

MAP-I: Doctoral Program in Informatics

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Proposal of a Curriculum Unit in Computing Paradigms

Software Testing

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Abstract: This document describes a Ph.D. level course, corresponding to a curriculum unit credited with 5 ECTS. It corresponds to a joint UPorto-UMinho proposal for OPTI (option in technologies) in the joint MAP-I doctoral program in Informatics. It is presented the programmatic component, the lecturing team, and the plans for the coordination with curriculum units in other PhD programs.

A. Programmatic Component

1. Theme, Justification and Context

Motivation

Software is increasingly present in our daily life. The software controls 80% of the functions of military aircraft, motor controls, TVs, mobile phones, etc., and it moves daily one billion dollars in the financial market, and is crucial for several businesses. Thus, the quality of software is becoming increasingly important. But assuring the quality of increasingly complex software systems is a challenging task. Failures in software are all too common and have a huge economic impact. According to NSF, the economic impact of inadequate software testing is estimated to represent 0.6% of the USA's GNP.

In the software industry, software testing typically consumes 30% to 50% of the development effort and schedule. Yet, the quality of delivered software products is not satisfactory. Considering the typical defect density of 1 to 7 defects/KLOC in delivered software products, typically with millions of lines of code, leads to a number of defects in delivered products in the order of thousands of defects. Hence, it is of upmost importance to improve testing efficiency and effectiveness, to reduce testing costs and improve product quality, namely through test automation.

Software testing is recognized as a major knowledge area or subject of software engineering, both by the IEEE's Guide to the Software Engineering Body of Knowledge (SWEBOK) and the ACM Computing Classification System.

2. Objectives and Learning Outcomes

This course aims to cover, both from the foundational and the methodological point of view, the concepts and techniques for Software Testing.

The course is not intended as an introductory survey on Software Testing, but as an opportunity of exposing students to cutting-edge research topics in this area, although presented in a coherent and integrated way. It is placed at a similar level and covers overlapping material with advanced modules in doctoral programs at leading academic institutions.

Upon successful completion of this curricular unit, students should be able:

- to recognize and explain the economic and social importance of software quality in general, and testing in particular;
- to understand the benefits and challenges of automated software testing techniques, such as mode-based testing or randomized testing;
- to understand the benefits and limitations of automated software test generation techniques;
- to identify test related measures (efficiency, effectiveness, coverage, rho, etc.);
- to understand the principles and techniques for test suite selection, minimization and prioritization.

3. Course Contents

Our society is increasingly dependent on the correct functioning of software systems, so the software industry should strive to deliver essentially defect free software in a cost-effective way, by using more effective and efficient defect detection and prevention techniques than are in common use today. The goal of this unit is to cover some of the most promising techniques in that direction, namely concerning software testing. Testing is the main defect detection technique in software industry. Manual testing is infeasible because of the ever-growing size and complexity of software systems, so the main focus in this course will be placed in the study of test automation techniques, notably automatic test generation.

The course is organized in two units:

3.1 Software testing fundamentals

This unit will review basic concepts related to testing, namely:

- Test process;
- Test levels and test types;
- Test coverage analysis and code instrumentation;
- Advanced unit testing techniques;
- Test suite minimization and prioritization for regression testing;
- Test management;
- Metrics for assessing test quality.

3.2 Automated software testing

This is the core unit of the course, focusing on the principles and techniques for automated software testing. A key topic to be addressed in this unit is model-based testing, namely the usage of formal specification languages to build models of software to serve as oracles and model finding techniques to automatically generate test cases.

More specifically, this unit will cover the following topics:

- Survey of automated testing techniques;
- Survey of model-based testing techniques (from patterns, algebraic specifications, state-based specifications, scenario-based specifications, etc.);
- Automatic GUI testing;
- Test case generation: theory, techniques and tools;
- Specifying formal models of software with Alloy to support model-based testing;
- Using model finders to automate test generation;
- Testing in IoT systems.

4. Teaching Methods and Student Assessment

Studies show the need to consider software testing as a multidisciplinary activity that requires systematization. This course will allow:

- learning the fundamental concepts and principles of software testing;
- knowing and understanding the solutions and proven practices to improve software testing through exploration of examples and case studies;
- applying the knowledge gained by using and adapting known solutions for a particular problem in an individual project.

No textbook adequately covers the course's range of topics, so a diversity of bibliographic elements (books, journals and conference proceedings) will be used.

Classes

The class meetings are meant to be conversational, and we encourage students to ask questions and make comments. Consequently, the discussion may follow tangents to the prepared lecture, but they should be fruitful, informative, and thought provoking. These classes are conducted by all the elements of the lecturing team.

