

Reliability Analysis in Healthcare Imaging Applications

C. S. Vidya* and B. P. Vijaya Kumar

Department of Information Science Engineering, M. S. Ramaiah Institute of Technology
(Autonomous Institute Affiliated to VTU), Bangaluru - 560054, Karnataka, India;
vidyashekar06@gmail.com, hod_is@msrit.edu

Abstract

In recent years, software applications are widely used in the healthcare domain for diagnosing, scanning, generating reports and in treating various diseases. As healthcare systems are safety-critical systems, it should be highly reliable. It is one of the major concerns in healthcare systems as defects in healthcare applications might lead to serious injury or death. So the reliability of software plays a very important role in the healthcare domain. Reliability is one of the most significant attributes for computing software quality. It tells us about the failures occurred during the execution of the software. Unlike hardware reliability, it is very difficult to measure software reliability due to the complexity of the software. Standard way of reliability measurement such as the Mean Time To Failure (MTTF) and Mean Time between Failures (MTBF) can't be an effective way of measurement in an integrated environment. As the reliability test points are more text based, some quantitative text analysis has to be done to measure reliability. In this paper, a model is proposed to arrive at accurate reliability of the healthcare application. Failure data is collected from various data points to analyze the reliability of healthcare application. A tool is used to parse the failure data from the applications which are in the form of log files. Further, this data is represented in a graphical format which helps us arrive at the current reliability status of the application and also help business to decide on how much to invest on quality roadmap.

Keywords: High Reliability, Healthcare Applications, Hospitals, Patient Safety, Software Quality

1. Introduction

In recent years, healthcare systems are entirely reliant on software applications for diagnosing, preventing and treating various diseases. There are various kinds of healthcare applications which is used for CT scan (Computed tomography), NM(Nuclear-medicine) for diagnosing and treating diseases like tumors, cancers, heart diseases and other irregularities within the human body. As these are safety-critical system, any malfunction or failure in devices might result in a harmful event causing in greater illness or even death. Patients expect hospitals to be highly reliable organizations, where zero error is the norm. To be a highly reliable institute, all the healthcare apparatus, procedures and processes, will have to be built with high quality. It is essential to ensure the reliability of each and every equipment when it is put

under test as a standalone subsystem and in integration with the hospital eco system and other devices.

The IEEE definition of software reliability is stated as "The ability of a system or component to perform its required functions under specified conditions for a specified period of time"¹.

Reliability is the key factor in software quality. The reliability of a system is a measure of its ability to deliver a failure-free operation. It is the function of the number of failures experienced by a particular user of that software. Hardware components can wear-out due to time but software doesn't Metrics which can be used to measure hardware reliability cannot be used to measure software reliability due to complexity of the software.

Standard way of reliability measurement such as the MTTF and MTBF can't be an effective way of measurement in an integrated environment. As the system needs

*Author for correspondence

to be put under test in integration with several other systems, the reliability test points are much more text based. As the data points are mostly text based, statistical analysis techniques cannot be applied on this data out of the box. Hence this approach requires text analysis such as Quantitative text analysis, Relationship, facts, and event Extraction, etc. In this paper, a model is proposed to measure the reliability of healthcare applications by collecting failure data from various data points and a tool is used to parse the failure data and extract the required data for reliability analysis. Further, this data is represented in graphical format which helps us to know the current reliability of the healthcare application.

A healthcare system is a collection of processes, sub-processes where each process contain a number of pathways that collectively ensure the delivery of safe care services and the satisfaction of stakeholders². Reliability is often presented in terms of defect rate. In healthcare, an opportunity for a defect usually translates to a population of patients at threat for the medical error or adverse event³. A high reliability organization is one which attains a high degree of reliability and safety regardless of operating in menacing environments⁴. Reliability analysis methods are used for hardware and software medical devices. More than 30 years ago, in declared principal items of reliability engineering in the healthcare system as reliability analysis of medical equipment and devices⁵. The Reliability engineering methods are used for equipment estimation analysis which includes the fault-tolerant systems design; software reliability analysis; availability, safety, analysis of medical equipment and devices⁶.

