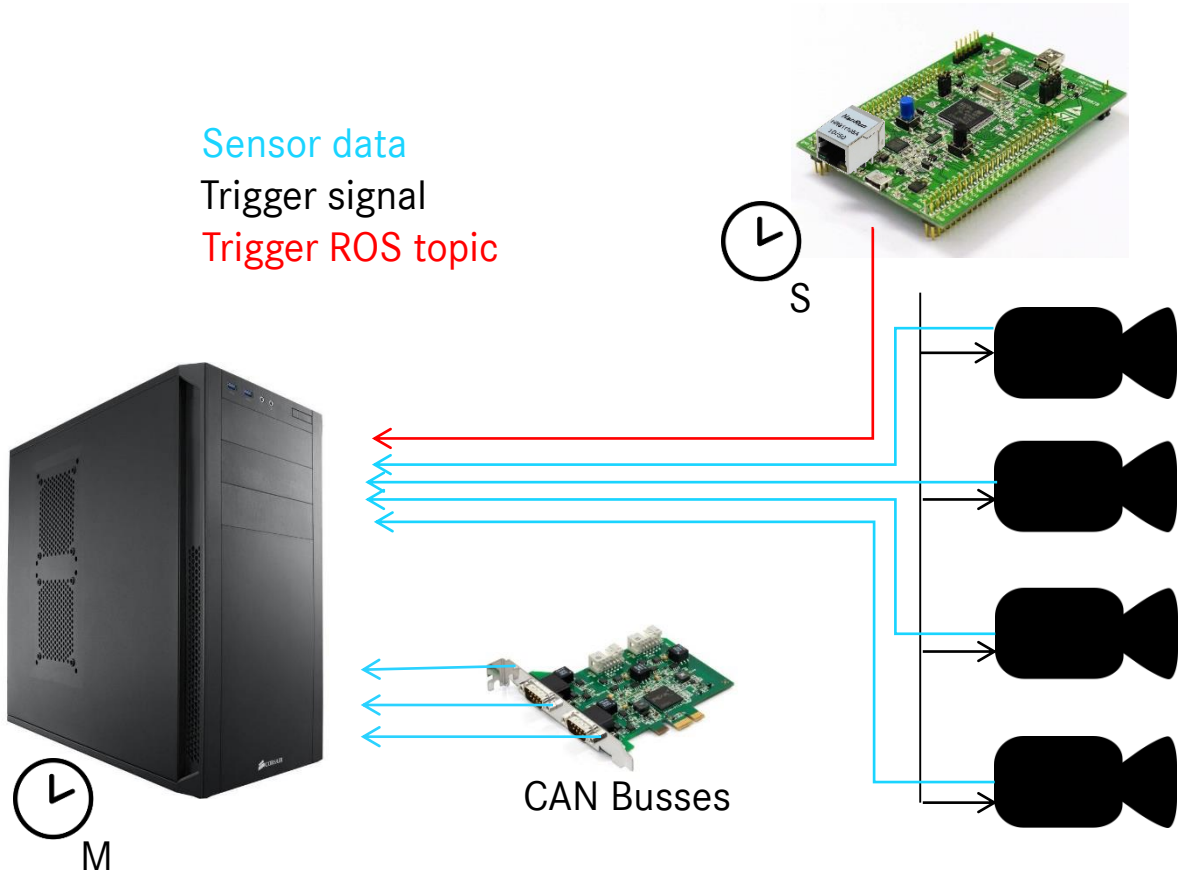
- With each trigger signal, also a trigger message is generated
- Publishing trigger message (std_msgs/Header)

