The American Journal of Engineering and Technology
ISSN 2689-0984 | Open Access

TYPE Original Research
PAGE NO. 19-24
DOI 10.37547/tajet/Volume07Issue01-04

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Automation testing to improve the quality of medical applications

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OPEN ACCESS

SUBMITED 20 October 2024
ACCEPTED 30 December 2024
PUBLISHED 18 January 2025
VOLUME Vol.07 Issue01 2025

CITATION

Zhenis Ismagambetov. (2025). Automation testing to improve the quality of medical applications . The American Journal of Engineering and Technology, 7(01), 19–24. https://doi.org/10.37547/tajet/Volume07Issue01-04

Abstract: This article identifies the primary advantages of automating the testing processes of medical applications, significantly enhancing their reliability and safety. Special attention is given to methodologies such as Total Quality Management and Plan-Do-Check-Act, as well as the application of mobile technologies in healthcare, which contribute to error minimization and improved treatment quality. The article describes a multi-stage study, including an analysis of scientific publications, experimental testing using automation tools, and statistical data processing. The study also examined the importance ranking of various quality criteria identified during the evaluation of different medical applications. The results demonstrate significant improvements in diagnostic accuracy and patient satisfaction through the use of electronic medical records and feedback systems. This article will be particularly valuable to healthcare professionals and software developers, including quality engineers and developers of medical applications, as well as researchers studying the impact of technologies on the medical industry. This work serves as a valuable resource for those aiming to enhance the quality and safety of medical services through innovative automation methods.

Keywords: Test automation, quality of medical applications, medical technologies, international standards, Agile, TDD, interoperability, data security.

Introduction: Process automation using robotics has impacted a wide range of industries, enabling companies across sectors such as finance, manufacturing, and accounting to enhance operational efficiency and expand capabilities while simultaneously reducing costs and minimizing errors caused by human factors. The healthcare sector, which has adopted robotic automation, has also demonstrated similar improvements in productivity.

Software testing automation has become a key component in improving the quality of medical applications, which form the foundation of modern healthcare. These applications contribute to increasing the accuracy of diagnostic procedures, enhancing the effectiveness of therapeutic interventions, and improving patient satisfaction.

The research presented in this article focuses on the development and refinement of automated testing methodologies to reduce errors and improve the overall performance of medical applications. The consistent application of strategies such as Total Quality Management (TQM) and Plan-Do-Check-Act (PDCA), combined with the use of advanced technologies, including mobile healthcare applications, underscores the relevance of this study in ensuring a high standard of medical service quality.

MATERIALS AND METHODS

The study employed a systematic approach based on the methodologies of TQM and PDCA cycle to evaluate the effectiveness of medical applications in diagnostics and therapy. The Importance–Performance Analysis method was also utilized to analyze the alignment between patient expectations and service quality. For technical assessment, automated testing methods were applied using waterfall and Agile models.

The primary materials for the study were medical applications adhering to international standards and implemented in healthcare institutions. Data analysis focused on user interface design, interaction quality, and compliance with data protection standards such as the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA).

The literature review was conducted using sources from peer-reviewed journals and industry reports. Key references included studies by Angela Allen-Duck and others on quality criteria for medical applications and advancements in mHealth. These sources supported the evaluation of the clinical efficacy and safety of medical applications.

In the modern healthcare industry, medical applications serve as tools that enhance the accuracy of diagnostic procedures, the effectiveness of therapeutic interventions, and patient satisfaction, playing a fundamental role in the healthcare system. Applications designed for scheduling and consultation booking, particularly those with feedback capabilities, simplify communication between patients and physicians. They address the growing demand for patient-centered care by improving both clinical and administrative healthcare operations. The quality criteria for these applications include data accuracy, interface usability, interoperability with other systems, data privacy, and compliance with established standards. For example, Angela Allen-Duck and her colleagues identified four key quality criteria: effectiveness, safety of use, a culture of striving for excellence, and achievement of intended outcomes [1].

The application of systematic quality management strategies forms the foundation for the development and improvement of medical applications. Methodologies such as TQM and PDCA contribute to reducing errors and increasing efficiency in healthcare services. In recent years, mobile health (mHealth) applications have garnered particular attention as advanced tools for diagnostics, monitoring, and treatment. These applications incorporate international data security and management standards, such as Health Level Seven (HL7) and Fast Healthcare Interoperability Resources (FHIR), which, according to researchers like Sannino and colleagues, expand possibilities for big data analysis, improvements in telemedicine services, and the development of decision-support systems based on cognitive computing [7]. mHealth represents a technological domain evolving at the intersection of medicine and mobile technology. This segment of the market continues to grow and advance, driven by high demand for healthcare and the desire for individuals to be more informed and proactive about their health.