In³ a model is projected to increase the healthcare reliability. This model includes identifying evidence-based interventions and developing measures to evaluate the reliability. Moreover the operation properties of healthcare applications have to address the reliability requirements, which have to guarantee the seamless operation of the supported healthcare services respecting the necessary standards of care⁷.

In⁸ Failure Mode and Effective Analysis (FMEA) model is described. This is a systematic and proactive method for evaluating the relative impact of different failures⁸. A board-level commitment to a goal of zero preventable harm leads to changes in leadership behaviors, greater transparency and investment strategies for the organization⁹.

Although a number of researchers have considered the reliability prediction of medical systems at the design

and development stage over the last two decades, less literature deals with the reliability prediction and trend analysis of medical devices while they are in use in hospitals¹⁰. Ensuring reliability of medical devices when put under test in integration with the hospital eco-system is important.

The remaining paper is structured as follows: In section 2, reliability analysis in software systems is discussed. In Section 3, we discuss about the proposed system to measure reliability of healthcare applications. In Section 4, implementation results are discussed. Finally, Section 5 contains summary and conclusion.

2. Reliability Analysis in Software Systems

Reliability quantities can be defined with respect to time units. The two kinds of time concerned with this are the execution time and the operating time¹¹. The execution time is the time that is actually spent by a processor in executing the instructions of that program. The operating time is the period during which a system is working in a manner acceptable to its operator or user. Generally there are four ways of characterizing failure occurrences in time. They are time to failure, Cumulative failures experienced up to a given time, time interval between failure and failures experienced in a time interval.

Reliability is inversely proportional to failure rate i.e. as number of failure increases reliability of the software decreases. Hence failure rate should be very less for the application to be highly reliable.

Some of the terms used while measuring reliability are MTTF, MTBF and Failure Rate. The term Mean Time TO Failure (MTTF) is used in the hardware reliability and to a decreasing extent in software reliability. MTTF is the mean time to the first failure under specified experimental conditions. The hardware reliability field uses Mean Time Between Failure (MTBF). This is defined as the mean operating time (up time) between failures of a specified item of equipment or a system. Failure rate is defined as the frequency with which an engineered or component system fails. Failure rate can be calculated using the formula.

Failure rate = (Number of Failures)/Total operating Time

MTBF can be calculated using the following formula.

MTBF = (Total operating time)/Number of failures

From this we can know that MTBF is inversely proportional to failure rate. This also tells us that reliability is inversely proportional to failure rate.

Software reliability is a very specific and measurable property in the larger concept of software quality. It is probably the most inclusive and important property since it deals with freedom from departure from user specified behaviour during execution. When considered in healthcare, reliability is given high priority because any failure while using the application might lead to severe injuries in patients. Human dependency is maximum in critical applications such as healthcare applications and hence these applications are expected to reach their maximum level of acceptance. While using software in healthcare domain we should make sure that the applications are highly reliable which helps in better treatment of patients.

3. Proposed Model for Reliability Assessment

Reliability is one of the most important attributes for measuring software quality. The main issue in measuring reliability is collection of failure data. Various existing methods for analyzing reliability in healthcare applications consider only few data points to collect the failure data. If complete failure data is not collected from various data points, it is difficult to arrive at accurate application reliability. The existing methods consider only application logs for measuring reliability. As the system needs to be put under test in integration with several other systems, the reliability test points are much more text based. As the data points are mostly text based, statistical analysis techniques cannot be applied on this data. Hence this approach requires text analysis such as Quantitative text analysis, Relationship, facts, and event Extraction, etc.

The proposed architecture of the system for reliability analysis in healthcare application is as shown in the Figure 1. It consists of various components like clients, server, text analyzer engine, database.

Healthcare applications are installed in client and server machines which are used in various hospitals. These applications are developed such that each and every operation made in the application is recorded as a log in the required format. These logs are the main input for reliability analysis. The logs from various hospitals are collected and stored in a database.

The proposed model for reliability analysis is as shown in Figure 2. The detailed function of each of the activities involved in reliability analysis is discussed.

