Bulletin of Business and Economics, 13(1), 510-515
https://bbejournal.com
https://doi.org/10.61506/01.00234

An Innovative Framework for Automated Software Testing and Validation

Nouman Arshid[1], Riasat Ali[2], Hafiz Shoaib Ur Rahman[3], Sadia Watara[4], Muhammad Waseem Iqbal[5], Saleem Zubair Ahmad[6], Sadaquat Ali Ruk[7], Zulfiqar Ali Ayaz[8]

Abstract
The rising scale and the intricate nature of these systems make the verification & validation (V&V) of classifications that are automated more costly and to much time-taking. Furthermore, the V and V of the following systems might be hampered if the techniques and procedures are not effectively documented, assessed, and selected. Practitioners must employ appropriate V and V methodologies and conduct acceptable V and V procedures to ensure the following systems perform as proposed and in cost-effective way. Earlier efforts have produced several categorizations and models that may be used to categorize V and V approaches and technologies. The goal of this study is to give a wide, comprehensive, and simple framework for characterization needs, rather than focusing on particular parts of V and V methodologies and procedures. To that purpose, in this study, we provide a multi-domained and multi-dimensioned framework for characterizing and classifying V and V approaches and tools in an organized manner. The framework reflects a complete description of several key features of V&V. As an example of usage, a web-based repository has been created based upon the framework to gather information regarding the use of V and V approaches and tackles. Experts and scholars may readily learn about and select acceptable V and V procedures this way.
Keywords: V and V (Verification and Validation), Automation Systems, Framework for Windows, Method

1. Introduction

Testing is a method of assessing the degree to which a system satisfies its initial criteria. It is essentially a method that comprises verification and validation to ensure that the industrialized system meets the user's expectations. As a consequence of this activity, there is a difference between actual and projected outcomes. Software testing is the process of identifying problems, errors, or missing specifications in an established system or program. As a consequence, this is a probe that supplies stakeholders with specific information regarding the product's quality. Software testing is sometimes considered a risky endeavor. The most crucial skill for program testers to learn during tests is how to condense a huge number of jobs into manageable test sets and then make educated selections about which dangers are critical to test and which are not.

Automatic systems, including robots for manufacturing and healthcare devices, have become essential parts of today's world. These organizations are designed to interact separately and securely with the natural to monitor and validate their behavior throughout their of development. To achieve this purpose, verification and validation (V&V) operations occur through the final testing phase. V and V is growing increasingly costly and time consuming as automated systems grow in complexity and interconnection. This is highlighted by the fact that those structures are made up of a few related subsystems created by various stakeholders.

The growing demand to optimize standard V and V operations to minimize costs and boost productivity has led to the adoption of innovative approaches and technologies in both corporate as well as study environments. However, as each industrial sector has its own set of norms, practices, and nomenclature, it is challenging for practitioners to evaluate and execute state-of-the-art methodologies and workflows due to the diverse and domain-specific framework of V and V procedures (*IEEE Standard for System and Software - ProQuest*, n.d.).

This study proposes a sophisticated structure that defines a domain-agnostic approach to structuredly characterize and partition V and V procedures in order to overcome these challenges. The framework covers a broad spectrum of description and categorization elements related to the methods, resources, environments, and ideas required for computerized system validation. The framework was created as a component of VALU3S, an EU-funded project (Goncharov et al., 2020) (Iqbal et al., 2024), which involves a group of 41 corporate and educational collaborators and is being used in 13 sample pilots across six sectors: automobiles rail, aerospace, related to agriculture, health, and industrial robots. Furthermore, a web-based library has been built and populated using the suggested framework1 to let academic and industry professionals learn about innovative V and V toolchains in addition to practical cases, despite the specific sectors for which they were originally intended.

2. Literature Review

We created a ordering approach for V and V procedures (Yang et al., 2012) that reflects the kind of assessment, such as evaluation, in addition to whether they are concerned with security, online security, or privacy. It can be considered a predecessor of the structure presented in this work. Previous research has focused on constructing a taxonomy that takes into consideration various V and V features (Hamid, Iqbal, Aqeel, Rana, et al., 2023). Created a grouping that encompasses the basic features of model-based evaluation, (Hamid, Iqbal, Aqeel, Liu, et al., 2023) planned an outline for early products V&V, and (*Verification and Validation of Automated Systems' Safety and Security | VALU3S Project | Results | H2020*, n.d.) gave a testing ontology that addresses seven abstract groupings of the softest sorts. This grouping aims to help testers develop test strategies by analyzing different test types.