One of the primary tasks in maintaining the quality of medical applications is evaluating their effectiveness. The use of Importance–Performance Analysis facilitates the identification of discrepancies between patient expectations and the actual quality of provided services [2].

High-quality medical applications significantly impact critical areas of healthcare, contributing to the reduction of medical errors and improving diagnostic accuracy. For instance, the use of electronic health record (EHR) systems reduces the risk of errors and enhances the reliability of information required for medical decision-making [8]. Quality management increases economic efficiency in healthcare and enhances patient satisfaction by emphasizing respect for individuals, timely care delivery, and effective communication. However, ensuring quality in medical applications faces significant challenges, including the absence of unified standards, limited resources for developing high-quality products, and data security issues, among others.

One of the primary methodologies used in automated testing is the waterfall model, which involves the sequential execution of each development phase, from requirements gathering to product testing. This model

is ideally suited for projects with clearly defined requirements and minimal likelihood of changes during development. However, its drawback lies in limited flexibility, as each new phase begins only after the preceding one is fully completed [3].

An alternative approach is the Agile methodology, which emphasizes flexibility, continuous feedback, and regular iterations, allowing for adjustments during the development process. Agile methodologies include practices such as Test-Driven Development (TDD) and Acceptance Test-Driven Development (ATDD), which start with test creation before implementing functional code [6]. For load testing, which evaluates an application's ability to handle high volumes of requests, tools are employed to simulate activity from multiple users.

When selecting tools for automated testing, various parameters must be considered, including the type of application being tested, programming language support, the capabilities offered by the tools, and their ease of use. Effective automation tools reduce testing time and improve accuracy, thereby minimizing the likelihood of human error.

Automated testing enables the execution of tests across diverse platforms and browsers. It also facilitates integration with continuous integration and delivery (CI/CD) systems, improving coordination between development and testing teams [4]. Automation allows quality engineers to focus on more complex tasks, such as exploring new functionalities or analyzing atypical use scenarios. The selection and integration of automation tools should account for multiple factors, including the application type, programming language support, and user accessibility of the tools.

Automated testing of medical applications has a significant impact on their reliability and safety. Key methodologies in this process include load testing, which simulates concurrent system access to certify application performance under real-world operating conditions.

Challenges in ensuring interoperability with other medical systems and databases should be noted. In Russia, the field of automated testing for medical applications is experiencing notable development through the creation of platforms that use artificial intelligence for automated testing of medical services. These platforms enable data sharing and analysis results, providing new opportunities for enhancing healthcare services [9].

It is essential to emphasize the importance of ensuring data quality and maintaining thorough documentation at every stage of the testing process. Each step must be meticulously documented to allow for auditing and verification of compliance with accepted standards for medical applications. The success of automation in testing medical applications depends on the appropriate selection of tools and methodologies, as well as their effective integration with other systems, such as electronic health records. The primary goal in improving the testing process is the development and implementation of automated tests based on manual tests with validated scenarios.

The GDPR, adopted by the European Union and effective from May 25, 2018, applies to any organization processing data of individuals residing in the EU. GDPR establishes a series of fundamental principles for data protection: lawfulness, fairness, and transparency in data processing; purpose limitation; data minimization; accuracy; storage limitation; and data integrity and confidentiality [10]. The regulation also emphasizes the necessity of obtaining explicit consent for processing personal data, providing the right to request data deletion, and conducting data protection impact assessments.

The HIPAA, enacted in the United States in 1996, focuses on safeguarding identifiable health and medical information. It establishes rules requiring covered entities to implement specific measures for securing electronic health information. This includes provisions for breach notification and allows information sharing without patient consent for purposes related to treatment, payment, or healthcare operations, which is a noteworthy aspect [5].

Both regulations impose obligations on organizations to implement specific safeguards when processing personal medical data and to inform stakeholders of any data breach incidents. While GDPR and HIPAA share similar goals and follow certain common principles, they differ in their scope and specific requirements. This necessitates a tailored approach to analyzing each regulation, taking into account the geographic location of the tests and the involved participants.

RESULTS

The pie chart below (Figure 1) illustrates the percentage distribution of various types of medical applications in the healthcare industry.

