SCIENCE
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fROS: A Generic Fieldbus Framework for ROS

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- M.Sc in Advanced Driver Assistant Systems
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- Scenario specific performance evaluation for ADAS
- Data-mining, Big Data processing and scenario extraction

Agenda

1. **Introduction**
   1. Use case
   2. Middleware
   3. Fieldbus

2. **fROS**
   1. General Overview
   2. Node Architecture
   3. Implementation

3. **Temporal Validation**
   1. Validation principle
   2. Validation results

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1.1 Use case

- Data-driven development and validation for ADAS and AD requires real-world data with high-precision sensors – so-called reference sensors

- Especially in sensor development and testing, reference sensors are strictly required for evaluation of sensor-performance, software-comparison, and application

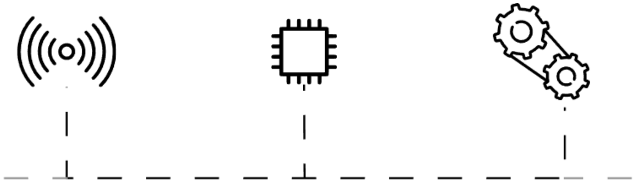
- Combining both, reference sensors and vehicle-internal communication is often challenging and cost intense

- We are presenting an open-source framework for reading vehicle-internal communication alongside with additional sensor signals such as reference LiDAR, IMU, camera, …

1.2 Middleware

- To connect multiple sensors and actuators, a central software framework (so-called middleware) is required
- Beside sensor-system-communication, timing, visualization, calibration but also message-recording and message-processing is a central part of the middleware
- In the field of ADAS, automotive data and time-triggered framework (ADTF) is often used
- Due to the license model, but also due to the excellent support open-source such as the robot operating system (ROS) are often used in research and development
- To cover the specific requirements of the automotive industry, real-time and failsafe communication, but also end-to-end encryption is available (ROS 2)

1.3 Fieldbus Protocols



- For communication between sensors, ECUs, and actuators, various Fieldbus protocols are used
- Controller Area Network (CAN) as the most common protocol was standardized in 1993
- Extensions such as CAN-FD, but also different protocols such as LIN, (Automotive)Ethernet, EtherCAT, MOST, …. available and mostly tailored for its application
- Deterministic behavior only for few protocols such as FlexRay (FR)
- For all protocols, principles for ensuring secure transmission, encryption, etc. are applied
- Few Fieldbus nodes in ROS available

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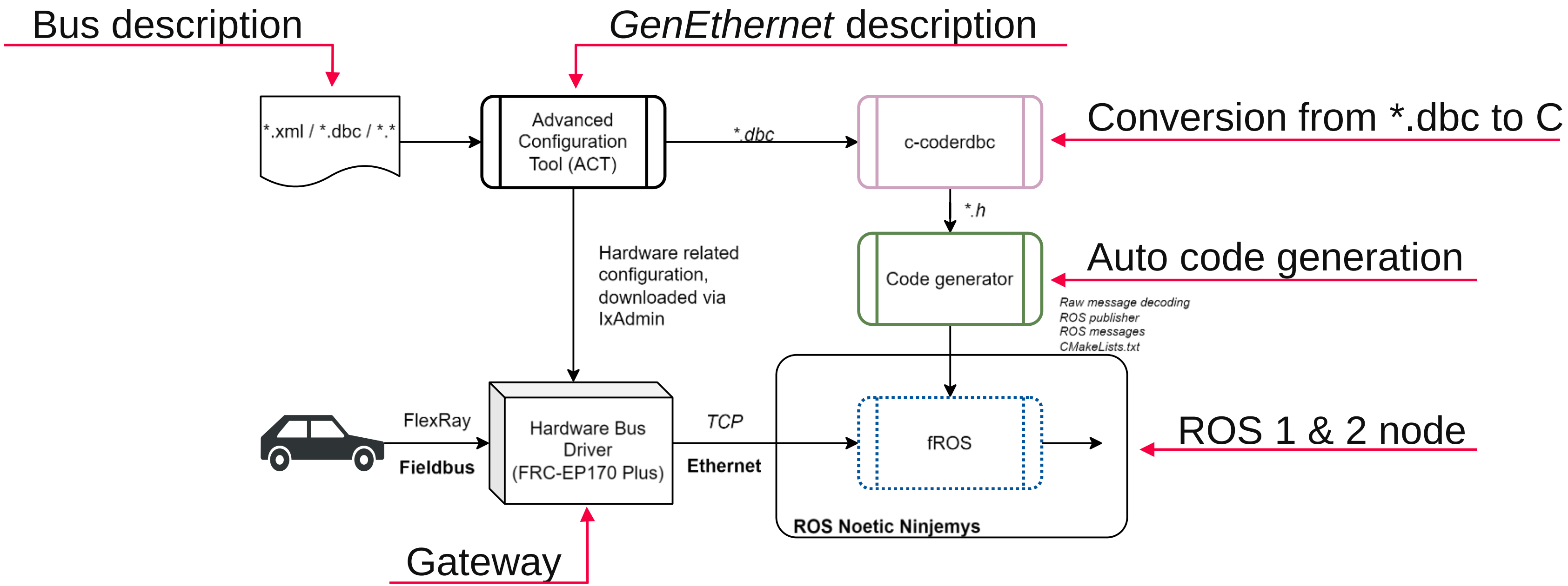
2.1 General Overview



