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ABSCHLUSSBERICHT

MASSIVE

Modellsynthese aus sequenzbasierten Verhaltensanforderungen zur modellbasierten Testfallgenerierung

MASSIVE

Vorhaben Nr. 19536 BG

Modellsynthese aus sequenzbasierten Verhaltensanforderungen zur modellbasierten Testfallgenerierung

Abschlussbericht

Kurzfassung:

Die zunehmende Komplexität und Vernetzung von Produkten als auch Anlagen in der Produktion, die meist auf verteilten Systemen basieren, stellen neue Herausforderungen für Hersteller und Anwender industrieller Automatisierungstechnik dar. Die dadurch steigende Komplexität von Software verbunden mit hohen Qualitätsanforderungen erfordern einen umfassenden und möglichst vollständigen Test, bevor ein System eingesetzt beziehungsweise ausgeliefert werden kann.

Damit einhergehend werden neue Methoden und Konzepte zur Testerstellung, Testhandhabung und hochautomatisierten Testdurchführung sowie Testauswertung benötigt, um den stetig zunehmenden Testaufwand technologisch als auch wirtschaftlich beherrschen zu können. Der Einsatz von Methoden des modellbasierten Tests wie der Testgenerierung reduzieren den Aufwand und damit auch die Kosten für den Test signifikant, wobei gleichzeitig häufig eine Verbesserung der Testabdeckung und damit der Güte der Qualitätssicherung erreicht werden kann. Trotz der potenziellen Vorteile finden modellbasierte Testprozesse in der industriellen Praxis bisher jedoch nur eine geringe Verbreitung. Hier stellen in erster Linie die hohen initialen Anforderungen an Personal und Infrastruktur eine große Einstiegshürde dar, so zum Beispiel bei der Erstellung der notwendigen Modelle, welche für die Anwendung modellbasierter Testprozesse benötigt werden.

Ziel des Vorhabens MASSIVE ist die Erforschung einer Methodik und die prototypische Umsetzung eines Algorithmus zur Modellsynthese aus sequenzbasierten Anforderungen zu einem Spezifikationsmodell für die Verwendung zur modellbasierten Testfallgenerierung im Bereich der Testautomatisierung. Der Ansatz soll die Synthese eines komplexen Spezifikationsmodells aus mehreren Anforderungsmodellen mit jeweils geringerer Teilkomplexität ermöglichen und hierdurch den Aufwand bei der Modellierung reduzieren. Die zunehmende Komplexität und Vernetzung von Produkten als auch Anlagen in der Produktion, die meist auf verteilten Systemen basieren, stellen neue Herausforderungen für Hersteller und Anwender industrieller Automatisierungstechnik dar. Die dadurch steigende Komplexität von Software verbunden mit hohen Qualitätsanforderungen erfordern einen umfassenden und möglichst vollständigen Test, bevor ein System eingesetzt beziehungsweise ausgeliefert werden kann.

Das Ziel des Forschungsvorhabens ist erreicht worden.

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Weitere Berichte zum Forschungsvorhaben:	-

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1 Executive Summary

Manufacturers of mechatronic products are increasingly using complex software to meet their customers' growing demands for functionality, degree of automation and safety. Mechatronic products are characterized by close integration of the mechanical, electronic and software sub-areas, thus achieving valuable synergy effects. Especially for small and medium sized enterprises (SME), the mechatronic development process is often unsystematic and especially the requirements of increasingly complex software are considered too late during development. The increasing complexity of the overall system architecture in connection with high quality demands requires extensive tests before a device or software can be deployed. Only by applying methods of test automation, these requirements can be realized with manageable effort. In addition to test execution, test automation also requires the generation and management of test cases. As in other areas of system development, model-based methods have been established in this area in research and some first companies, so that test cases can be derived automatically from a model. It has generally been proven that model-based test approaches drastically reduce effort and costs. However, model-based testing is rarely used in industry yet, since infrastructure and personnel are not yet able to use such approaches due to the high initial effort. The MASSIVE project aims to reduce the effort for applying model-based test processes to industrial testing problems drastically.