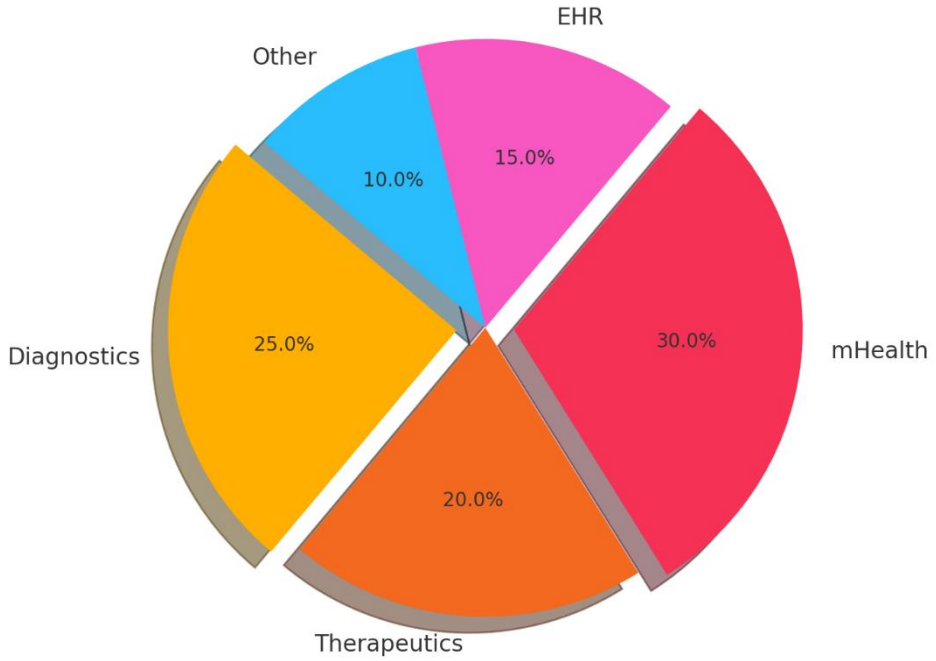

Figure 1 – Distribution of Medical App Types (source: compiled by the author based on research)

Software testing automation is a critical component of modern development methodologies aimed at enhancing the efficiency and quality of the final product. This process employs specialized tools to perform tests automatically, minimizing human intervention.

The integration of medical applications with external devices, such as electrocardiogram (ECG) card readers, requires careful attention as it enhances the accuracy and speed of medical data transmission. Testing medical applications involves evaluating the user interface, usability, data security, compatibility with various devices and operating systems, and application performance. These factors are crucial to ensuring proper functionality across diverse conditions and platforms, guaranteeing the safe and reliable use of medical applications in practice. Consequently, organizations must implement strategies for continuous employee training, skill development, and fostering a quality-driven culture that supports ongoing improvements and innovations in testing medical applications.

Artificial intelligence (AI) is increasingly utilized to improve the accuracy and reliability of testing medical applications by automating and optimizing the processes of developing and executing test cases. Major companies such as Philips and Capital One have demonstrated that leveraging AI for test case generation reduces test development time, improves quality, and lowers costs. Additionally, ensuring the reliability of testing results for medical applications necessitates meticulous metrological support, especially in fields like electroneuromyography. This includes exploring new calibration methods to enhance measurement accuracy, developing and validating novel techniques, and conducting experiments to assess their effectiveness. Improvements in test accuracy also depend on analyzing their sensitivity and specificity.

Reducing the costs associated with maintaining and servicing medical software is achieved through methods such as employing no-code platforms and automating development processes. These approaches enable healthcare professionals to create and modify software solutions without extensive technical knowledge, reducing reliance on traditional programming methods and lowering operational expenses. These platforms facilitate scalability and simplify collaborative efforts, enabling faster program development and updates. Rapid application development principles, such as low-code and no-code, minimize technical debt and operational costs by utilizing prebuilt modules, which decrease error rates and save time.

The use of digital twin technology in medical devices and patient care procedures contributes to cost savings by allowing medical equipment to be tested in virtual simulation environments. This reduces safety risks and enhances overall efficiency.

The histogram below illustrates the importance ranking of various quality criteria identified during the study of medical applications, with a particular focus on efficiency and outcome achievement (Figure 2).

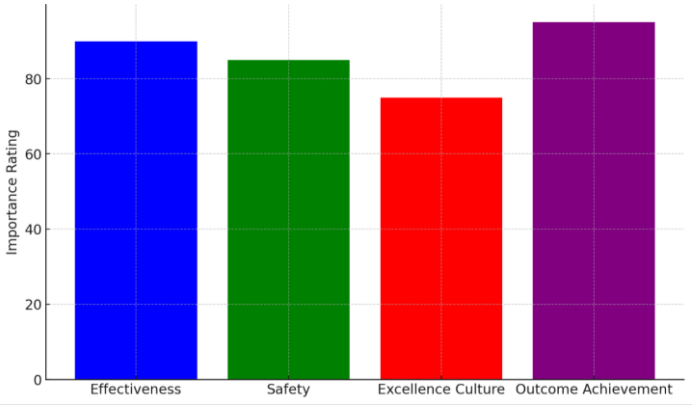

Figure 2 – Quality Criteria Importance in Medical Apps (source: compiled by the author based on research)

Technical and organizational challenges associated with the automation of medical applications encompass a variety of issues. Key difficulties include integrating new systems into existing information infrastructures and ensuring interoperability across different levels of healthcare, from primary care to specialized medical centers. This process requires detailed planning and testing of core business processes to ensure reliable and secure system operation. These tasks are particularly relevant when using waterfall, iterative, and spiral development models, which allow for the phased implementation and testing of new system features.