Meta systems for V and V characterization may also be found in the literature, but they are often limited to certain V and V industries, such as tests (Rasool et al., 2023) and certifications (de la Vara et al., 2016). Meta-models determine ideas, concept attributes, and the relationships between concepts that determine the associated V and V domain. Concrete solutions have also

[1] Department of Information Technology, Superior University, Lahore, 54000, Pakistan, msit-f21-002@superior.edu.pk
[2] Department of Computer Science, Superior University, Lahore, 54000, Pakistan, mscs-f21-016@superior.edu.pk
[3] Department of Information Technology, Superior University, Lahore, 54000, Pakistan, msit-f21-007@superior.edu.pk
[4] Department of Computer & Mathematical Sciences, New Mexico Highlands University Las Vegas, USA, swatara@live.nmhu.edu
[5] Department of Software Engineering, Superior University, Lahore, 54000, Pakistan, waseem.iqbal@superior.edu.pk
[6] Department of Software Engineering, Superior University, Lahore, 54000, Pakistan, saleem.zubair@superior.edu.pk
[7] Department of Computer Science, Shah Abdul Latif University, Ghotki Campus, Pakistan, sadaquat.ali@salu.edu.pk
[8] Department of Information Technology, Superior University, Lahore, 54000, Pakistan, msit-f21-006@superior.edu.pk

been developed using meta-models; one such example is the Eclipse Open Certification tool platform (Schumann & Goseva-Popstojanova, 2019), which offers certification and assurance for Cyber-Physical Systems. While this kind of arrangement aids in defining some of the V and V techniques information needed for certification, it is only partial and at a high conceptual level. The open-source Cert meta-model, for instance, does not list the many forms of evaluation that can be done on a V and V process or its surroundings.

Some engineering norms, such as (*Verification and Validation*, n.d.), outline V and V operations for various types of systems, with security and safety in mind. They fail to address other critical variables to consider while designing or employing a V and V strategy. These features include the assessment surroundings, the type of demand under consideration, and performance signs. The NIST Foundation for CPS (Hamid, Iqbal, Nazir, et al., 2022) covers several qualities and attributes. The elements encompass CPS principles such as working, human, and temporal considerations. There are three main aspects: idea, realization, and certainty. Assertions, deductive thinking, confidence, and evidence aimed at testing ideas are all examples of assurance features. Concerning the growing issue of V and V for computerized systems, numerous Research has mostly concentrated on summarizing particular subjects for dependable, large-scale systems. For SoS (Systems of Systems), the AMADEOS framework (Iqbal et al., 2024) offers a point-of-view-based specialization as well as a high-level perspective. Four layers make up the high-level view: aim, conceptual, sensible, and implementation. The analysis influenced by viewpoint encompasses organization, motion, Darwin's theory of trustworthiness and safety, and its development. The AMADEOS system focuses on SoS notions instead of broad V and V features (Hamid et al., 2024), giving the results of a review of formal strategies that might be used for reliability analysis of machinery control systems, while (Hamid, Iqbal, Ashraf, et al., 2022) has looked into runtime testing of actively adaptive and remote systems, granting specifics on procedures, frameworks, and tools. Proposed a V and V test structure to support open system designs, which is used for combining subsystem interfaces and increasing platform compatibility (Hamid, Muhammad, Iqbal, Bukhari, et al., 2022). Presented the SERP test, a taxonomy designed to improve interactions among software evaluation researchers and practitioners. This can be helped to lessen the effort necessary to develop V and V approaches for the well automated systems.

Describes in aspect of reliability, safety, and V&V, including key principles, fault types, and assessment methods (Hamid, Iqbal, Muhammad, et al., 2022). It fails to tackle critical aspects such as the type of assessment instrument, the assessment phase, or the purpose of the module being examined. Some projects (Ahamed et al., 2018) and (Ibrahim et al., 2023) argue for employing cost, usefulness, efficacy, and applicability as V and V characterization metrics. The primary improvement that goes above and beyond the current state of the art in the context of defining V and V is the bigger, more comprehensive structure that fulfills numerous trait requirements, rather than paying attention to particular traits such as test or tool of different types, or a limited set of properties. As a consequence, the framework allows for a more detailed explanation, enabling users to make more informed judgments about V and V operations.

3. Overview of The Framework

3.1. Stakeholders

The possible users of the structure and the online repository are divided into two categories:

Participants in the VALU3S project include industrial partners V and V investigators, systems, applications, or hardware architects and developers, as well as QA (quality assurance) engineers and executives.

People of the public who do not participate in the VALU3S research but work with V and V on systems that are automated. The stakeholders in question will have open access to the digital repository. To take advantage of the repository's operations, participants must first register. Given that the things to be contributed are reviewed, both sets of interested parties may add to the repository.