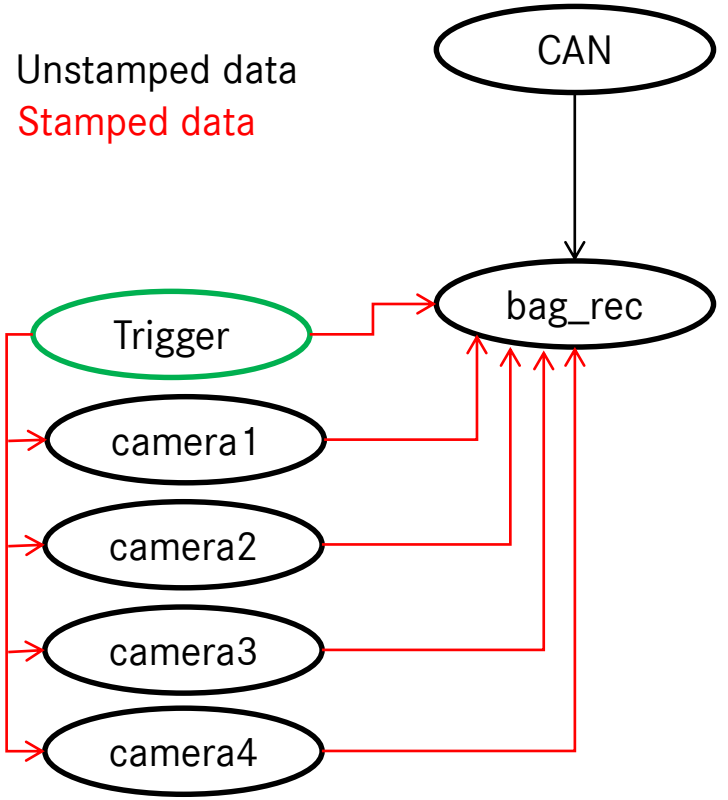
- Sensor nodes receive the trigger message before the sensor data arrives: proper timestamped images, while ensuring all different sensor data have the exact same timestamp!

- Result: All camera images show the exact