Towards C-ITS-based communication between bicycles and automated vehicles

Simon Gröchenig, Karl Rehrl

Salzburg Research, Jakob Haringer Straße 5/3, 5020 Salzburg, Austria

Abstract. Cooperative Intelligent Transport Systems (C-ITS) technologies will play a significant role in the communication of automated vehicles. So far, vulnerable road users such as cyclists or pedestrians are often excluded from the communication and therefore are not able to actively create awareness for themselves. The Austrian research project Bike2CAV aims at improving bicyclists' safety via Cooperative Intelligent Transport Systems (C-ITS) technologies. The work introduces the implemented prototype of a C-ITS-enabled helmet consisting of a GNSS (Global Navigation Satellite System) device (XSens MTi 680G) to determine the current location and two additional IMUs (MetamotionR by Mbientlab) mounted on the left and right hand to recognize turn intentions indicated by hand signals. The overall goal is to evaluate the C-ITS-prototype in real-world situations, especially whether localization accuracies (0.1 m accuracy at 95% confidence) can be achieved. For the LBS 2021 conference, first results will be available.

Keywords. C-ITS, Vulnerable Road User, Road Safety

1. Introduction

According to the European Road Safety Council, 47% of all killed people on the road are vulnerable road users (pedestrians, cyclists, motorcyclists) and 83% of those deaths are caused by collisions with motorized vehicles (Adminaité-Fodor and Jos 2020). Since cycling is experiencing a boom in many countries (Nikolaeva et al. 2019), without dedicated measures, cycling safety will further be at risk. Beside safety-related improvements of the cycling infrastructure and regulatory measures (being considered by far most important) (Loidl and Zagel 2014), smart cycling accessories or wearables can contribute to enhanced safety, e.g. by making cyclists more visible for motorized vehicles (Oliveira et al. 2021). Furthermore, it is expected that progress in vehicle automation is able to lower risks, also for cyclists, but at

LBS 2021
16th Conference on Location Based Services
24-25 November 2021 Online

Published in "Proceedings of the 16th International Conference on Location Based Services (LBS 2021)", edited by Anahid Basiri, Georg Gartner and Haosheng Huang, LBS 2021, 24-25 November 2021, Glasgow, UK/online.

https://doi.org/10.34726/1753 |

the same time new challenges arise (Botello et al. 2019; Sandt and Owens 2017). While automation can contribute to lower or avoid human errors, the reliable recognition of cyclists by automated vehicles' perception systems is still in its infancies (Ahmed et al. 2019).

The Austrian research project Bike2CAV[1] aims at improving bicyclists' safety via Cooperative Intelligent Transport Systems (C-ITS) technologies. C-ITS technologies such as ETSI ITS-G5 (Festag 2014) will play a significant role in the communication of automated vehicles (e.g. to share positions and intentions or to warn each other) and between vehicles and road operators via so-called roadside ITS stations (e.g. to get information on the state of the infrastructure). These technologies are worked out in Europe by the C-Roads Platform[2] and the Car2Car Communication Consortium[3] and standardized by ETSI[4]. So far, vulnerable road users such as cyclists or pedestrians are often excluded from the communication and therefore are not able to actively create awareness for themselves. In Bike2CAV, this should be changed by enabling bicycles to send Cooperative Awareness Messages (CAMs) (ETSI EN 302 637-2 2019) being received by other C-ITS-enabled vehicles, bicycles or roadside ITS stations. Besides raising awareness, automated vehicles and cyclists should be further warned by Decentralized Environmental Notification Messages (DENMs) (ETSI EN 302 637-3 2019) in case of collision risk situations. Such collision risks should be primarily detected based on CAMs but being also supported by environmental perception from the automated vehicle, the bicycle (via mounted radar or LiDAR sensors) as well as sensor-equipped intersections for local perception. Perceived moving objects are communicated via Cooperative Perception Messages (CPM) (ETSI TR 103 562 2019) which should contribute to a more reliable perception. Beside reliable perception and C-ITS-based communication, the main challenge arises from highly accurate localization of moving objects such as automated vehicles and cyclists (0.1 m accuracy; 0.95 % confidence) (Reid et al. 2019). In order to achieve high localization accuracies and to enable bicycles with C-ITS technology, the approach going to be evaluated in Bike2CAV is twofold: On the one hand, a multi-sensor enabled smart bike (Holoscene Edge Bike) from Boreal Bikes[5] with built-in ITS-G5 capability is used. On the other hand,

---

[1] https://www.bike2cav.at/

[2] https://www.c-roads.eu/

[3] https://www.car-2-car.org/

[4] https://www.etsi.org/

[5] https://www.borealbikes.com

a proof-of-concept prototype of a C-ITS-enabled bicycle helmet with high-quality localization as well as C-ITS-communication is evaluated.

