Process Model for the Development of Semi-Autonomous Service Robots

From the Faculty of Physics and Electrical Engineering
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by

Dipl.-Ing. Oliver Prenzel

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'The character of software development sometimes seems closer to mathematics and art than it does to most other engineering disciplines. Software is inherently an intangible, intellectual development medium. No laws of physics govern its behavior; it is both marvelously and dangerously malleable. For this reason, it is critical that mature disciplines and processes be applied when working with software.' [Ahern et al., 2003]

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Bremen, July 2009 *Oliver Prenzel*

Abstract

The creation of a universal service robot for daily use in the home or working environment is an ambitious objective of ongoing research and engineering efforts. Considering today's state-of-the-art, service robots cannot be expected to be able to act fully autonomously and intelligently in unstructured environments within the middle-term future. This is due to the generally high complexity of meaningful task executions, with still unsolved problems in task and motion planning as well as sufficient scene understanding. To encounter these problems, an approach has been developed that reduces the technical complexity with the help of two development paradigms: The task knowledge for a certain scenario is pre-structured, and the robotic system executes its tasks semi-autonomously, i.e. involves the user into task execution. By means of simulations in representative sample scenarios it has been demonstrated that the real time suitability of task planning based on this approach can be guaranteed.

Within this work, the fundamental concepts are now integrated into a complete process model for the development of semi-autonomous service robots. The process model gives a clear guidance for a scenario- and behavior-driven development of a service robotic system. The process contains four levels and starts with analysis steps that lead to well-defined outputs for guiding subsequent steps. Due to the paradigm of pre-structuring and offline verification of task knowledge, a lot of effort is required for the introduction of new task knowledge and the enhancement of existing one. The complexity of the specification procedure is encountered with the development of special tools that provide a user-friendly input of task knowledge and fully integrate into the overall concept. The process of task knowledge specification leads to the definition of software interfaces that encapsulate functionality of a robotic system. Besides defining the interfaces, the process model guides the development process on the functional level and also supports the final testing on component and scenario level. As it will be argued, the application of a process model cannot be successful without support of suitable tools. Besides the tools that especially target at task knowledge specification methods developed throughout this work, the complete process model makes use of a state-of-the-art CASE tool for the development of software systems based on executable UML-models.

The applicability of the proposed method is validated with the help of different scenarios from the AMaRob project. The AMaRob research project, currently running at the Institute of Automation (IAT), at the University of Bremen, targets at the development of rehabilitation robots for severely impaired persons and the robot's evaluation in domestic and professional environments. Three representative scenarios that are realized with the help of the process model cover the preparation of a meal, the functionality control of workpieces in a rehabilitation workshop as well as various service tasks at a library service counter.

Kurzfassung

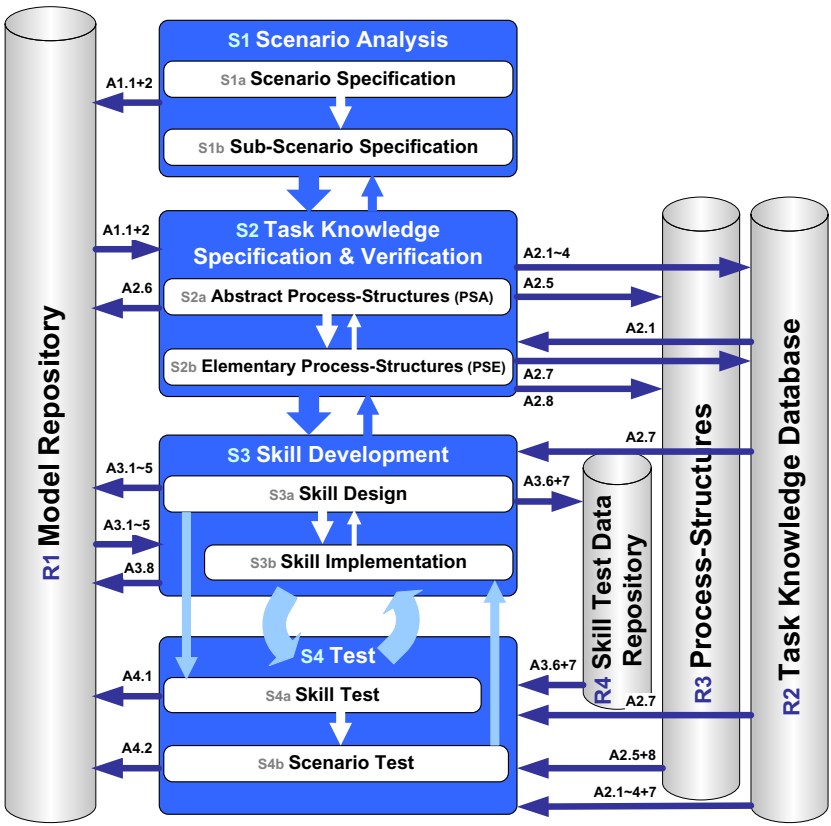
Der universelle Serviceroboter für den alltäglichen Gebrauch im häuslichen oder beruflichen Bereich ist als ambitioniertes Ziel laufender Forschung und Entwicklung zu sehen. Nach aktuellem Stand der Technik ist es in naher Zukunft nicht zu erwarten, dass Serviceroboter voll autonom und intelligent in unstrukturierten Umgebungen agieren. Die Gründe hierfür liegen in der hohen Komplexität nutzbringender Aufgabenbearbeitung, was wiederum auf aktuell immer noch ungelöste Probleme in der Aufgaben- und Bewegungsplanung sowie auf unzureichendes Szenenverständnis zurückzuführen ist. Aufgrund dieser Problematik wurde ein Ansatz entwickelt, welcher die technische Komplexität mit Hilfe von zwei Entwicklungsparadigmen reduziert: Das Aufgabenwissen für ein bestimmmtes Szenario wird vorstrukturiert und das Robotersystem bearbeitet eine Aufgabe teilautonom, d.h. der Benutzer wird in die Aufgabenbearbeitung mit einbezogen. Mit Hilfe von Simulationen repräsentativer Beispielszenarien konnte gezeigt werden, dass mit diesem Ansatz die Planung einer Aufgabe in Echtzeit garantiert werden kann.