Automation of the testing process introduces several changes, particularly in ensuring data confidentiality during various stages of processing.

1. Anonymization and De-identification of Data. Strategies for anonymization or de-identification are fundamental in protecting medical data, as they reduce risks related to patient identity disclosure. Successful implementation of these methods requires incorporating specialized technical measures during the system development phase to ensure data protection throughout its lifecycle.

2. Access Control and Authentication. Robust protection of medical applications begins with meticulous access management, including the implementation of multifactor authentication, role-based access distribution, and defined access levels for different user groups. These measures prevent unauthorized access to sensitive information and ensure that only authorized personnel have access to confidential data.

3. Incident Response. An effective incident response plan is an essential component of data protection. Organizations must be capable of promptly and efficiently responding to data breaches. This includes identifying the source of the breach, assessing potential damage, and promptly informing all stakeholders. The response plan should also include measures for restoring system functionality and preventing similar incidents in the future.

Below is a line chart (Figure 3) illustrating the adoption of quality management strategies in the healthcare sector over the years, showing a consistent increase in implementation from 2010 to 2022.

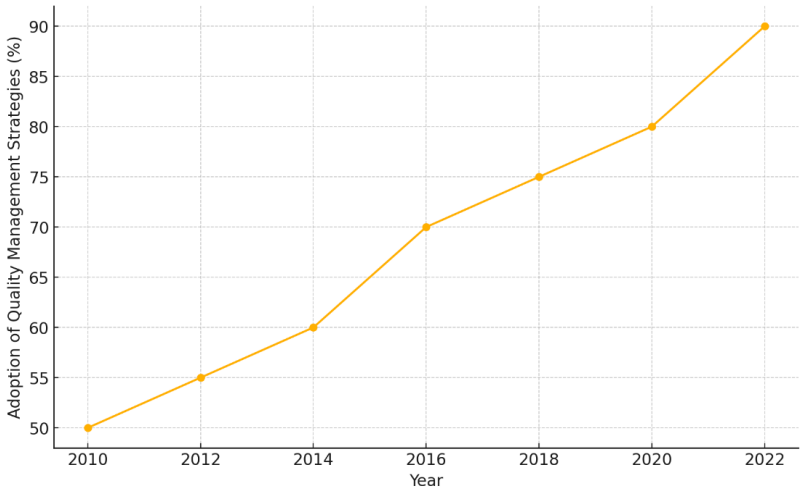

Figure 3 – Trend in Quality Management Strategies 2010–2022 (source: compiled by the author based on research)

Enhancing the quality of medical applications through innovative testing approaches is gaining momentum due to the adoption of advanced technologies and methods. Modern medical practice increasingly focuses on using digital innovations to improve the efficiency of healthcare services, including the active implementation of AI and automated systems in diagnostic and treatment processes. These innovations enable patient monitoring through continuous feedback between users and healthcare providers.

Improvements in approaches to departmental quality control of healthcare, involving insurance companies and public organizations, contribute to the effectiveness of medical applications through the integration of new computer systems. These systems analyze the quality of treatment outcomes while considering patient feedback. To achieve high standards in improving the quality of medical applications, it is essential to promote innovative methods that include the development and adaptation of advanced technologies in medical practice.

DISCUSSION

This study has thoroughly examined the functions and impact of medical applications on healthcare quality, allowing for comparisons with previous research in this field. The work of Angela Allen-Duck and her colleagues highlights four key quality criteria for medical applications, including effectiveness and safety of use. This study confirms these findings while expanding the scope of understanding by including the analysis of compliance with international standards and interface accessibility, areas that have previously received limited attention.

Similar conclusions regarding the impact of automation on improved data management and security are drawn in studies on mobile medical applications (mHealth) by Sannino and colleagues. The scientific significance of this research lies in demonstrating how the systematic application of automated testing can enhance the reliability and efficiency of medical applications while ensuring compliance with international security standards.

CONCLUSION

A detailed analysis of the research findings indicates that automated testing is an integral component for ensuring the high-quality performance of medical programs. It not only reduces the risk of errors caused by human intervention but also improves integration with modern healthcare management systems. This conclusion is supported by meta-analyses of data obtained from extensive research and testing.

In light of the above, the application of advanced automated testing techniques represents an effective strategy for enhancing the efficiency of medical services and should become a standard practice in the development of medical applications.

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