This work introduces the implemented prototype of a C-ITS-enabled helmet consisting of a GNSS (Global Navigation Satellite System) device (XSens MTi 680G) to determine the current location and two additional IMUs (MetamotionR by Mbientlab) mounted on the left and right hand to recognize turn intentions indicated by hand signals. A Raspberry Pi 4 device is acting as a local data hub for collecting data from both data sources, wrapping positions and indicated directions into a CAM and sending it via C-ITS IP Based Interface Profile of the C-Roads Specification Version 1.8[6] to a C-ITS broker that distributes the messages to registered roadside ITS stations or other vehicles and bicycles. The broker assembles CAMs to position trajectories, map-matches these trajectories in near real-time onto a local high definition (HD) map and calculates intersection collision risks (ETSI TS 101 539-2 2018). In case of detected collision risks, collision risk warnings (DENMs) are generated and distributed to all connected vehicles or bicycles. The overall goal is to evaluate the proof-of-concept-prototype in real-world situations, especially whether localization accuracies (0.1 m accuracy at 95% confidence) can be achieved.

2. Methodology

This section introduces the bicycle C-ITS prototype and the message broker.

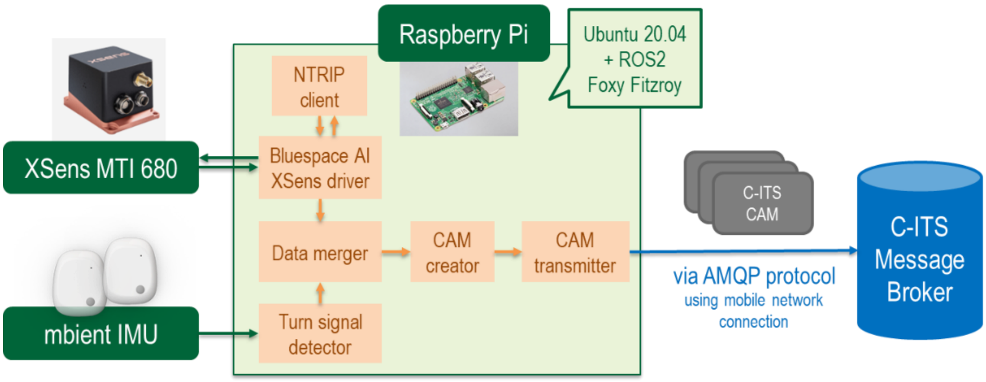

Figure 1. Components of the prototypical acquisition device; green components are devices, orange boxes and lines show ROS nodes and topics, blue represents the C-ITS broker (images © xsens.com, raspberrypi.com, mbientlab.com)

[6] https://www.c-roads.eu/fileadmin/user_upload/media/Dokumente/Harmonised_specs_text.pdf

As mobile data collection node, the prototype uses a Raspberry Pi 4 Model B set up with Ubuntu 20.04 and ROS 2.0 Foxy Fitzroy. All components (Figure 1) of the prototype are introduced in the following list. Technically, these components are ROS[7] nodes that process, subscribe and publish data to each other.

- **XSens MTi driver** reads multi-frequency GNSS locations from the XSens MTi 680G device. The GNSS locations are improved by RTK and an internal filter algorithm using INS data. The latter especially improves localization in areas with limited GNSS coverage. The applied ROS node is forked from the XSens MTI driver for ROS 2.0 developed by Bluespace AI[8], which itself is based on the official XSens driver being only compatible with ROS 1.0. For the prototype, this driver is enhanced to forward NRTK messages to the XSens device. A RTK- and INS-enhanced localization device has been selected in order to meet the proposed positional accuracy targets, which are required for the intended collision detection.
- **Ntrip client** retrieves RTCM (Radio Technical Commission for Maritime Services) messages from a NRTK (Network Real Time Kinematics) service and provides the correction data to the XSens device in order to improve the precision of the GNSS coordinates. The client implemented for the work[9] is based on the implementation offered by XSens (XSens Base 2021). Modifications on the ROS node for this work include the upgrade to ROS 2.0 and the continuous sending of NMEA messages at a 5-second interval.
- **Turn signal detector** reads left and right hand signals to indicate direction or lane changes. The signals are detected from data acquired with IMUs (MetamotionR by Mbientlab) attached to the cycling gloves in real time. The data is transferred via Bluetooth to the turn signal detector ROS node.
- **Data collector/merger** collects the GNSS and turn signal data and merges both to a bicycle data message that is forwarded to the CAM creator. The component also calculates the motion attributes speed and heading from the RTK- and INS-corrected GNSS data.
- **CAM creator** builds CAM (ETSI TS 102 894-2 2014) in XML format from the data stored in the received bicycle message. Due to

[7] https://www.ros.org/

[8] https://github.com/bluespace-ai/bluespace_ai_xsens_ros_mti_driver

[9] https://github.com/SGroe/ntrip_client_ros2

missing dedicated parameters, bicyclist's turn signals are written to the leftTurnSignalOn and rightTurnSignalOn fields within the exteriorLights element of the BasicVehicleContainerLowFrequency.