github.com/AdriveLivingLab/fROS

2.1 General Overview

- IXXAT defines *GenEthernet* (GE) as generic bridge between Fieldbus and TCP-message

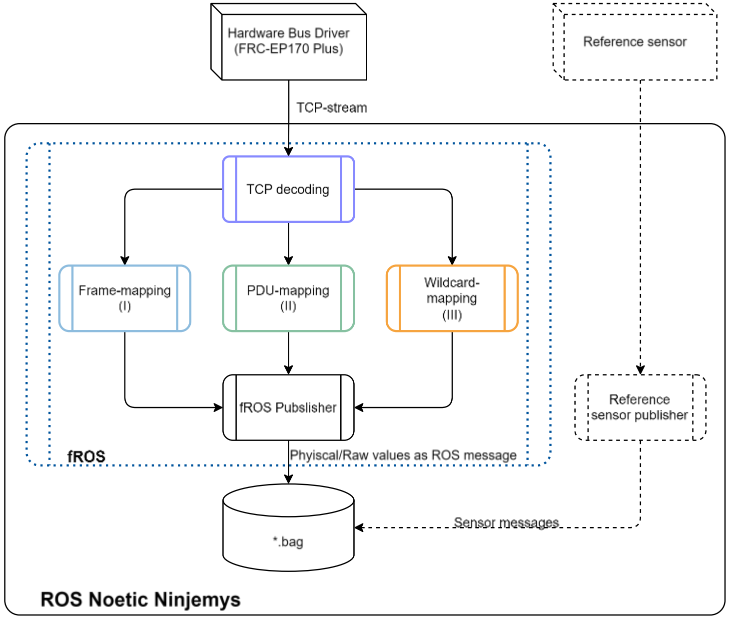
- The idea behind GE is that all messages are mapped into defined binary structure:

```
typedef struct {
  uint16_t w_msgSign; // B space
  uint16_t w_msglen; // message complete length
  uint32_t dw_id; // message ID
  uint8_t b_format; // message frame format info
  uint64_t qw_timestamp; // message timestamp
  uint16_t w_reserved; // reserved
  uint16_t w_datalen; // num of data bytes
  uint8_t ab_data[]; // data bytes
  } IXXAT_BIN_PKT;
```

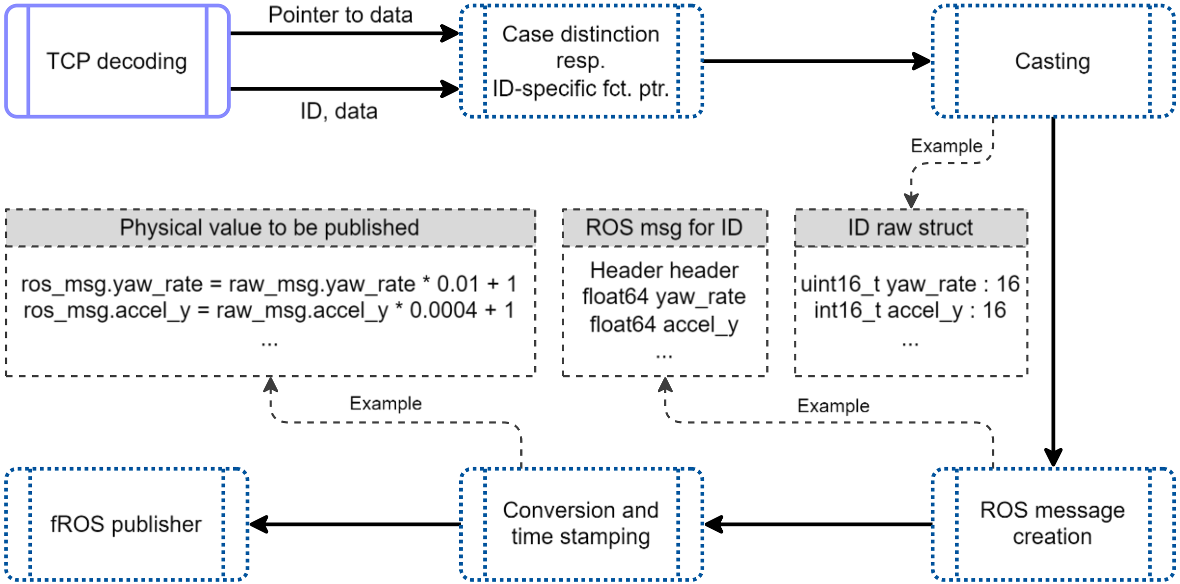
- With that, LIN, CAN, FlexRay, and EtherCAT can be converted into *GenEthernet*