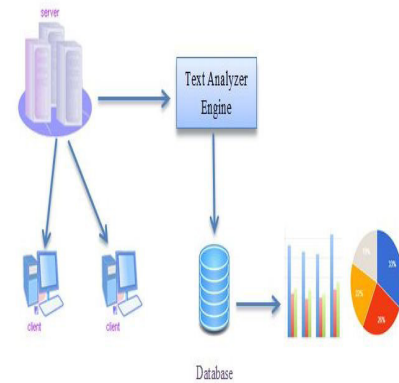


Figure 1. Typical system architecture for proposed system.

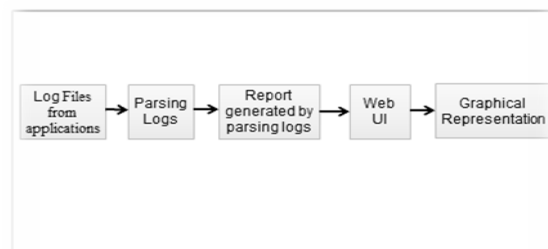


Figure 2. Proposed model for reliability analysis.

3.1 Identifying various Failure Modes

Various failure modes in the application are identified and classified. Failure modes are the modes in which the application or the system might fail. The classification of failure modes is as shown in Figure 3.

Failure Modes	Description
FM-1	App Service Crashed
FM-2	App Login failed due to server
FM-3	Clinical App. Crash (> 3 mins)
FM-4	Clinical App. Crash(< 3 mins)
FM-5	Failure to save Image to Local Folder
FM-6	Interoperability failure
FM-7	Reporting error
FM-8	Printing error

Figure 3. Classification of failure modes.

3.2 Parsing Log Files using Text Analyzer Engine

Text analyzer engine is a component which takes log files that are generated from the application as input. Various text patterns are matched with the log entries to classify the failures. These log files which are collected from various data points are parsed to generate the required data for reliability analysis in a particular format.

3.3 Generation of Report by Text Analyzer Engine

Once parsing of all these log files i.e. client logs, server logs and event logs are complete, a report is generated. The report consists of details about the services provided by the server, clinical application usage, infrastructure application usage and also system application usage. Server provides services to the clients. Clinical application gives us information about failures in the system applications like saving the image to a local folder, error while generating report or while printing the report, etc. This also gives us information about whether the application was crashed due to some error in the application itself or the system error or database error that resulted in application crash. So we consider not only application logs but also event logs of the system which helps us arrive at accurate reliability value.

3.4 Data Input to Web Application

The report generated by parsing the log files is stored in the database which is accessed by the web application, developed to analyze the reliability of healthcare application. The UI retrieves the data required for analysis from the database. The UI contains tabular analysis and graphical analysis. In tabular analysis certain statistical methods are used to calculate the reliability of the application and the results are normalized. Actual reliability of each failure mode is calculated and it is matched with the target value to check if reaches the target. This gives us information about the reliability of various failure modes, thus helping us in finding the cause for application crash or failure.

3.5 Representing the Data in Graphical Format

Resulting data is represented in graphical format to know the reliability of different failure modes. Graphs of various reliability indicators are generated. Graphs like percentage of various application usage and its crashes, percentage of application usage in different hospitals and crashes related to various failure modes are plotted. These graphs indicate the reliability of the product.

4. Results and Analysis

As there will be many Failure Modes (FMs), FMs in healthcare application are identified and classified according to

the application for which reliability has to be analyzed. Sample failure modes classification is shown in Figure 3.

The log files are parsed and report is generated which gives a count of various modalities and services launch and failure.

The web application retrieves the data from the database and the reliability is calculated for various modalities in the healthcare applications. Reliability is calculated using the formula given below and is normalized for 500 operations.

