PhD thesis – Program CSC 2022

Title: Bio-inspired model to control inclusive mobility for supply chain resilience

Context

Industry 4.0

Industry 4.0 corresponds to the era of digitalization, interconnection, ecology, sustainability and smartability to develop future autonomous and self-learning factories. Although frameworks for Industry 4.0 and particularly for supply chain 4.0 imply an increasing dependence on automation, the role of human factors remains an important issue for the design of adapted human-machine interfaces. These interfaces and the associated role of workers facing future technologies are identified through the labeling "Operator 4.0" by integrating innovative interaction and artificial intelligence based supports as cooperative or analytical ones (Romero et al, 2016; Ruppert et al., 2018). Staff of supply chain of the future will have to face new kinds of degraded situations due to sanitary and climatic conditions for instance. The design of future supply chain has to consider resilience abilities.

Resilience

Resilience relates to the ability of a system or a human to avoid any loss of auto control or self-control despite the occurrence of whatever disturbances. It is linked with different kinds of ability and criterion (Vanderhaegen, 2017 ; Enjalbert et al., 2020). On ecology or biology viewpoints, it relates to the survival of species when they undergo attacks or aggression. On psychology or medicine domains, it depends on individual ability to recover from a physical or psychological chock or traumatism. From an engineering point of view, it is the ability to manage any unstable system state whatever events by recovering it as quickly as possible. Other engineering approaches consider that a resilient system can prevent, absorb, recover or mitigate any disorder, can successfully control unprecedented situations, or can successfully self-organize interconnected system components to react to any breakdown. Finally, in a more general viewpoint, the resilience of isolated or interconnected systems relates to the acceptable control of their stability or instability by considering a single reference or several references of acceptability. A sustainably stable system state can be an obstacle to react efficiently to unknown disturbances due to hypovigilance for instance. On the other hand, the regular occurrence of unstable states can train the system to control this event, and to go back to a previous stable state, to discover new stable states or new strategies to accept and manage sustained instability. Resilience of supply chain applies such plasticity characteristics to control or recover unprecedented situations for ensuring the continuity of acceptable services (Ribeiro, Barbosa- Póvoa, 2018).

Inclusive mobility

Inclusive mobility is one possible solution for making systems more resilient. Indeed, it relates to the mobility of people or of goods without any discrimination and by considering social, ecological and economic impact (Vanderhaegen, 2019, 2021). Its application to supply chain concerns the control or the recovery of any breakdown of service flows that may affect the entire supply chain credibility. For example, consequences of climate changes or of pandemic situations as COVID-19 will affect more regularly these flows in different domains as drug delivery in pharmacies, food delivery in distribution centres, transport service offer in cities, etc. Economical efficiency of supply chain can then be assessed

by levels of benefits or of wastes, its environmental impact by greenhouse gas emissions or environment protection, and its social ones by the level of empowerment of people or by their commitment in defining a recovery solution

Bio-inspired models

Several models exist for designing resilient supply chain by considering such criteria to control or recover unprecedented situations (Enjalbert et al., 2020). Engineering approaches simulate traffic flow by making analogies with fluid or gas-kinetic characteristics. Naturalistic models aim at modelling the behaviours of species as ants or birds to avoid collision and maintain movement (Antoniou et al., 2009; Kammoun et al., 2011; Jabbarpour et al., 2014; Li, Huang, 2019). Human-machine approaches are automation-supported human based models or human-supported automation-based ones. They contribute to develop pedagogical and learning abilities in order to take benefits of human and technical assets.

PhD objectives

The PhD thesis consists in developing a bio-inspired model of inclusive mobility control for supply chain resilience to control or recover unprecedented degraded situations. The model will support the reconfiguration of a multi-modal mobility system in case of the occurrence of such situations that may affect supply chain services due to climate change or pandemic for instance.

The research work is divided into four steps:

- The first step of the project will aim to make a synthesis of existing bio-inspired approaches.
- The second step will study definitions and criteria about resilience and inclusive mobility for supply chain and industry 4.0.
- Regarding the outputs of these syntheses, the third step will propose a bio-inspired model to recover unprecedented situations in order to maintain inclusive mobility purpose of supply chain services by optimizing social, economic and ecological criteria.
- The last step will evaluate the proposal in terms of resilience of supply chain services by defining an experimental protocol with scenarios of supply chain service breakdown. Existing platforms as MissRail or InnoRail can be adapted to simulate transport services of people or of goods.

Program

The work program is planned for three years as follows (T0 : first month of the first year of the PhD):

- Phase 1 (T1-T6 - 6 months): Synthesis of a state-of-the-art on the scientific topics of the research subject: resilience, inclusive mobility, resilience assessment, supply chain, bio-inspired models

- Phase 2 (T4-T9 - 6 months): Choice and testing of appropriate bio-inspired model of inclusive mobility for supply chain and of economic, environmental and social criteria of impact assessment

- Phase 3 (T10-T27 - 18 months): Development of the dedicated model

- Phase 4 (T19-31 - 12 months): Tests and experimental validation in different human-machine environments of supply chain

- Phase 5 (T13-T36 - 24 months): valorisation of the research work with publications on international journals and conferences and with participations to workshops and seminars.

Rererences

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