2.2 Node Architecture

- Overall architecture can be adapted according to the use case
- Entire bus description file is not required (compliance) for data recording
- Gateway generates TCP-stream via *GenEthernet*
- TCP-stream is decoded and mapped to ROS message according to the selected principle:
  - Frame-mapping
  - PDU-mapping
  - Wildcard-mapping
- The resulting message is published and saved



2.3 Implementation



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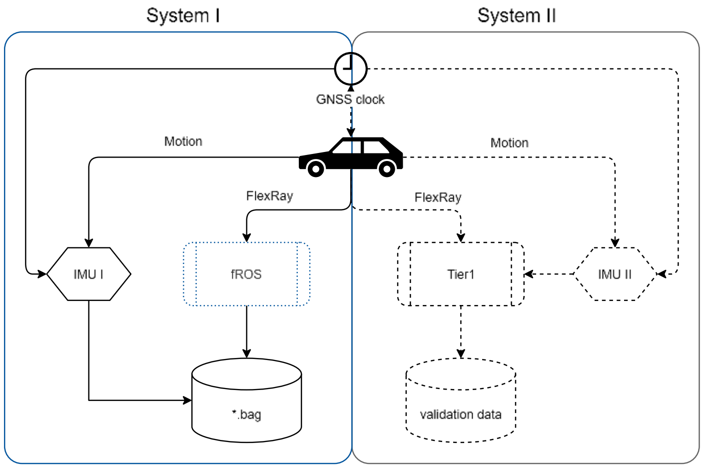
3.1 Validation Principle

- For temporal validation of fROS, a vehicle dynamics-based validation process was applied

- Two independent systems are installed in the same vehicle, measuring the same motion, FlexRay, and time information

- Weave-test according to ISO 13674-1 was conducted at 60 $\frac{km}{h}$ with $\pm 22°$ steering wheel angle to achieve $\pm 2\frac{m}{s^2}$ lateral acceleration

- Cross-correlation identifies temporal difference between the two sinusoidal signals of the yaw rate

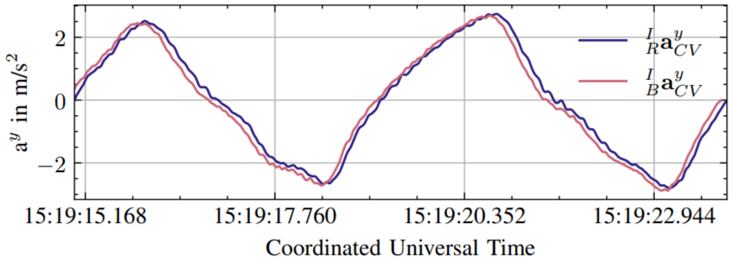


Hardware	System *I*	System *II*
FlexRay Interface	Ixxat FRC-EP170 Plus	Vector VN7640
Inertial Sensor	GeneSys ADMA-G-PRO+	GeneSys ADMA-G-PRO+
GNSS Antenna	NovAtel VEXXIS GNSS-502	NovAtel GPS-702-GG
RTK-GNSS	✓	✓
CPU	AMD EPYC 7401p	Intel Core i7 7820HQ
RAM	256 GB	16 GB
Software		
Operating System	Linux Ubuntu 20.04	Windows 10 Professional
Framework	ROS 1 Noetic Ninjemys	Vector CANoe 15 SP2