- **CAM transmitter** sends CAMs via Apache QPID and S-AMQP (Secure Advanced Message Queuing Protocol) to a C-ITS message broker (edge computing node) following the C-Roads C-ITS IP Based Interface Specification 1.8.0.

Challenges during the development of the prototype primarily arose from the two major ROS versions, namely ROS 1.0 and ROS 2.0. Each version is built and recommended for a specific version of Ubuntu and Python. Consequently, all available ROS nodes and required dependencies are implemented for a specific ROS/Ubuntu/Python version. For instance, the official XSens MTI driver is built for ROS 1.0; however, there exists an upgraded version from a third-party company.

Apart from the bicycle prototype, the second major component of the collision detection system is an edge-computing node including a C-ITS broker (Apache ActiveMQ® Artemis[10]) as well as the collision detection module. This broker receives CAMs from the prototype as well as CAMs and CPMs from connected and automated vehicles and a roadside ITS station being enhanced by a camera-based perception system. The further processing of all messages is done on the edge-computing node. Figure 2 shows an exemplary trajectory moving across an intersection represented by a local HD map.

[10] https://activemq.apache.org/components/artemis/

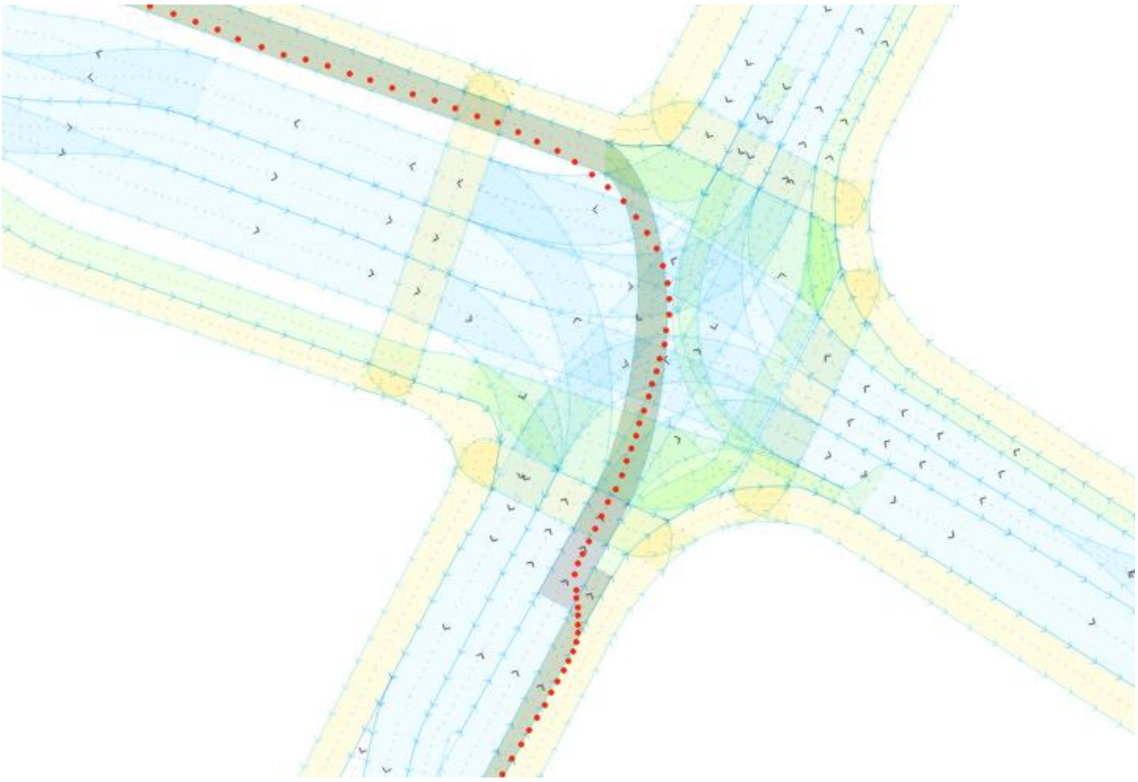

Figure 2: Extract of a trajectory (red points) visualized on a HD map; map-matched HD segments are highlighted grey

2.1. Next Steps and Expected Findings

On the one hand, the localization accuracy of the prototype will be evaluated. This is done by matching the position trajectories of test drives on a lane-accurate HD map including bicycle infrastructure. It should be evaluated whether lane-accurate localization for bicycles can be achieved. On the other hand, algorithms for detecting collision risks for cyclists will be evaluated. The hypothesis is that lane-accurate localization in combination with cyclists' intentions and HD map matching can contribute to improve the detection of collision risks in real-world scenarios (especially at risky intersections). First results are expected for the 2021 LBS symposium.

