SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number: CA15127
STSM title: Resilient communications for autonomous platooning
STSM start and end date: 2018-06-18 to 2018-06-22
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PURPOSE OF THE STSM

(max.500 words)

In this short term scientific mission, we pursued several purposes. The focus was on an extension of recent research on cooperative adaptive cruise control (CACC) with robust networked control systems for autonomous vehicular platooning. The areas of expertise of the research group at the host institution and the home institution complement each other perfectly: the research group at Halmstad University focuses on the data age behavior of vehicular communication standards and networks such as 5G, IEEE 802.11p, and ETSI ITS-G5. On the other hand, the latest research at the Institute of Communication Networks from Hamburg University of Technology analyses the impact of such data age behavior of intra-platoon communication on the reliability of platooning in terms of risk of collision and string stability of connected systems.

For this scientific mission we expected results about the impact of communication resilience on the robustness and stability of autonomous platooning. This is important for platooning in infrastructure-based networks like LTE or 5G in particular, which are technologies that are inherently prone to disaster-based failures.

Furthermore, possible collaboration between host and home institutions should be set up for future joint research, publications, and for joint supervision of Master's and Bachelor's theses.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

(max.500 words)

The short term scientific mission started with an in-depth introduction into previous research of the respective institutions, with extensive discussions about the following topics:

- Definition of string-stability as control theory property of interconnected systems
- Physical channel abstraction by a two-state Gilbert-Elliott channel model
- Definition of burst packet losses
- Vehicle controller specifications in terms of reaction times, fuel-efficiency, and passenger-comfort

- Risk of vehicular collisions subject to vehicle time headway distances and Cooperative Awareness Message (CAM) data age
- Comparison of control system behavior with periodic beaconing and variable transmission times in cases of packet losses

Following this introduction, there were several follow-up discussions and working groups with different members of the research team, including:

- Overview on the verification of robustness of networked control systems with regard to data age in the following events:
    - In a delayed communication channel, evaluated comprehensively in previous research.
    - In a lossy communication channel, evaluated in previous research for independent packet losses. Recently evaluated for correlated packet losses according to the Gilbert-Elliott channel model by the home institution
    - In a lossy communication channel with mutual interference by channel access of different communication partners. Simulated for specific cases, communication protocols and technologies in previous research, e.g. in SUMO/Veins using the IEEE 802.11p protocol. An overview by mathematical evaluation and/or abstracted simulation is up for future work
- Investigating state of the art of performance and robustness of CACC by simulation, including evaluation of recent publications by Michelle Segata, University of Trento and Jeroen Ploeg, TNO, Netherlands
- Networked control system design, parameterization, and implementation in MATLAB/Simulink. It included:
    - Modeling of an proportional-derivative acceleration controller $K(s) = K_p + K_d s$ with the control gains K_p and K_d
    - The time headway h which affects the desired distance $d_{r,i}(t)$ of vehicle i, $d_{r,i}(t) = r + hv_i(t), 2 \leq i \leq m$
    - Physical and technical feasibility of a spacing policy transfer function $H(s) = hs + 1$, both in simulation and real world
    - The vehicle transfer function, modeled as third-order system $\mathrm{G(s)} = \frac{k_{dc}}{s^2(\tau s+1)} e^{-\phi s}$, with the engine dynamics DC gain k_{dc}, time constant τ, and time delay ϕ
    - Possible workarounds for the lossy integration of acceleration information, which comes from the plant output and is used as system feedback information, both in simulation and real world
- Comparison of simulation frameworks and tools used by the host and home institution. It included:
    - Skill exchange of the MATLAB/Simulink simulation model and the Plexe/Veins framework for simulation of vehicular communication
    - Degree of abstraction of the communication model, both in Simulink and in Veins
    - Degree of abstraction of the control model, both in Simulink and in Plexe
    - Advantages and disadvantages of higher degrees of abstraction, with regard to general statements about communication requirements
- Requirements of the MATLAB/Simulink model for a convincing channel access implementation. Investigation of feasibility of ALOHA/TDMA/CSMA channel access methods, including evaluation of available implementation in Simulink
- Propose dependencies between CAM information data age and the required minimum distance among platoon members. Includes mathematical definition of upper limits of the required distance

DESCRIPTION OF THE MAIN RESULTS OBTAINED

(max. 500 words)

The most important outcome from this short scientific mission is the establishment of close regular exchange between host and home institution. Furthermore, the following results are obtained:

- Work on possible future publications in the area of dependencies between CAM information data age and required minimum distance between platoon members, both in mathematical evaluation and in simulated verification. CAM data age can become arbitrarily long, e.g. due to disaster-based failures of the communication infrastructure
- Implementation of channel access methods in MATLAB/Simulink. The goal is to be able to give convincing statements about platoon performance when using a lossy communication channel with mutual interference by channel access of different communication partners
- Verification of MATLAB/Simulink simulation model in terms of control system implementation
- Drafting calls for master's theses in the area of networked control systems performance in diverse channel access methods such as ALOHA/CSMA, under joint supervision of the host and home institution
- Expanding the current work schedule of the applicant's PhD thesis for the upcoming months by drawing up milestones and open topics for research

FUTURE COLLABORATIONS (if applicable)

(max.500 words)

A strong collaboration between members of the host and home institution was established during the short scientific mission. Possible future outcomes from this collaboration may be a joint publication in the area of dependencies between data age and minimum vehicle distance and joint supervision of theses.