Reliability = (Total crashes / Total usage of the system)*500

The data retrieved from database is represented in the graphical format so that comparing reliability of different versions of healthcare applications will be easy. Various graphs are plotted. Graphs like total number of failures including all modalities in different hospitals Figure 4, total number of application launches in different hospitals

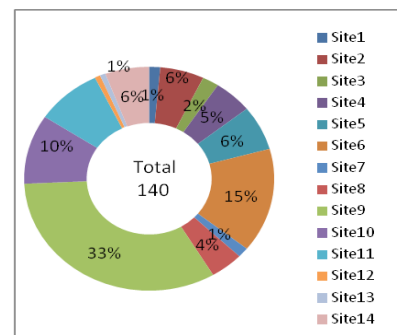


Figure 4. Total events per site.

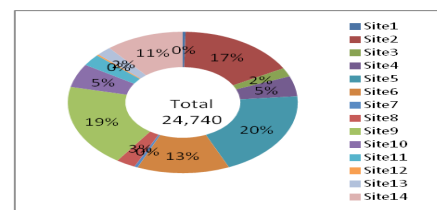


Figure 5. Total cases per site.

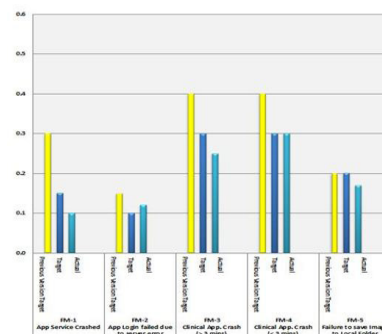


Figure 6. Reliability of various failure modes.

Figure 5, graph which indicates the reliability of different failure modes are generated Figure 6.

The graphs indicate the reliability of different versions of healthcare applications which tell us about the reliability trend. This also gives input to the developers about which modality is causing too many failures so that the defects can be fixed and a better version can be released.

5. Conclusion

Reliability is very important in healthcare domain as healthcare systems are used in diagnosing, preventing and treating patients. So measuring reliability plays a very important role in healthcare systems. Reliable system reduces injury and death of patients. It also reduces the delay in treating patients by correctly diagnosing and generating the reports at a faster rate. The proposed system analyses the reliability considering various failure modes. It parses the failure data collected from various data points. Reliability of these failure modes is calculated. This data is represented in graphical format which indicates the reliability of the product. This also helps product managers to make business decision on product readiness for market release.

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7. References

1. Pecht M. Product Reliability, Maintainability and Supportability Handbook. 2nd ed. CRC Press; 2009 Apr.
2. Ben Atallah Z, Ramudhin A. Improving healthcare reliability by integration six-sigma in a business process modelling and analysis strategy. IEEE International Conference on Industrial Engineering and Engineering Management (IEEM); 2010 Dec. p. 2234–8.
3. Pronovost PJ, Berenholtz SM, Goeschel CA, Needham DM, Bryan SJ, Thompson DA, Lubomski LH, Marsteller JA, Makary MA, Hunt E. Creating high reliability in health care organizations. *Health Service Research*. 2006 Aug; 41(4 Pt 2):1599–617.
4. Pronovost B, Goeschel CA, Needham DM, Sexton JB, Thompson DA, Lubomski LH, Marsteller JA, Makary MA, Hunt E. Creating high reliability in health care organizations. *Health Services Research*. 2006 Aug; 41(2):1599–617.
5. Taylor EF. The reliability engineer in the health care system. *Proceeding of the IEEE 18th Annual Reliability and Maintainability Symposium (RAMS)*; 1972. p. 245–8.
6. Zaitseva E. Reliability analysis methods for healthcare system. 3rd International Conference on Human System Interaction; 2010 May. p. 211–6.
7. Matousek K. Security and reliability considerations for distributed healthcare systems. 42nd Annual IEEE International Carnahan Conference on Security Technology; 2008 Oct. p. 346–8.
8. Holly C. Failure Modes and Effective Analysis (FMEA). Institute for Healthcare Improvement; 2004.
9. High Reliability: The Path to Zero Harm. Available from: https://www.jointcommission.org/high_reliability_the_path_to_zero_harm/
10. Sharareh T. Reliability and Maintenance of Medical Devices. LAP LAMBERT Academic; 2012 Jan.
11. Musa JD. Software Reliability Engineering. 2nd ed. Osborne/McGraw-Hill; 1998 Jul.