

Simulation-Based Validation of Safe Human-Robot-Collaboration

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Abstract : Human-machine-collaboration defines a direct interaction between humans and machines to fulfil specific tasks. Those so-called collaborative machines are used without fencing and interact with humans in predefined workspaces. Even though, human-machine-collaboration enables a flexible adaption to variable degrees of freedom, industrial applications are rarely found. The reasons for this are not technical progress but rather limitations in planning processes ensuring safety for operators. Until now, humans and machines were mainly considered separately in the planning process, focusing on ergonomics and system performance respectively. Within human-machine-collaboration, those aspects must not be seen in isolation from each other but rather need to be analysed in interaction. Furthermore, a simulation model is needed that can validate the system performance and ensure the safety for the operator at any given time. Following on from this, a holistic simulation model is presented, enabling a simulative representation of collaborative tasks - including both, humans and machines. The presented model does not only include a geometry and a motion model of interacting humans and machines but also a numerical behaviour model of humans as well as a Boole's probabilistic sensor model. With this, error scenarios can be simulated by validating system behaviour in unplanned situations. As these models can be defined on the basis of Failure Mode and Effects Analysis as well as probabilities of errors, the implementation in a collaborative model is discussed and evaluated regarding limitations and simulation times. The functionality of the model is shown on industrial applications by comparing simulation results with video data. The analysis shows the impact of considering human factors in the planning process in contrast to only meeting system performance. In this sense, an optimisation function is presented that meets the trade-off between human and machine factors and aids in a successful and safe realisation of collaborative scenarios.

Keywords : human-machine-system, human-robot-collaboration, safety, simulation

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