Im Rahmen dieser Arbeit werden diese grundlegenden Konzepte in ein komplettes Vorgehensmodell zur szenario- und verhaltensbasierten Entwicklung teilautonomer Serviceroboter integriert. Das Vorgehensmodell ist vierstufig und beginnt mit Analyseschritten, deren klar definierte Ergebnisse alle nachfolgenden Schritte steuern. Die Anwendung der Vorstrukturierung und Offline-Verifikation von Aufgabenwissen geht mit einem hohen Aufwand bei der Einführung von neuem oder der Erweiterung bestehenden Aufgabenwissens einher. Die Komplexität des Spezifikationsvorgangs wird mit Hilfe speziell entwickelter Werkzeuge bewältigt, welche eine benutzerfreundliche Eingabe von Aufgabenwissen ermöglichen und sich zudem nahtlos in das Gesamtkonzept integrieren. Die Spezifikation von Aufgabenwissen führt zur Definition von Software-Schnittstellen, welche die Funktionalität des Robotersystems kapseln. Neben der Schnittstellendefinition steuert das Vorgehensmodell den Entwicklungsprozess auf funktionaler Ebene und organisiert schließlich das Testen von Komponenten und Szenarien. Die erfolgreiche Anwendung eines Vorgehensmodells hängt von der Verwendung geeigneter Werkzeuge ab. Neben den Werkzeugen, welche speziell auf die im Rahmen dieser Arbeit entwickelten Methoden zur Spezifikation von Aufgabenwissen abzielen, macht das Vorgehensmodell von einem modernen CASE-Werkzeug Gebrauch, welches die Entwicklung komplexer Software-Systeme auf Grundlage ausführbarer UML-Modelle ermöglicht.

Die Anwendbarkeit der entwickelten Methoden wird im Rahmen von Szenarien aus dem AMaRob-Projekt validiert. Das AMaRob-Forschungsprojekt, welches aktuell am Institut für Automatisierungstechnik an der Universität Bremen läuft, hat die Entwicklung von Rehabilitationsrobotern für schwer beeinträchtigte Personen sowie die Evaluierung der Robotersysteme im häuslichen und beruflichen Umfeld zum Ziel. Drei repräsentative Szenarien, die mit Hilfe des Vorgehensmodells entwickelt werden, beinhalten die Zubereitung einer Mahlzeit, Funktionskontrollen von Werkstücken sowie verschiedene Aufgaben am Servicetresen einer Bücherei.

The "FRIEND::Process"

In the following an overview is given of the process model *FRIEND::Process*, which has been developed in this work. It serves as a graphical contents description and is referenced throughout the work. The diagram contains process steps (S), process repositories (R) and development artifacts (A). A compact summary of the FRIEND::Process can be found in Appendix A, page 205. An online version of the summary is included in the IAT Wiki: [Prenzel, 2009].



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