Panels and talks

Two panels or talks will be organized to complement the topics covered by the formal classes. These panels or talks will involve both the lecturing team and possibly faculty members that are not formally associated with this UC.

Readings

Each week, the students must read papers or some few supplemental materials provided, related to the topics discussed in class. All reading assignments come from journals and conference proceedings. This exposes many students to extensive readings from the research literature for the first time. To help them with their reading, we require them to write a brief summary for each paper, and submit it electronically before the next class. We also ask them to submit a list of questions about the readings, which we try to work into the lecture if possible. Whenever applicable, students will also be encouraged to experiment with the technologies mentioned in the reading materials. During the last few weeks of the course, we no longer require reading summaries, to give students more time to focus on the project.

Individual research project

Whilst the goal of the readings is to develop a critical but shallow view over a broad range of topics addressed in classes, the goal of the individual research project is to develop a more in depth understanding on a software testing research topic, matching as much as possible each student interests, as well as the lecturers' areas of expertise. Projects are designed to combine a state of the art analyses with an experimental assessment. Grading of individual research projects is based on an oral presentation (for a more methodological project) or demonstration (for a more technological project), and a final written report. No two students can work on the same project. A few weeks into the course, descriptions of possible projects are handed out to students, who are also encouraged to propose projects of their own. Once students complete their project, they must demonstrate it, make an oral presentation, and submit a final written report.

5. Basic Bibliographic References

- Ilene Burnstein. *Practical software testing*, Springer, 2003.
- Aditya P. Mathur. *Foundations of software testing*, Pearson Education India, 2008.
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- R. M. Poston. *Automating Specification-based Software Testing*, IEEE Press, 1996.
- Software Verification and Analysis: An Integrated, Hands-On Approach, by Janusz Laski and William Stanley (Nov 5, 2010).
- Christof Ebert, Reiner Dumke. *Software Measurement: Establish - Extract - Evaluate – Execute*. Springer-Verlag, 2007.
- Daniel Jackson. *Software Abstractions – Logic, Language, and Analysis (revised edition)*. MIT Press, 2011.
- Andreas Zeller. *Why Programs Fail: A Guide to Systematic Debugging*. Elsevier, 2009.

B. Lecturing Team

1. Team Presentation

This course is supported by a team involving researchers from the University of Porto (Ana Paiva and João Pascoal Faria) and the University of Minho (Alcino Cunha).

All team members are working, and have worked actively in the past few years, on topics that are directly related to the subjects covered by this course, as detailed below.

2. Coordinator

The coordinator of the unit is Ana Paiva.

3. Short Presentation of Team Members

In the sequel we introduce a brief presentation of each team member, which includes, for each of them, up to 5 key publications related to the scientific area in which this course is proposed. All CVs are supplied in separate PDF documents.

Ana Paiva is assistant Professor at the Informatics Engineering Department of the Faculty of Engineering of University of Porto (FEUP) where she works since 1999. She teaches subjects like Software Testing, Formal Methods and Software Engineering, among others. She belongs to the group on Software Engineering (softeng.fe.up.pt) which gathers researchers and post graduate students with common interests in software engineering. She has a PhD in Electrical and Computer Engineering from FEUP with a thesis titled "Automated Specification Based Testing of Graphical User Interfaces". Her expertise is on the implementation and automation of the model based testing process. She has been developing research work in collaboration with Foundation of Software Engineering research group within Microsoft Research where she had the opportunity to extend Microsoft's model-based testing tool, Spec Explorer, for GUI testing. She was a member of the CYTED network on software verification and validation (REVVIS), she is vice-president of the PSTQB (Portuguese Software Testing Qualification Board) board (www.pstqb.pt), member of the Council of the Department of Informatics Engineering, and member of the Council of Representatives of FEUP.

Key Publications:

- Pattern-based GUI testing: Bridging the gap between design and quality assurance in Journal of Software: Testing, Verification and Reliability (STVR), Rodrigo M.L.M. Moreira, Ana C.R. Paiva, Miguel Nabuco, Atif Memon, 2 March 2017, DOI: 10.1002/stvr.1629.
- Multidimensional test coverage analysis: PARADIGM-COV tool in Cluster Computing Journal, Ana C.R. Paiva, Liliana Vilela, 16 January 2017, DOI: 10.1007/s10586-017-0728-4.
- Faria, J. P., & Paiva, A. C. R. (2014). A Toolset for Conformance Testing against UML Sequence Diagrams based on Event-Driven Colored Petri Nets. International Journal on Software Tools for Technology Transfer, December 2014, 1-20. doi: 10.1007/s10009-014-0354-x
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- Moreira, R. M., Paiva, A. C., & Memon, A. (2013). A pattern-based approach for GUI modeling and testing. IEEE 24th International Symposium on Software Reliability Engineering (ISSRE), (pp. 288-297). doi:10.1109/ISSRE.2013.6698881

