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Mutation Testing and Its Analysis on Web Applications for Defect Prevention and Performance Improvement

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ABSTRACT

The society's increasing reliance on web applications with the growing online market and digitization of almost every service, there is an increasing demand for better reliability, security, and interoperability of web applications. Testing becomes an integral part of improving this reliability on web applications. Despite the innumerable number of tools, techniques, methods for testing web applications, there is still scope for expansion in the code coverage of web applications. Mutation testing with its expansive potential to expose vulnerabilities of web applications took a backseat owing to its exhaustive testing cycles. Some mutation operators related to security, performance, and other non-functional attributes of web applications are presented in the current work. In the current work, a thorough analysis of various mutations operators proposed by authors towards the non-existent operators thus far is presented. An augment of 47% of operators occurred in the present work. A concise discussion on the scope of work future direction of work is presented.

KEYWORDS

Automated Testing, Mutation Operators, Mutation Testing, Security Testing, Web Application Testing

1. INTRODUCTION

Mutation testing is an established white box fault based testing method often overlooked for its laborious and exhaustive execution of test suites. Seeding of faults at known points, to trying to kill mutants by constantly increasing the input size, to analyzing the dead mutants versus the live mutants tests the typical tester's time constraints (Woodward 1993). If a mutant is alive, the test is re-executed with an increase in the sample input size. If a mutant is alive despite increasing the input size, then the tester needs to enhance his test suite with a new test case incorporating the live mutant as the new mutation operator. Mutation testing not just helps thorough testing of the software in test but also helps in enhancement of test suite to cater to the future needs like regression testing and health testing of the software in test, be it a web application or any application. However, a thorough effort went into understanding the needs of a web application in testing in the current work and a consolidated effort concluded that web application testing becomes critical given its immense heterogeneity in terms of interactions, implementations, languages, etc (Lakshmi & Millika 2017).

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Some of the popular case studies which emphasized on the importance of proper testing of web applications and implications of a poorly tested application are as below.

Pricing error on Amazon's UK site lists iPaq H1910 Pocket PC for under $12 instead of regular retail price of $449 resulting in abnormally high sales in March 2003 (News.com n.d).

PayPal suffered from service outages for five days in October 2004 after upgrading site. They reason quoted to be as glitches in the software update and waived customer fees for a day http://www.eweek.com/article2/0,1759,1684427,00.asp (eWeek.com n.d.).

A bank in Denmark experiences outage due to errors in database recovery routines following replacement of defective disk in April 2003 (eWeek.com n.d.).

Comair airlines had to cancel more than 1,000 flights on Christmas Day 2004 when its computer systems for reservations crashed after a rough weather caused a damage to the physical computer systems of the organization (Internetnews.com n.d.).

Earlier researchers have done some extensive work in terms of proposing mutation operators for testing web applications (Kumar 2019; Kumar & Ramamoorthy 2018; Offutt et al., 2006; Praphamontripong & Offutt 2010; Kumar & Ramamoorthy 2017; Schuler & Zeller 2009; Schuler et al., 2009). However, there is a dearth for security related mutation operators which can further reveal security vulnerabilities of web applications (Lakshmi & Mallika 2017).

2. RELATED WORK

Previous mutation systems modelled (Fevzibelli et al., 2016; Wang & Huang 2008; Wang et al., 2009; Martin & Xie 2007) a) faults based on link transitions b) faults based on arithmetic operators by replacing them with another and c) operators that simulate some uncommon programming errors (Mirshokraie et al., 2015; Misra 2014; Nishiura & Maezawa 2013; Lee et al., 2008; Ferrari et al., 2008). An exhaustive survey of various web application faults (Sujata & Idate 2013; Praphamontripong 2012; Karthikeyan et al., 2019; Delamare et al., 2009) led to the identification of several security vulnerabilities with web applications. By modelling each security vulnerability, a unique operator is designed. The categories of web applications faults however overlap according to various classifications done by earlier researchers (Jiang et al., 2009; Wang & Haga 2014; Kumar et al., 2018; Nanavati et al., 2015; Kouser et al., 2018). In the current work, an attempt to propose mutation operators for session management and web application security is made. A tool to implement these operators on an inhouse built web application is done. A broader web applications fault classification proposed by the authors after an exhaustive survey on vulnerabilities in web applications is presented in Figure 1. After thorough survey it is evident that some of the earlier researchers contributed several mutation operators towards testing of web apps. However, their contributions got limited only to specific types of faults classified in the Figure 1. The operators proposed by earlier researchers are presented in Table 1.

The remaining paper is structured as follows: Section 2 discusses the classification of web faultsand most vulnerable areas in a web application and some of the mutation operators presented by earlier researchers pertaining to those classifications of web faults. Section 3 presents the web mutation operators proposed by the authors in earlier works along with a set of another 5 new operators for testing web apps. Section 4 presents the architecture of a tool designed and implemented by the authors for testing web applications for the mutation operators discussed in Section 3. Section 5 deals with the results obtained after testing five open source web apps with the operators proposed by the authors on the tool discussed in Section 4. Section presents a detailed analysis on the contributions of the authors in comparison with the existing work and further highlights the future directions of work.

Dynamic web applications suffer from a wide variety of vulnerabilities including application logic failures, session management (Biqer & Diri 2015), authentication problems, cross site scripting (Maithili et al., 2018), database connectivity etc. during run time. Confidentiality of data and security is a cause of growing concern given the failures of many of the e-commerce applications in the past

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