same moment AND we know the timestamp of that moment

Hardware Triggering with known time

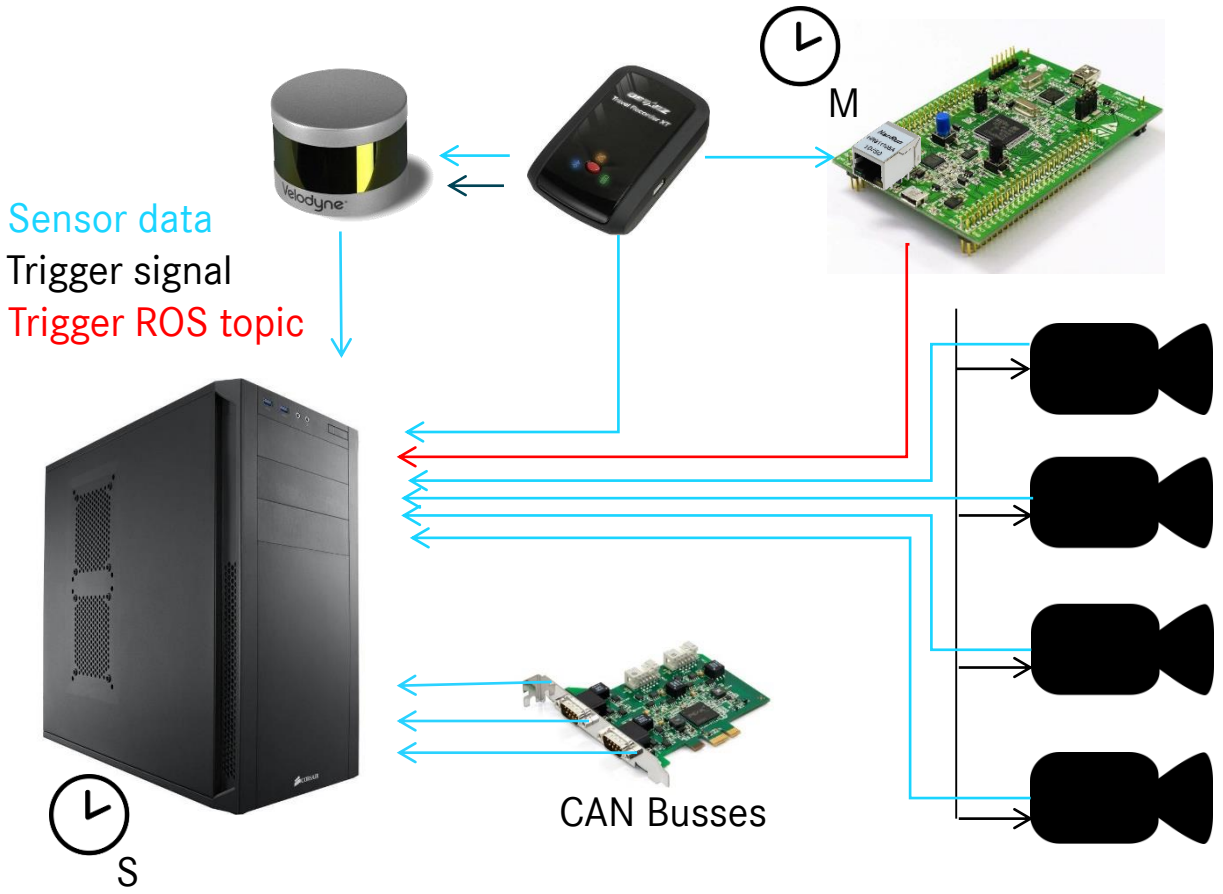
- Microcontroller does know about reference time (via PTP from PC)
- Microcontroller publishes trigger as ROS std_msgs/Header