Acknowledgement

Funded by the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology.

References

Adminaité-Fodor, Dovilé, and Graziella Jos. 2020. "How Safe Is Walking and Cycling in Europe? Pin Flash Report 38." 2020. https://etsc.eu/wp-content/uploads/PIN-Flash-38_FINAL.pdf.

Ahmed, Sarfraz, M. Nazmul Huda, Sujan Rajbhandari, Chitta Saha, Mark Elshaw, and Stratis Kanarachos. 2019. "Pedestrian and Cyclist Detection and Intent Estimation for Autonomous Vehicles: A Survey." *Applied Sciences 2019, Vol. 9, Page 2335* 9 (11): 2335. https://doi.org/10.3390/APP9112335.

Botello, Bryan, Ralph Buehler, Steve Hankey, Andrew Mondschein, and Zhiqiu Jiang. 2019. "Planning for Walking and Cycling in an Autonomous-Vehicle Future." *Transportation Research Interdisciplinary Perspectives* 1 (June): 100012. https://doi.org/10.1016/J.TRIP.2019.100012.

ETSI EN 302 637-2. 2019. "ETSI EN 302 637-2 V1.4.1 (2019-04), Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service."

ETSI EN 302 637-3. 2019. "ETSI EN 302 637-3 V1.3.1 (2019-04) ETSI EN 302 637-3 V1.3.1 (2019-04) Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service." ETSI. https://www.etsi.org/deliver/etsi_en/302600_302699/30263703/01.03.01_60/en_30263703v010301p.pdf.

ETSI TR 103 562. 2019. "ETSI TR 103 562 V2.1.1 (2019-12) Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS); Release 2." ETSI. https://www.etsi.org/deliver/etsi_tr/103500_103599/103562/02.01.01_60/tr_103562v020101p.pdf.

ETSI TS 101 539-2. 2018. "ETSI TS 101 539-2 V1.1.1 (2018-06), Intelligent Transport Systems (ITS); V2X Applications; Part 2: Intersection Collision Risk Warning (ICRW) Application Requirements Specification."

ETSI TS 102 894-2. 2014. "ETSI TS 102 894-2 v1.2.1 (2014-09) Intelligent Transport Systems (ITS); Users and Applications Requirements; Part 2: Applications and Facilities Layer Common Data Dictionary."

Festag, Andreas. 2014. "Cooperative Intelligent Transport Systems Standards in Europe." *IEEE Communications Magazine* 52 (12): 166–72. https://doi.org/10.1109/MCOM.2014.6979970.

Loidl, Martin, and Bernard Zagel. 2014. "Assessing Bicycle Safety in Multiple Networks with Different Data Models." In *GI_Forum 2014. Geospatial Innovation for Society*, edited by R. Vogler, Adrijana Car, Josef Strobl, and Gerald Griesebner, 144–54. Wichmann Verlag.

Nikolaeva, Anna, Marco te Brömmelstroet, Rob Raven, and James Ranson. 2019. "Smart Cycling Futures: Charting a New Terrain and Moving towards a Research Agenda." *Journal of Transport Geography* 79 (July): 102486. https://doi.org/10.1016/J.JTRANGEO.2019.102486.

Oliveira, Franklin, Dilan Nery, Daniel G. Costa, Ivanovitch Silva, and Luciana Lima. 2021. "A Survey of Technologies and Recent Developments for Sustainable Smart Cycling." *Sustainability 2021, Vol. 13, Page 3422* 13 (6): 3422.

https://doi.org/10.3390/SU13063422.

Reid, Tyler G.R., Sarah E. Houts, Robert Cammarata, Graham Mills, Siddharth Agarwal, Ankit Vora, and Gaurav Pandey. 2019. “Localization Requirements for Autonomous Vehicles.” *SAE International Journal of Connected and Automated Vehicles* 2 (3): 173–90. https://doi.org/10.4271/12-02-03-0012.

Sandt, Laura, and Justin M Owens. 2017. “Discussion Guide for Automated and Connected Vehicles, Pedestrians, and Bicyclists.” Washington, DC.

XSens Base. 2021. “Using an NTRIP Client with the Xsens ROS Driver.” 2021. https://base.xsens.com/knowledgebase/s/article/Using-an-NTRIP-client-with-the-Xsens-ROS-driver?language=en_US.