3.2. User Stories

The aims of all stakeholders in using the framework may alter based on their requirements in altered V and V activities. Consequently, the development participants created 24 customer stories in order to specify the requirements that the structure needed to fulfill. These user stories, which served as a guide for the validation process, specify the functionalities that must be included in the VALU3S design. There are four main categories of user stories pertaining to V and V activity out of the 24 total.

- **Illustrate V and V method**
- **Describe V and V tool**
- **Exploration and relate V and V methods**
- **Exploration and relate V and V tools**

3.3. Structure of the framework

The V and V system is structured on two primary ideas: artifacts (see V) and dimension (see IV). A collection of characteristics called dimensions aids users in classifying necessary soft heart products. Applied to specific systems and domains, artifacts are methods and instruments utilized in the V and V methodology (e.g., instantiated for certain use cases, associated scenarios, scenarios for testing, and so on).To put it briefly, the framework allows technology and V AND V procedures to be categorized into multiple categories. Additionally, as part of the VALU3S program, the framework facilitates the storing of extra artifacts including demands, test cases, and evaluation scenarios (Zafar et al., 2023) (Hamid, Iqbal, Muhammad, et al., 2022). Users could search for V and V strategies and solutions when finishing a new V and V work that will meet their needs and optimize their workflows.

An AUML class diagram was created to demonstrate the structure and interactions between the framework's components (see Fig. 1 for a reduced version). The V AND V Framework's core components are the V and V Procedure and V and V Tool courses, which are organized by dimension. On the users end, the primary concentration is on leveraging possible scenarios to find a collection of test cases. Each instance of testing is broken down into a process and a context. The Process represents the sequence of actions that comprise the test case. Each activity in the pipeline represents a V and V Method. The background refers to the set of elements that are under which the test scenario behaves, such as the part being tested, the surroundings, and so on. The Test Tools used to run the test cases are linked to their respective V AND V Tools. The Process and Context

components are also grouped by dimensions, allowing users to use the framework as a reference tool when deciding which methods and resources to employ to build their test cases.

4. Measurements of the Framework

This section describes in depth the framework's several aspects. Evaluation and creation of V and V methods and instruments. Dimensions are descriptive components in the V and V structure. Scopes provide a direction and road map for users with unique requirements for V and V procedures. Overall VALU3S Research Description of Action (DoA) detailed the framework structure. The proposal outlined six dimensions and their respective layers. A survey was conducted among the VALU3S project's 43 partners, with these fundamental dimensions and layers as the foundation for discussion. As a outcome of the questionnaire, the eight categories of the VALU3S paradigm were developed (see Fig.2). There are distinct layers for each dimension. A layer symbolizes of dealing with a aspect. The type of demand being assessed (dimension) by a V and V approach may be health or information security (layers).

4.1. Dimension

Type of Evaluation Environment This dimension is made up of components that sustenance V and V implementation through hardware, programs and configurations of network. Various environments for testing and V and V operations can be performed during system validation. These environments can provide circumstances that mirror predicted real-life settings, or they may enable V and V in expected potentially anomalous illness setups, and scenarios (Salahat et al., 2023). The V and V framework has three high-level settings. The assessments focused mostly on the structure's subcomponents as well as the system model, which is presently being developed. Among the key approaches inside this layer is the use of emulators and simulation environments.

4.2. Close devaluation environment

The next natural assessment level is the closed evaluation environment. When the prototype of the system is complete, it may be evaluated in a setting similar to how it is going to be utilized. A closed assessment environment enables monitoring and control of the evaluation process's outputs. A closed-track demonstration ground (Syed et al., 2023) is one sort of automotive domain setting where a prototype of an automated functionality may be examined, such as within an expansive area, multilane path, or high-speed zone.

4.3. Open evaluation environment

Final evaluation operations that involve testing the developed system in actual scenarios are frequently linked to assessments carried out in an open testing environment, or in-field testing.