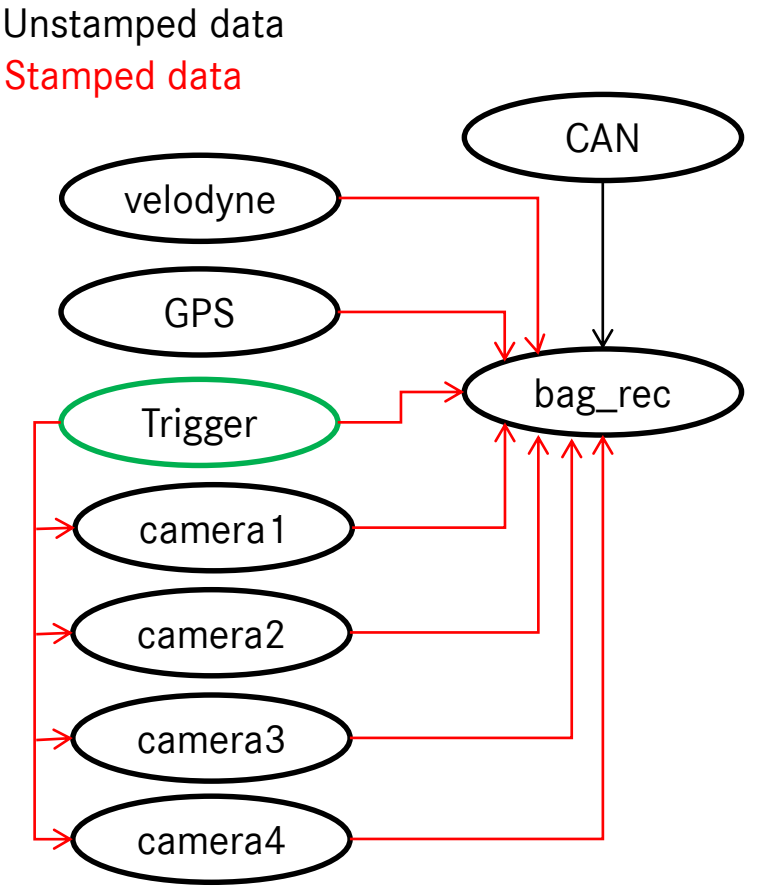




Synchronization with Velodyne LiDARs

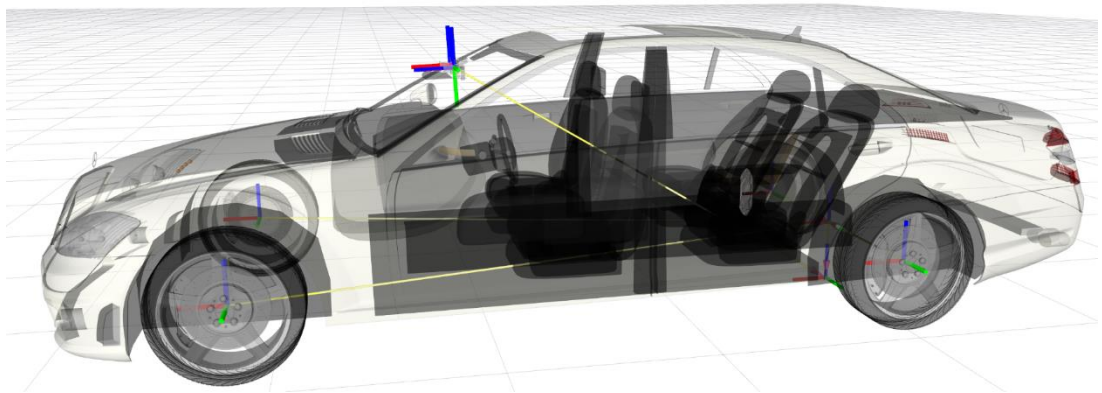
- Microcontroller is now PTP time master using GPS time (NMEA string parsing)
- PC is PTP time slave