In the MASSIVE project, the demanded machine behavior is modelled in a consistent way by formalizing the behavioral requirements of a mechatronic product in the form of UML sequence diagrams as a common language tool. Subsequent automatic generation, prioritization and execution of test cases is used to validate the behavior of the real product. By means of a continuous prototypical toolchain and three representative demonstrators it will be shown how such a model-based test process can be implemented realistically.

The prototype toolchain developed in MASSIVE uses methods of model synthesis and model-based test generation to implement an automated test process. This is used to systematically and efficiently generate a test collection that contains suitable test cases for validating all system requirements. This approach is based on formalized behavioral requirements, which are modelled on the basis of UML sequence diagrams with the help of a specially developed requirement notation (Reider, 2018) and function as input for the model synthesis. The result of the model synthesis is a graph-based specification model that contains all relevant behavioral requirements and forms the basis for model-based test generation. The specification model is mapped via an extended Petri net and well-known methods of Petri mesh theory are applied to automatically generate test cases using suitable graph-based test goals (all paths, nodes, edges) (Krause, Testfallgenerierung aus modellbasierten Systemspezifikationen auf der Basis von Petrinetzentfaltungen, 2011). Depending on the complexity of the specification model and the selected test targets, test generation results in a test suite with a large number of test cases and subsequently a high test coverage with regard to the relevant behavioral requirements.

In order to use automated test case generation economically in an industrial environment, an effective concept for managing the enormous number of generated test cases under consideration of practically limited test resources is necessary. Based on interviews with industrial experts, common practices were identified (Land, Neumann, Ziegltrum, Li, & Vogel-Heuser, 2019) which are currently used by companies to compose test schedules. The identified influencing factors are transformed into a method as well as a set of mathematical metrics, which allows automation of the previously elusive manual or experience-based procedures for test prioritization and thus disseminate and preserve expert knowledge within the company. In addition to common metrics such as test coverage or effort, new metrics are also introduced, which e.g. ensure the variance of the test selection and thus prevent operational blindness. By integrating fuzzy metrics, a balanced mix of different types of tests, which is often desired in practice, can be automatically replicated.

The execution of the generated test cases is realized using an approach that provides a protocol-independent interface for connecting the test tool to the System Under Test (SUT) as

hardware or software. Since the landscape of available protocols is very heterogeneous, especially in industrial automation, a generalized agent for connecting the test suite is required. For this purpose, a generalized test adapter was developed. This provides the test system with a uniform interface that abstracts the communication structure from the test system. With the help of different communication protocols like OPCUA or Modbus, the test communication to and from the SUT is realized. For the SUT, the test scenario therefore does not differ from integration into a real environment. The approach for automated test execution is presented and its prototypical implementation and application shown in the demonstrators.

In the context of complex mechatronic systems, tests can only be carried out economically and completely automatically within narrow limits. Necessary sensor and actuator technology for the execution and evaluation of the tests would be superfluous for the later productive operation and must therefore be replaced in the context of the tests by inclusion of test personnel. However, to ensure that the necessary manual test steps can be taken into account throughout the entire workflow, the test personnel must be seamlessly integrated into common model-based test approaches during model creation. To this end, a possible solution for integrating human-machine interaction into requirements modeling, its use for test prioritization and guided semi-automated test execution was developed and presented. After the (semi-) automatic execution and evaluation of the tests, their results are fed back into a central database in order to be taken into account for the prioritization of future test runs by means of further metrics.

All concepts presented were successfully evaluated using three demonstrators - an industrial actuator, a PLC program for a robot cell and a complex automated production plant on a laboratory scale.

