Ph.D. in Information Technology
Thesis Defense

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Livia LESTINGI – XXXV Cycle

MODEL-DRIVEN DEVELOPMENT OF FORMALLY VERIFIED HUMAN-ROBOT INTERACTIONS

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Abstract:

In a near-future society, robots will no longer be confined to industrial environments but are bound to enter the service sector, where they will interact with a wide variety of people with very different needs.
Efficiency-related factors drive existing software development techniques, but this will no longer suit everyday interactions.
Incorporating factors related to the human behavioral and physiological state into the development process will become essential.

This research addresses these issues by proposing a model-driven approach to design, formally verify, and adjust scenarios where human-robot interaction is a primary element. Target users of the approach are professionals in charge of designing the robotic application but lacking solid technical background, which motivates the high degree of automation of the whole development toolchain.

The entry point to the approach is a user-friendly Domain-Specific Language to specify the scenario and the robotic mission under analysis.
A formal model of the scenario based on Stochastic Hybrid Automata is then automatically generated.
The approach captures a set of physiological traits---including physical fatigue---and behavioral traits capturing the possibility of the human making haphazard decisions.
The formal model is subject to Statistical Model Checking to estimate the most likely mission's outcome.

Subsequently, the approach features a deployment framework to deploy the scenario in a real setting or simulate it in a virtual environment for further investigation.
The configured model of the interactive scenario is transformed into an executable version to ensure that properties formally verified at design time also hold at runtime.

Data collected during deployment are exploited to infer an updated model of human behavior and adjust the robotic mission accordingly.
To this end, we introduce an automata learning algorithm called \lsha{} specifically targeting Stochastic Hybrid Automata.

The learned model of human behavior is plugged into the Stochastic Hybrid Automata network to perform a new round of verification and revise the mission's design, if necessary.

All phases of the model-driven approach---the design-time analysis, deployment, and automata learning---have been empirically validated on realistic case studies inspired by healthcare scenarios. The formal foundation is a key component in guaranteeing the dependability of the resulting software components. At the same time, the high-level abstraction level and the presence of a learning procedure promote the framework's flexibility.

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