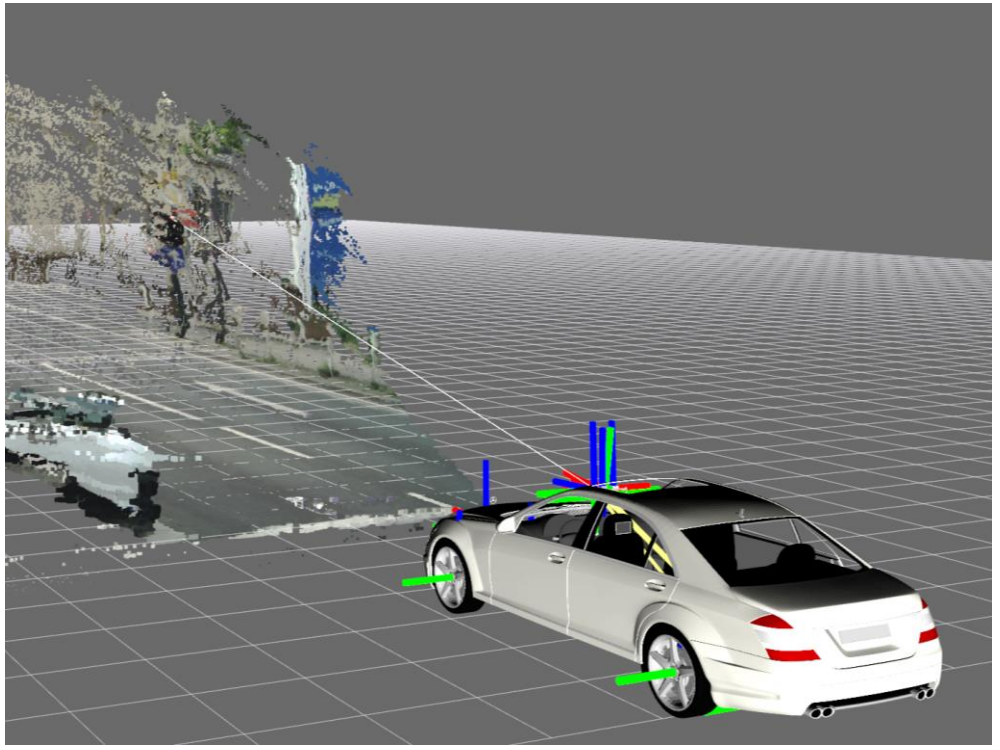




Calibration

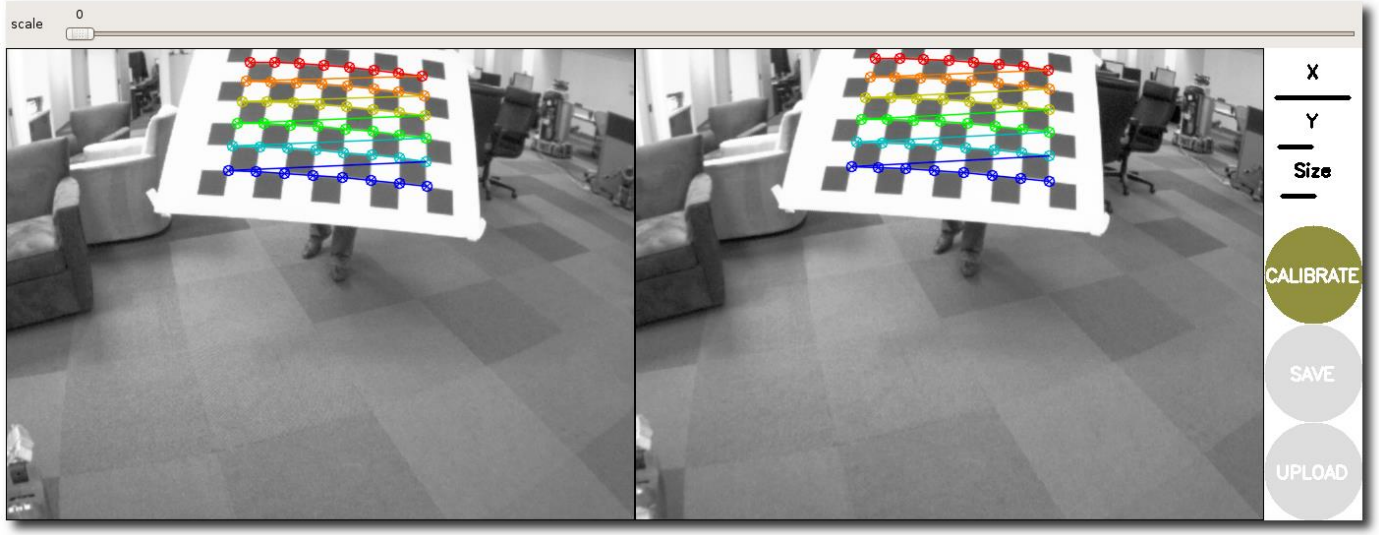
- Whenever you fuse data you need to know about times AND coordinate frames
- Even small errors (sub-decimal) in orientation result in huge position errors for distant objects
- We need a good extrinsic calibration
  - Cameras
  - Laser scanners
  - …





