Next Generation Computer and IT Applications

Proceedings
International Conferences,
NGCIT, CST, IESH, MMHS 2013
September 22 - 24, 2013
Haitian Grand Theatre Hotel Qingdao, China
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Empirical Practice of Embedded Software Quality Improvement for managing water resource system based on ISO/IEC 9126

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Abstract. According to the experience in testing department for many years, software testing in a company is usually verifying the completeness of developed code before product release. The program, which has shipped without verification of non-functional defects, causes user inconvenience. In this paper, we describes empirical practice for quality improvement of water resources management system based on ISO/IEC 9126 including developer-centric functional test.

Keywords: ISO/IEC 9126, embedded software, SCADA, TAG

1 Introduction

In my software testing experience in TTA(Telecommunications Technology Association), most software companies had lack of testing capability. Especially in the area of embedded system, there are lots of knowledge for development, not for testing and management. Because a product is released only after verifying source code, it has latent faults of usability which causes the end user inconvenience.

The TEmb[1] method is published in the book Testing Embedded Software by Bart Broekman and Edwin Notenboom. TEmb is a method that helps to assemble a suitable test approach for a particular embedded system. It provides a mechanism for assembling a suitably dedicated test approach from the generic elements applicable to any test project and a set of specific measures relevant to the observed system characteristics of the embedded system.

2 Related works

ISO/IEC 9126 defines terms for the software quality characteristics and how these characteristics are decomposed into sub-characteristics (Figure 1). The sub-
characteristics can be measured by internal or external metrics. Software quality can be evaluated by measuring internal attributes (typically static measures of intermediate products), or by measuring external attributes (typically by measuring the behavior of the code when executed).

![Software Product Quality Diagram]

*Fig. 1. ISO/IEC 9126 Software product quality [2]*

An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints such as cellular phone, railway signaling system, hearing aid, missile tracking system. An embedded software is sometimes used interchangeably with firmware, although firmware can also be applied to ROM-based code on a computer, on top of which the OS runs, whereas embedded software is typically the only software on the device in question. Figure 2 shows a generic layout, which is applicable to virtually all embedded systems.

Embedded software testing shares much in common with application software testing. Developer codes a software, compiles, and tests to check the function. This is a developer-centric test and is not sufficient to reduce latent faults.

There are just few embedded software testing methodologies. Test uses the four cornerstones of structured testing as defined by the test management approach TMap.

3 **Testing embedded software for water resource management system**


Product under test is a water resource management system, which controls water level of a dam, and monitors condition. It requires real-time commands and controls, but we use both simulated system and real system for testing.

With consideration of the characteristics of embedded software, we wrote test cases, and added more test cases in progress of testing. The test case has a unique ID, expected result, and execution result.
Empirical Practice of Embedded Software Quality Improvement for managing water resource system based on ISO/IEC 9126

![Testing environment diagram](image)

**Fig. 2. Testing environment (simulated system and real system)**

When performing the test, we found several faults, and classified based on ISO / IEC 9126 quality characteristics. We found 90 faults on 4 quality characteristics (functionality, reliability, usability, portability) (Figure 3)

![Faults per quality characteristics graph](image)

**Fig. 3. Faults per quality characteristics**

There were 4 patches to fix all found faults. In 1st stage, developers fixed faults without information of quality characteristics. After 2nd stage, developers fixed faults with information of quality characteristics. Rate of patch was only 6% in 1st stage, but 68% in 2nd stage. (Table 1).

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So providing information of quality characteristics helped developer to comprehend what was error. We also found latent fault, during patch.

4 Conclusion

Previous embedded software testing was verifying source code using functional testing. Therefore, actual testing was not sufficient except program function. In this paper, we tested an embedded system for water resources management based on ISO / IEC 9126. As a result, providing information of quality characteristics improves efficiency of modification 60%, and prevents mistakes of developer’s modification. However, even one case study of ISO/IEC9126 based test is not sufficient. Later, we will derive items to improve the quality except the quality characteristics of ISO / IEC 9126.

Acknowledgments. This work was supported by the IT R&D Program of MKE/KEIT [10035708, "The Development of CPS(Cyber-Physical Systems) Core Technologies for High Confidential Autonomic Control Software”]

References

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ISSN 2287-1233

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