João Pascoal de Faria is associate professor at the Department of Informatics Engineering of Faculty of Engineering of University of Porto (FEUP) and researcher at INESC TEC. He is the president of the Sectorial Commission for the Quality in Information and Communication Technologies (CS/03) in the scope of the

Portuguese Quality Institute (IPQ). In the past, he also worked with several software companies (Novabase, Sidereus, and Medidata), and was co-founder of two other (Qualisoft and Strongstep). He has more than 20 years of experience in teaching, research and consultancy in several software engineering areas. He is the main author of a rapid application development tool (SAGA), based on domain specific languages, that recently completed 25 years of continuous market presence and evolution. He is currently involved in research projects and supervisions in the areas of model-based testing, software process improvement, and model-driven development.

Key Publications:

- Lima, B., & Faria, J. P. (2015). Automated testing of distributed and heterogeneous systems based on UML sequence diagrams. *Communications in Computer and Information Science*, vol. 586, pp. 380-396, Springer Verlag, February 2016
- Raza, M., & Faria, J. P. (2015). A model for analyzing performance problems and root causes in the Personal Software Process. *Journal of Software: Evolution and Process*, vol. 28, Issue: 4, pp 254-271, John Wiley & Sons, April 2016 (first online: 19 November 2015). doi: 10.1002/smr.1759
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- Cruz, A. M. R., & Faria, J. P. (2010). A Metamodel-based Approach For Automatic User Interface Generation. In D. C. Petriu, N. Rouquette, & Ø. Haugen (Eds.), *Lecture Notes in Computer Science: Vol. 6394. MODELS'10 Proceedings of the 13th International Conference on Model Driven Engineering Languages and Systems* (pp. 256-270), Berlin, Germany: Springer-Verlag. doi:10.1007/978-3-642-16145-2_18 (best paper award)

Miguel Abrunhosa de Brito is assistant professor at the Department of Information Systems in the School of Engineering of University of Minho where he is the course director of the master in engineering and management of information systems. He teaches several course units, mainly in the areas of software verification and validation, software development and project management. He is a researcher of the Software-based Information Systems Engineering and Management Group (SEMAG) and also of the Engineering Process Maturity and Quality (EPMQ) where he is the responsible for the software testing parts of several research projects. During the spring semester of 2016, he was an invited researcher at the Institute for Software Research (ISR) / School of Computer Science (SCS) and visiting scholar in the master of software engineering at Carnegie Mellon, Pittsburgh, USA (Faculty Exchange Program of CMU Portugal). He is vice-president of the Sectorial Commission for the Quality in Information and Communication Technologies (CS/03) of the Portuguese Institute for Quality (IPQ) and member of the portuguese Ordem dos Engenheiros.

Key publications:

- Paulo Eira, Pedro Guimaraes, Monica Melo, Miguel A. Brito, Ricardo J. Machado, Antonio Silva, "Tailoring ISO/IEC/IEEE 29119-3 Standard for Small and Medium-sized Enterprises", 2018 IEEE International Conference on Software Testing, Verification and Validation Workshops (ICSTW), Sweden, in press.

- Miguel A Brito, Filipe de Sá-Soares, "Assessment Frequency in Introductory Computer Programming Disciplines", Computers in Human Behavior, Special Issue ICT's for Human Capital, Volume 30, January 2014, Pages 623–628.
- Vítor Serrano, Anabela P. Tereso, Pedro Ribeiro, Miguel A Brito, "Standardization of processes applying CMMI best practices", (2013) Advances in Intelligent Systems and Computing, 206 AISC, pp. 455-467.
- Isabel C. Viana; Ricardo J. Machado, Miguel A. Brito, "Between the Virtual and the Real: Technology and the City as an Opportunity and Challenge to the Education of the Future", Actas II Congreso Internacional de Ciudades Creativas, Icono14, Madrid, Spain, 3, 1580-1590, 2011
- Ricardo J. Machado, Pedro Guerreiro, Elizabeth T. Johnston, Marko Delimar, Miguel A. Brito, "IEEEExtreme: From a student competition to the promotion of real-world programming education". In Frontiers in Education Conference, 2009. FIE'09. 39th IEEE, IEEE.