The main objective of the MASSIVE project was to develop a sustainable and practical framework consisting of

- conceptual elaborations,
- practical guidelines,
- exemplary implementations

for the model synthesis from sequence-based behavioral requirements for model-based test case generation for complex systems. All aspects of the test process should be considered - from test creation on the basis of existing requirement specifications to test evaluation, prioritization and test execution as automatically as possible. If possible, existing standards for the respective context should be applied in order to enable a sustainable introduction of the project results into practice. By closely following existing standards, it should also be possible to transfer the framework to different fields of application. Using practical examples, the project results should be evaluated with regard to their correctness and applicability and published accordingly.

The aim of the MASSIVE project is to investigate a methodology and an algorithm for model synthesis from sequence-based requirements to a specification model for use in model-based test case generation in the field of test automation. The generated test cases are managed, evaluated and prioritized for semi-automated test execution by an innovative management concept. The intended results of the research project will mean a concrete increase in performance and competitive advantages for SMEs in the manufacturing and application sector. They will enable a significant improvement of the internal testing processes and will also enable extensions of the portfolios for test service providers.

The results obtained in MASSIVE are a major milestone on the way to an efficient test process for distributed, complex systems. They combine current research results with practical requirements and represent a collection of methods and prototypical implementations required for all activities of a test process in this context.

The results for the

- formalization of requirements (AP 2),

- model synthesis based on this (AP 3)
- test generation (AP4)
- test prioritization (AP5)
- automatic test execution (AP 6)

should be emphasized.

For the formalization of requirements, enriched sequence diagrams were chosen. Initial presentations of these project results showed that this was a good choice. Sequence diagrams are easy to understand and are used by developers as well as requirements engineers and test engineers. The resulting model synthesis now combines requirements analysis with modern methods for model-based test generation. The step of model creation with the purpose of test generation, which in practice is perceived as the biggest hurdle, is no longer necessary or is greatly simplified. These results promise a good positioning of the applicant for the acquisition of future projects in this field of work. These will also be necessary in order to make the methods for formalizing requirements and the model generation based on them even more practical, so that they will have an industrial release that will then give the applicant better chances on the highly competitive market in industrially relevant research.

With the specification and implementation of the test system for testing distributed, complex systems, the applicant has a framework at his disposal that allows the provision of domain-specific test systems with this application context. Also with these results it showed up that a large industrial relevance can be expected, since the trend goes ever more to the conversion of complex systems in the different application domains. The testing of such systems or system networks can be significantly simplified with the results from AP 6.

The results of the work package for model transformation for test case generation (AP 4) represented an extension of existing approaches. These topics are very complex and require further fundamental research in order to arrive at truly practical solutions.

The work in the other work packages served for the requirements analysis (AP 1), for the test management and selection (AP 5), for the exemplary implementation of the developed methods (AP 7) and for the evaluation and documentation of the MASSIVE results (AP 8 and AP 9). Overall, the results from MASSIVE are seen as a success, promising a significant improvement in the applicant's market position in the highly competitive applied research market.

An essential goal of this project is the usability and further development of the project results by the economy. With the reference implementation available at the end of the project and the methods developed, companies should be able to develop appropriate model synthesis and testing tools. In the course of project, companies could define specific requirements in each processing phase and thus had a say in the course of the project. This ensured that the results of the project find a broad acceptance and are integrated into the processes of the companies.

From the start of the project, the project committee is at the center of all activities: from requirements analysis to evaluation. In addition, they are in the role of the user and decide on the achievement of milestones and thus ensure a control of success. During the project, the results of the project were published in relevant journals and international conferences. In addition, the main results were presented in workshops and industry working groups towards the end of the project. The use cases evaluated during the project ensure an efficient and sustainable transfer of results. The results are also used in the teaching and training of the chairs and thus ensure that the results are transferred to academic teaching and further training of employees of interested companies.

Volltext:

Der Volltext des Abschlussberichts kann auf Anfrage hin herausgegeben werden. Bitte richten Sie Ihre Anfrage an:

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