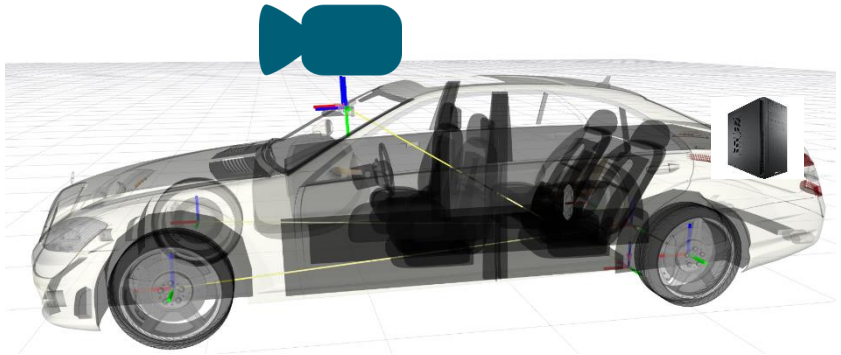
Intrinsic Camera Calibration

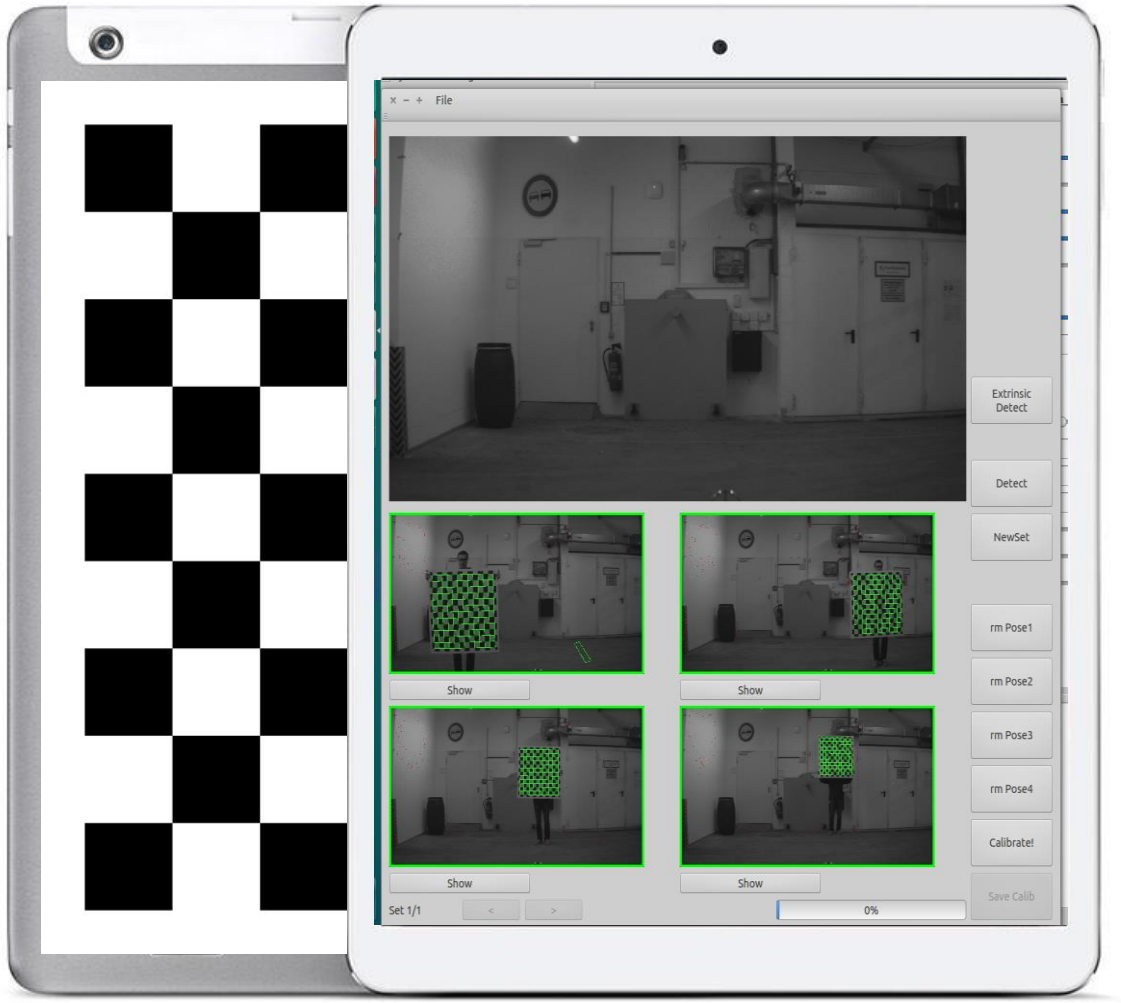
- cameracalibrator.py comes with OpenCV checkerboard-detector
- Has a informative UI that teaches you where to hold the checkerboard (X/Y/Size)
- Does pick the images from running video: user doesn‘t has the chance to hold still to avoid motion blur, etc.
- Does not allow to modify data that is used for the calibration step
- Does not generate a sensor-to-car transformation



