Guest Editors’ Introduction to the Special Section on Evaluation and Improvement of Software Dependability

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Reliance on the operation of software systems has increased tremendously over the years, spanning almost every aspect of our lives—from shopping and entertainment, to controlling medical devices that sustain human life, controlling airplanes, or managing the critical infrastructure. Advances in software engineering, combined with the fast increase of hardware performance and the widespread use of broadband network connectivity, have led to the development of an enormous number of useful applications. This explosion of functionality, however, often is achieved with larger and more complex software systems which pose new challenges to software engineers who need to develop highly dependable systems, while at the same time delivering the product on time and at a low cost.

Software dependability is the quality of the delivered service such that reliance can justifiably be placed on this service. The service delivered by a system is the system behavior as it is perceived by its users (computer or human). The notion of dependability integrates several attributes\(^1\): reliability: continuity of correct service; safety: absence of catastrophic consequences on the user(s) and the environment; availability: readiness for correct service; confidentiality: absence of unauthorized disclosure of information; integrity: absence of unauthorized alternation or deletion of information; and maintainability: ability to undergo repairs and modifications. Availability to authorized users only, combined with confidentiality and integrity are the three dependability attributes that comprise security. Obviously, safety and security are focused on specific classes of failures (i.e., catastrophic failures in the case of safety, and unauthorized access or handling of information in the case of security).

When a software fault is accidentally triggered by the provided inputs, users observe an accidental failure. On the other side, when a software fault is exploited intentionally by malicious attackers, it enables a successful security breach into computer systems and networks which can be treated as a malicious failure. Either way, achieving highly dependable software systems typically requires a combination of four sets of techniques: fault prevention, focused on preventing the introduction or occurrence of faults; fault removal, focused on reducing the number or severity of faults; fault tolerance, aimed at delivery of correct service in the presence of faults; and fault forecasting, focused on estimating the present number, the future incidence, and the likely consequences of faults.

The widespread use of software systems and their ever increasing size and complexity impose many challenges that the dependability research community, software developers, and quality assurance practitioners strive to meet. This special section addresses the current strong interest in developing improved means of specifying, designing, verifying, deploying, and maintaining complex software systems in contexts where high dependability is required and is crucial for system operation. The purpose of the special section is to compile a collection of papers that present novel theoretical and empirical research aimed at evaluating and improving different aspects of software dependability. The scope covers a wide range of methodologies, techniques, and tools applicable through different stages of the software life cycle. In response to our call for papers, we received 32 submissions, out of which 26 were considered to be relevant to the topics of this special section (i.e., evaluation and improvement of software dependability). Each of these 26 papers was reviewed by at least three expert referees. After two rounds of peer-review process, we selected four papers which present new findings on different aspects of software dependability.

Software testing plays a vital role in improving software dependability by detecting and fixing software faults before they manifest as field failures. The first paper in this special section addresses the problem of developing an approach for efficient and systematic testing of products in a software product line. In the paper “Incremental Test Generation for Software Product Lines,” Engin Uzuncaova, Sarfarz Khurshid, and Don Batory specify each product as a composition of features, where each feature is specified as an Alloy formula. To ensure soundness of generation, the authors introduce an automatic technique for mapping a formula that specifies a feature into a transformation that defines incremental

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refinement of test suites. Thus, the proposed approach of incremental test generation enables tests that are generated for one product to be used to generate tests for another product. Such reuse has great potential for optimized test generation, considering the large number of possible products in a software product line. The authors evaluate the proposed incremental approach to test generation using two subject product lines (i.e., binary trees and intentional names) and compare its performance with the conventional test generation based on the latest Alloy tool-set. Results show that for simple refinements, the performance of the incremental approach is comparable to the conventional approach, while for complex refinements, the incremental approach significantly outperforms the conventional approach. In addition, since the incremental approach solves the complete problem using subproblems that have significantly fewer variables and clauses, it holds potential for better scalability than the conventional approach.

The next two papers deal with security related aspects of software dependability. Considering the effectiveness of security mechanisms at design stage is addressed in the paper “Verification and Trade-Off Analysis of Security Properties in UML System Models” by Geri Georg, Kyriakos Anastasakis, Behzad Bordbar, Siv Hilde Houbm, Indrakshi Ray, and Manachai Toahchoodee. The authors advocate the use of the Aspect-Oriented Risk-Driven Development (AORDD) methodology for developing secure systems and specifically focus on two analysis approaches that can be used at design time. First, they demonstrate how designers can formally verify that a security mechanism is effective in protecting against a given security breach. This is achieved by transforming a UML misuse model into Alloy and using the Alloy Analyzer to reason about security properties. The results of the analysis either give assurance that the security properties exist or show that they do not. The second analysis approach is focused on trade-off analysis that designers can use to compare alternative security mechanisms. This approach is based on Bayesian Belief Networks, whose inputs consist of the evidence from the security analysis, risk information from other AORDD steps, and trade-off parameters such as project specific-goals, time-to-market, budget, laws and regulations, and business goals. The trade-off analysis computes a fitness score, showing how well the proposed security mechanism meets the project goals.

The last paper in this special section is focused on discovery of security vulnerabilities in already deployed open source or proprietary software. In “Vulnerability Discovery with Attack Injection,” João Antunes, Nuno Neves, Miguel Correia, Paulo Verissimo, and Rui Neves present an attack injection methodology which adapts and extends classical fault injection techniques with a goal to automatically discover vulnerabilities in software systems. The proposed methodology, implemented in a tool called AJEET, consists of an attack generation phase followed by an attack injection campaign phase. It does not need the source code of the server to generate and inject the attacks. Instead, it uses the specification of the server’s communication protocol and predefined test case generation algorithms to automatically generate a large number of attacks. During the attack injection campaign, the execution of the server in the target system and the responses returned to the clients are monitored. The collected information is later analyzed to determine if the server exhibited any abnormal behavior which would indicate that a particular attack was successful in triggering an existing vulnerability. The usefulness of the approach was assessed on 16 publicly available POP and IMAP servers. AJEET discovered vulnerabilities in five of these 16 fully patched up-to-date servers. Based on the results, the authors concluded that complex protocols are much more prone to vulnerabilities that simpler ones and that closed source, proprietary applications appear to have a higher predisposition to contain vulnerabilities.

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