Doctorate Thesis with scholarship

Doctoral School MADIS (Mathematics, digital sciences and their interactions).

PhD in Automatic Control.

PhD Supervisor (Directeur de thèse) : Prof. Vincent COCQUEMPOT

Research center (Laboratoire d'accueil) : CRIStAL UMR CNRS 9189 https://www.cristal.univ-lille.fr/

PhD co-superviseur (Co-Directrice de thèse) : Prof. Virginie DEGARDIN, IEMN UMR CNRS 8520 https://www.iemn.fr/

Location : Villeneuve d'Ascq, scientific campus University of LILLE

Subject title : Detection, localisation and identification of faults in wired communication and energy networks of autonomous electric vehicles

Description : Electric, intelligent and even autonomous vehicles are in full development. They are one of the priorities of public authorities and private companies for the years to come, both in France and in Europe (see in particular the Report: The European deployment of the autonomous vehicle, Mr. Damien PICHEREAU, 30 July 2021). These vehicles are equipped with new technologies and numerous on-board computers that exchange data and make it possible to offer new driving assistance functions to assist or even replace the driver (cruise control, braking assistance, automatic parking, autonomous driving, etc.). These computers control and command different systems thanks to a set of sensors and conventional or intelligent actuators, distributed in the vehicle, and exchange data between them through communication networks. This results in a high complexity of energy networks (to power the different components) and communication networks (to exchange information between components), resulting in a large number of wired conductors. The deployment of these new technologies requires the ability to guarantee optimal operating safety (reliability, maintainability, availability, security) in all circumstances. This requires the implementation of a monitoring system of the vehicle's state of health (detection, localization, fault identification and failure prognosis) and reconfiguration or adaptation procedures (reconfiguration of the control or of the objectives, fault tolerant control) in case of detected failure. A lot of work has been done to improve this reliability, but mainly to detect component faults such as sensors and actuators, little work has been done to detect and locate soft faults in cables/networks. These faults, due to cable wear, mechanical stress, excessive temperature or humidity, are nevertheless very present. They have no immediate effect because communication or energy transfer is maintained, but they can evolve into hard faults (short circuits or open circuits) which will impact the operation of these vehicles, and can lead to damage to the integrity of the vehicle and the safety of passengers.

Work has been carried out to address these issues of detection and localization of soft faults in wired networks as part of the DIACA project - Autonomous Predictive Maintenance of Wired Transport Systems, of the CPER ELSAT 2020 in the Nord Pas-de-Calais French region (OS 4: Dimensioning and performance of intelligent mobility vehicle functions). This work uses PLC technology (Power Line Communication) to transfer signals at specific frequencies that do not impact vehicle behavior. Health indicators (or residuals) are generated by comparing the transfer coefficients estimated online by the computers with the reference transfer coefficients. This work is conducted in the framework of Abdel Karim Abdel Karim's thesis (PhD contract University of Lille, started in October 2019), a multidisciplinary thesis co-directed by V. Cocquempot (Automatic - diagnosis) and V. Dégardin (Electronics - communication). Very interesting results, both theoretical and validated on a test bench, have been obtained and published (see list below).

The objective of the proposed thesis is to continue the work started in the framework of the thesis of Abdel Karim Abdel Karim.

Several works are envisaged:

- Study the sensitivity of the residuals and improve the decision procedure in disturbed environment (measurement noise in particular). Initial work has been done using different metrics to analyze the similarity between signals in the frequency domain. We have shown that weighting the residuals by a correlation index between signals greatly improves the sensitivity of the residuals, and consequently the decision.

- Estimate the severity of the fault, which will allow to follow the evolution of the fault and to predict the residual life of the cable (in a prognostic approach)

- Compare and study the complementarity between our monitoring approach based on the transmission coefficient and a more classical approach using the reflection coefficient (reflectometry approach). It is not a question here of opposing the two approaches but of combining them to improve the decision both for the detection and for the localization or the estimation of defects

- Detect and localize multiple faults, including cable faults in complex networks combining bus, star, ring topologies, ... but also component faults such as sensors.

- Reconfigure the network and the communication protocol when an incipient cable fault is detected/located, allowing to anticipate the effects of a possible open fault

- Implement the monitoring method on the autonomous electric vehicle Zoé of CRIStAL (PRETIL platform: Research platform on Robotics and Intelligent Transport of Lille - platform accredited by the University of Lille and the Equipex Robotex). The tests carried out on a test bench, and the first measurements carried out on the Zoé vehicle confirm the relevance of our network monitoring approach. These experimental validations must be continued and carried out on the vehicle in circulation.

These objectives can only be achieved by combining two approaches: a signal approach and a system approach. The two host laboratories CRIStAL and IEMN have respectively an expertise in one of these two approaches. We have shown in the framework of the co-supervision of the thesis of A. K Abdel Karim the interest of conducting this research in collaboration. The results obtained are recognized by both scientific communities as shown by the publications accepted or under evaluation.

This subject is part of several projects and structures in which CRIStAL and IEMN are involved:

- The CNRS Research Federation: FR TTM: Transport Terrestre Mobilités CNRS 3733,

- the CPER 2021-2027 RITMEA: Research and Innovation in Eco-responsible and Autonomous Transport and Mobility,

- The autonomous vehicle axis of the structuring equipment for research: TIRREX Technological Infrastructure for Robotics Research of Excellence, winner of the ESR / EquipEx+ call for expressions of interest,

- the CUMIN project: Campus à Mobilité Innovante et Neutre en carbone (Innovative and Carbon Neutral Mobility Campus), an interdisciplinary program of the University of Lille on electro-mobility

Articles published in the framework of Abdel Karim's thesis

1. Abdelkarim Abdelkarim, M.Amine Atoui, Virginie Degardin, Vincent Cocquempot. Fault Detection and Localization in Vehicular Embedded Network Using Power Line Communication. *International Conference on Systems and Control (ICSC21)*, Nov 2021, Caen, France.
2. Abdelkarim Abdelkarim, Mohamed Amine Atoui, Virginie Degardin, Vincent Cocquempot. Fault detection and localization in Y-shaped network through power line communication. *The conference on Control and Fault-Tolerant Systems (SysTol'21)*, Sep 2021, Saint-Raphaël, France.
3. Abdelkarim Abdelkarim, Virginie Degardin, Vincent Cocquempot, Mohamed Amine Atoui. Soft fault detection and localization in an unshielded twisted pair network using power line communication. *7th International Conference on Vehicle Technology and Intelligent Transport Systems (VEHITS)*, Apr 2021, Online, Portugal.
4. Abdelkarim Abdelkarim, Virginie Degardin, Mohamed Amine Atoui, Vincent Cocquempot. Using power line communication for fault detection and localization in star-shaped network, accepté à la conference IFAC Safeprocess 2022, June 2022, Cyprus.

Expected qualifications for the applicants and how to apply.

The applicant possesses good background in mathematics, control, network, decision theories.
He/she has completed or about to complete a Master or Engineering degree in the appropriate field.

Please send before April 15th, 2022 to Vincent.cocquempot@univ-lille.fr and virginie.degardin@univ-lille.fr :

Cover/motivation letter, detailed CV, Grades of Master studies (or Engineering degree), copy of the publications or research report by the applicant (if any).