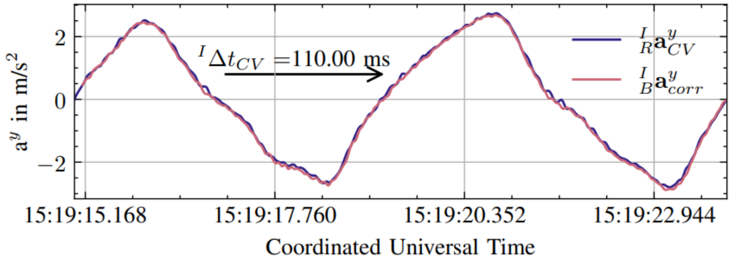
3.1 Validation Principle Verification

- All data are mapped to the common GNSS-clock via INS
- The intersection of the abscissa for the yaw rate in the first rising half-wave are defined as the event start point (esp) of the validation
- The event end point (eep) was identified exactly two periods later, formally:

$$
{}^{I}_{B}\dot{\Psi}_{TV} = \left\{ {}^{I}_{B}\dot{\Psi}_{i} | i \in \mathbb{N},\ {}^{I}_{B}\mathrm{esp}_{TV} \leq i \leq^{I}_{B} \mathrm{eep}_{TV} \right\}
$$
$$
{}^{I}_{R}\dot{\Psi}_{TV} = \left\{ {}^{I}_{R}\dot{\Psi}_{i} | i \in \mathbb{N},\ {}^{I}_{R}\mathrm{esp}_{TV} \leq i \leq^{I}_{R} \mathrm{eep}_{TV} \right\}
$$



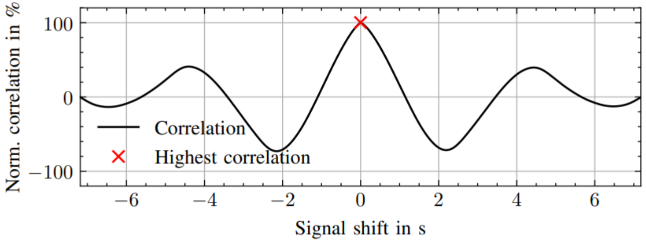
(a) Filtered lateral acceleration signals obtained from the on-board sensor (red) and IMU (blue) on system *I*.



(b) Time-corrected acceleration signal (red) and IMU signal (blue) on common UTC axis.

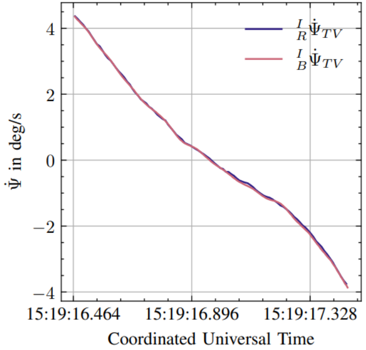
3.1 Validation Results

- Cross-correlation between the yaw rate of system *I* and system *II* determines $0\ ms$ time shift between it

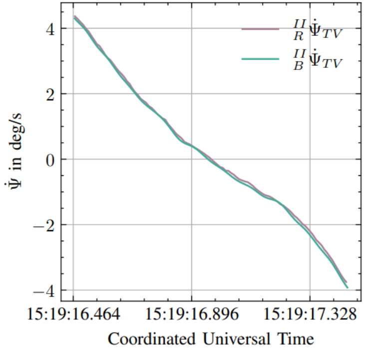


- However, system *II* shows more precise timing for the 200 Hz sampled data

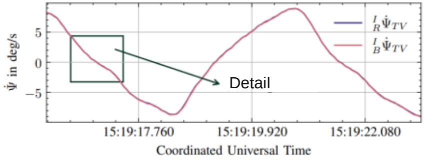
System	Mean cycle time in s	Cycle time standard deviation in s
I	5.00×10^{-3}	3.53×10^{-4}
II	5.00×10^{-3}	3.00×10^{-6}

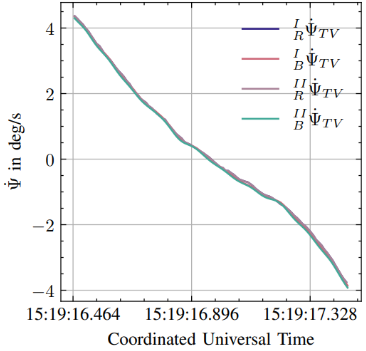


(a) Yaw rates measured on system *I*.



(b) Yaw rates measured on system *II*.





(c) Yaw rates of both systems combined.

- This work was funded by the Bavarian Ministry of Economics Affairs, Regional Development and Energy [grant number DIK0229/02] and supported by AVL/DE

- Daniel Schneider and Ludwig Kastner worked on the presented topic together. Ludwig mainly developed the fROS node, whereby Daniel developed the methodology around it

github.com/AdriveLivingLab/fROS

github.com/schneider-daniel

github.com/ludwig-kastner