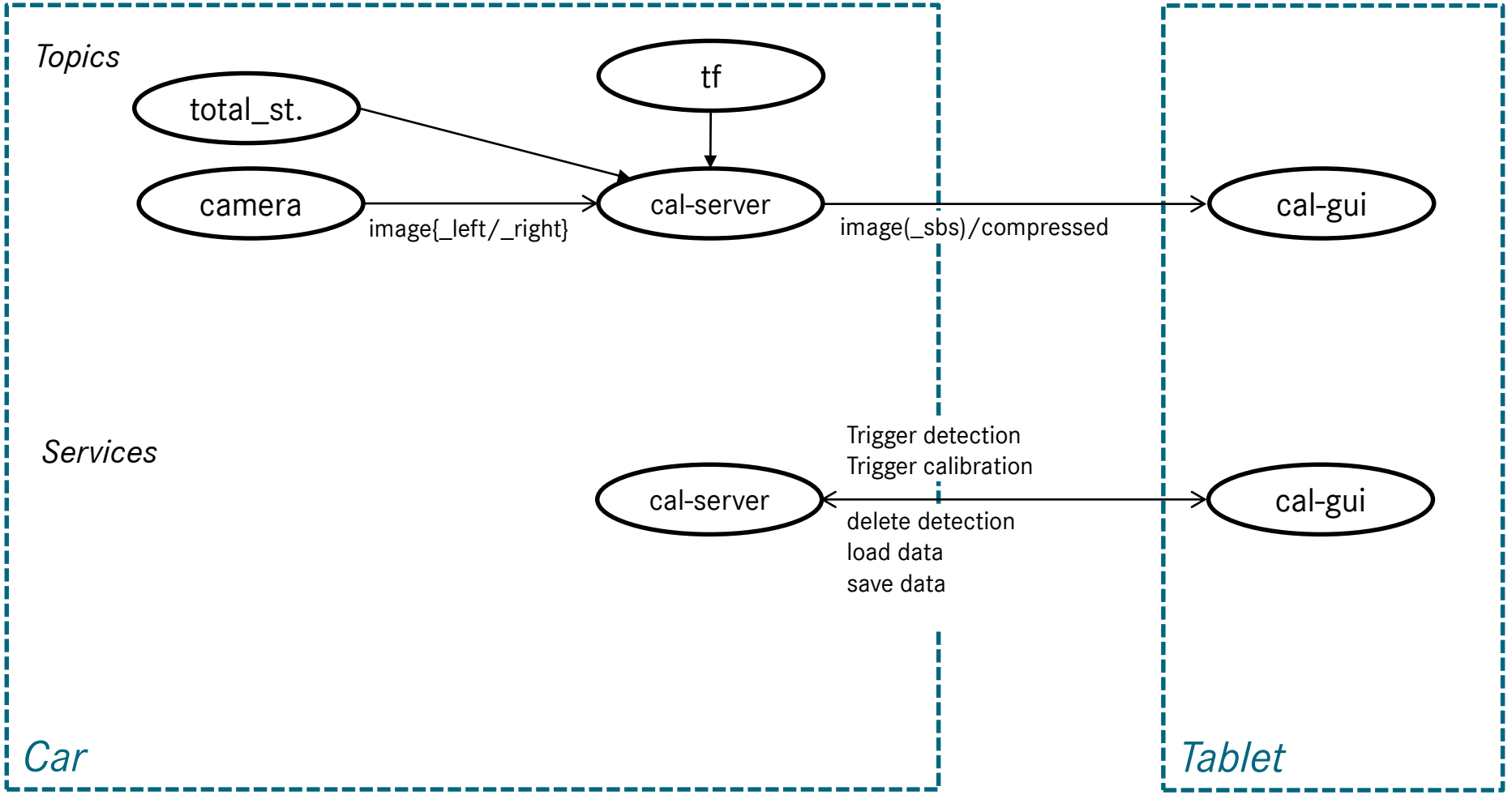
Calibration Requirements

- One-man show
- On demand checkerboard detection
- Live detection inspection
- Remove images
- Add specific images





Server-Client Calibration using Car-PC + Linux-Tablet



Timeshift Recording

- Good example for ROS-tool enhancement
- Start recording in the past
- RAM Buffer
- Trigger topic (delayed start/stop)

Seconds of rec.

Minutes of rec.

Hours of rec.

Rosbag player enhancements

- Step-topic (play/pause)
- Triggered playback

Rewriting Rosbags

- Don’t be afraid using rospy.rosbag to modify existing ROSbags
  - add sensor data
  - add TF (Calibration)
  - add ground truth
  - correct data (e.g. frame_ids, image_encodings, …)
  - …

Powerful tools / packages

- Setting up complex image processing setups using nodelets
- Strongly typed messages lead to node exchangeability
  - Example: different detectors all use the same in/output messages
- Extremely powerful packages like image_geometry speed up research
- Having tf as the transformation central
- Launch system is very helpful (especially including other launch files)
- Diagnostics capabilities, ...

Our lessons learned

- ROS already includes the concepts to realize complex, heterogeneous sensor setups
- ROS can handle high data throughput and high cycle rates
- ROS is a good starting point for handling large data
- If your needs exceed what ROS comes with – extend it!

Questions ?