Interdependency Analysis for Collaborative Robot Applications Through FRAM Analysis

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Highlights of Recent Work
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- This project takes interdependency relations in terms of observability, predictability, and directability (OPD), derived from Coactive Design Theory as the basic principles to assess human-robot interaction safety in collaborative robot (cobot) applications.
- The performance variability potential from OPD requirements will be assessed in a multi-scale modelling framework for human-robot with a Joint Cognitive Systems (JCS) unit of analysis.

1. SUMMARIZE NEW RESULTS

Although collaborative robots (cobot) applications are increasingly utilised to physically collaborate in real-time with human operators, current cobot safety mainly focuses on a techno-centric perspective (Guiochet, Machin, & Waeselynck, 2017) in terms of physical separation and managing the net result of kinetic energy in the cobot system. Human Factors (HF) research or its subcategory Cognitive Systems Engineering (CSE) are largely absent in cobot safety (Kadir, Broberg, & Conceição, 2019). To complement the current techno-centric approach, this project introduces a socio-technical safety and resilience analysis perspective for human-robot interaction by applying systemic safety analysis methods, with a specific focus on OPD requirements for JCS in relation to cobot operations. The scope of cobots in our project is wider than the typical industrial cobot definition and encompasses other robot operations, as long as they are defined by the potential for foreseeable or intentional physical contact between robots and humans, not necessarily restricted to system operators.

The project sets out a generic cobot safety framework that is based on a FRAM analysis of the work system and will follow the three first steps of a FRAM analysis (Hollnagel, 2012): (i) identification of functions in a given work system; (ii) identification of variability, and; (iii) aggregation of variability. The fourth and last step, being the management of variability will be omitted, but the results from the analysis will typically lead to a design reiteration of the work system, which has the same ultimate purpose of managing variability. FRAM has previously been applied to JCS analysis in which agents can be defined as any human or technical system actor or medium. (Adriaensen, Patriarca, Smoker, & Bergström, 2017)

The traditional FRAM model, based on the identification of functions will be supported by a number of additional function labels: (i) the functions will be allocated to the agents that perform the function in the work system, e.g. robot, operator, supervisor; (ii) thereafter, the functions that belong to the same functional cluster from a bottom-up grouping of clusters will be assigned to a number of JCS subunits, e.g. functions like ‘navigation’, ‘picking’, ‘releasing’, but also implicit functions like ‘separation behaviour interpretation’ or other functional implicit functional clusters that emerge from the FRAM analysis etc. Such subunits that consist of multiple individual functions will be considered as JCS agents.

The second and third step, being the identification and aggregation of variability in terms of assigning aspects and their resonance between functions will be mapped on a RAM matrix representation (Patriarca, Del Pinto, Di Gravio, & Costantino, 2018) of the traditional FRAM model. The RAM matrix will be designed in order to interpret the output variability from a multi-scale model, where both inter and intra-level resonance between agents on the one hand, and JCS subunits on the other hand can be assessed. The assessment will examine to which extent pre-defined rules or mechanisms correspond to the OPD principles in cobot systems as the essential interaction requirements to complement the physical safety aspect of human-robot separation and kinetic energy management. Observability can be defined as the capability of mutually predicting agent status; predictability as the system ability to rely on another agent’s actions while considering one’s own agent’s actions, and; directability as the ability to influence the behaviour of others as well as being influenced by others. Together these principles can be seen as the most essential interaction requirements that can be generically applied to any human-robot interaction, as the essence of joint activity is about interaction and negotiation, borrowed from Interdependency Analysis in Co-Active design (Johnson, Bradshaw, & Feltovich, 2018).

2. WHO WOULD BENEFIT FROM KNOWING ABOUT YOUR WORK

Developers, integrators and users of industrial, medical and other cobot applications will benefit directly from the published results. Additionally, other Joint Cognitive work Systems will benefit from the inter- and intra-agent analysis framework as the RAM representation can be tailored to other needs.

3. THE IMPACTS OR IMPLICATIONS OF THE RESULTS OR HOW THEY CAN BE UTILIZED

The results should push for a socio-technical complement in robot safety, which is currently governed by a techno-centric safety perspective. Developers, integrators and users will have the chance to learn about theoretical and practical implications in relation to systemic safety methods applied to the specific challenges of cobot design, cobot task analysis and workplace integration. An interdependency analysis has also been proposed to counter the substitution fallacy in functional allocation. Instead of substituting one agent for another, such as in the 'Men-are-better-at/Machines-are-better-at' (MABA-MABA) approach (Fitts, 1951), or comparing two different levels of automation through empirical evaluation, such as in the LoA approach (Parasuraman, Sheridan, & Wickens, 2000), interdependency should shape automation by taking into account the joint action potential (Johnson et al., 2018).

4. THE WIDER SCOPE OR RELEVANCE OF THE WORK

These activities were initially developed within a PhD research project but are expected to contribute to literature via publications about the generic framework and applied to case studies in the domain of industrial and medical collaborative robots.

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