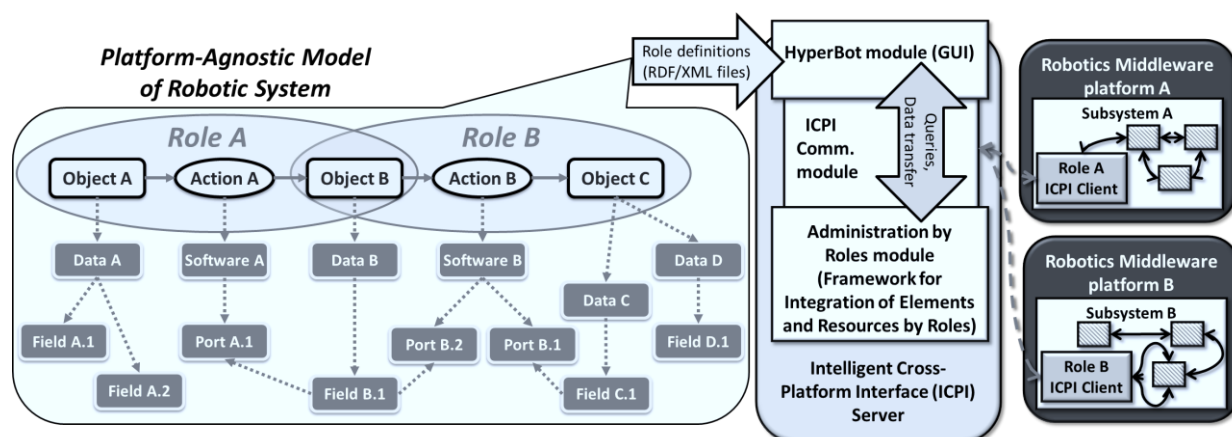


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Title: Normalizing Abstractions of Middleware-Based Software to Compose Highly-Integrated Robotic Systems

Abstract: The use of robotics middleware platforms has become a widely-accepted practice in the development of software for service robots. However, this platform-driven approach produces a discrepancy of abstractions across platforms, hindering the composition and usage of highly-integrated systems. We identified that to compose such systems, it is necessary to switch to a model-driven approach that can normalize the abstractions from the existing platforms at runtime, improving the usability in the administration of the composed system. In this thesis, we propose a framework that sets the paradigm of “Roles” to define a novel way of creating and reasoning a system model by normalizing abstractions of middleware-based software, producing a platform-agnostic model of a robotic system. Additionally, the concepts of the framework were used to conceptualize a systematization method for resource requests in highly-integrated systems, and implemented as an IDE. We verified and validated the functionality of the implemented framework concepts through proofs of concept, and tested the usability (by benchmarking) through case-studies with subjects using real and simulated service robots. The results showed improved usability, and demonstrated overall advantage of using our model-driven approach.



Chapter 1 - Introduction: Background on related projects and research’s terminology are discussed in this chapter. Service robots are complex systems, where their required capabilities are usually developed independently in the respective research fields. For this, the use of robotics middleware platforms has become a widely-accepted practice in the development of software for service robots. Nevertheless, for highly-integrated systems, the discrepancy of abstractions among platforms is a problem that hinders the composition and usage of such systems, affecting usability. Therefore, there is active research on methods for normalization of abstractions and rapid system prototyping tools to solve this problem.

Chapter 2 - Proposal of the Framework for Integration of Elements and Resources by Roles: A survey on different ways of normalizing abstractions in robotics software is introduced. We identified that to increase usability of the employed software packages and tools in middleware, the normalization must be done at runtime through a

generalized model. We proposed a framework that sets a novel method for normalizing abstractions of middleware-based software that produces platform-agnostic models, as well as a method for reasoning such models through a framework that sets the paradigm of “Roles”. We named it as the Framework for Integration of Elements and Resources by Roles (FIERRo). A “Role” is a way of grouping a set of Elements that compose an activity; each Element represents a specific type of abstraction in a normalized way, and can become a Resource when it can be resolved, accessed and retrieved. Elements can be mapped to one or various other synonym elements in the system representing resources. Then, Roles are used to create platform-agnostic models of robotic systems. With such models, a system can be instantiated, and each Resource can be resolved by navigating through the proposed topology for a Role using propositional calculus (Administration by Roles method), therefore being able to locate software, data and services. Roles can be serialized using the RDF and reasoned through a SPARQL engine.

Chapter 3 - Implementation into an Interface for Accessing Multiple Middleware Platforms: The implementation of the proposed Framework for Integration of Elements and Resources by Roles (FIERRo) in the Intelligent Cross-Platform Interface (ICPI) is described in this chapter. The ICPI is composed of the ICPI-Server and the ICPI-Clients. An ICPI-Client can represent a Role in the system, taking care of the Elements grouped in that Role. The ICPI-Server implements the Administration by Roles method into a module. The server can receive queries to issue different administration tasks in the system through a graphic user interface (GUI).

Chapter 4 - Graphical User Interface for Administering Roles: In this chapter, the implementation of a GUI for the ICPI-Server, named the Hyper-High Level Interface for Service Robots (HyperBot) is described. The “System Developer Screen” is the main screen, which is used to compose, visualize and operate each element in the highly-integrated system through the platform-agnostic models based on Roles. Proofs of concept were performed to compose and use a highly-integrated system through HyperBot, confirming its functionality. Moreover, the concept of FIERRo and HyperBot was validated and verified through a usability test. In overall, the results have shown that our approach (use of FIERRo, ICPI and HyperBot) has a superior usability when compared against a benchmark approach (use of tools already available in middleware platforms and operating systems).

Chapter 5 - Integrated Development Environment for the Rapid Prototyping of Applications: An integrated development environment (IDE) based on the HyperBot interface is introduced, where rapid prototypes of robotics applications can be created through the implementation of a proposed method for the systematization of resource requests in platform-agnostic system models. The systematization method and its implementation on the IDE were verified through proofs of concept and usability tests.

Chapter 6 - Conclusion: A summary from the overall contribution of this research work is given, as well as final comments and discussion on the future work. This chapter also gives an insight in the possible applications of the proposed concepts that can improve the current technologies for service robots, especially when rapid application prototyping is required to develop a project.