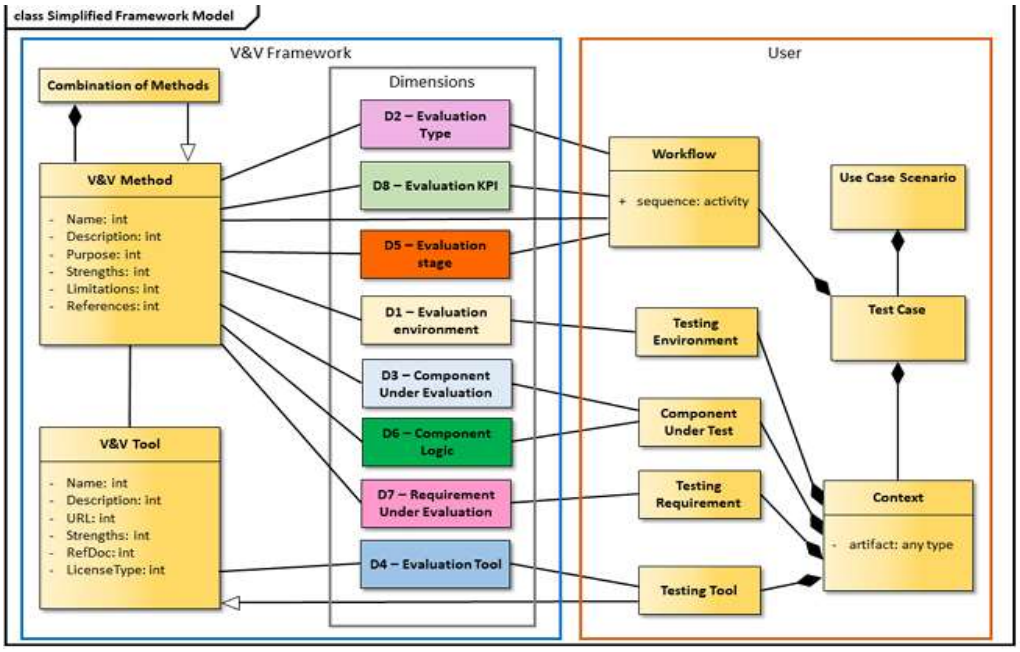

Figure 1: Types of Evaluation

Dimension2

Types of Evaluation

The goal of the Assessment Type Aspect is to group V and V methods according to the processes utilized to analyze the system. Extensive research has been conducted to ascertain and broaden the categorization of wide system models (Hamid, Muhammad, Iqbal,

Hamza, et al., 2022). These attributes are categorized into experimental and analytical methods that add to this dimension's layer in the V and V technique. Note that all V and V approaches could tackle any of the requirements stipulated inSIV-G.

4.4. Experimental Methods

Experimental techniques are founded on individual experience or research. After that, the layer is divided into three sublayers:

- **Testing**

4.5. Testing is running a system or module (hardware, software) in order to evaluate a variety of interesting features.

- **Monitoring**

  Runtime monitoring is a simple technique that involves

inspecting a system's internal operations and/or interactions with multiple outside parties to determine whether it conforms with or violates a validity specification.

- **Simulation**
  Simulation is an estimate of the processing system's behavior over time.

\

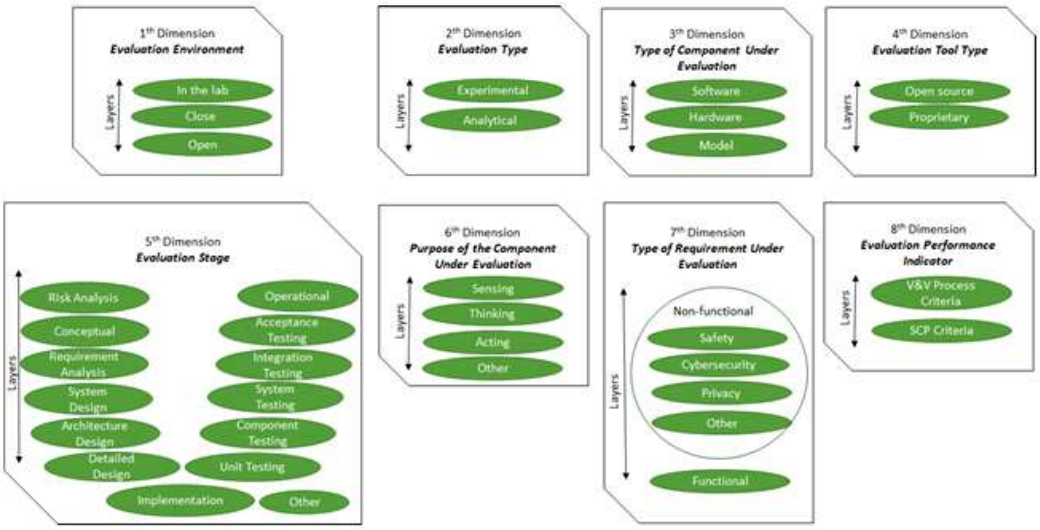

Figure 2: Dimensions layer

4.6. Analytical Methods

Analytical techniques rely on examination or logical reasoning. This layer is furthermore splits into the following three sublayers:

- **Formal**
  Formal approaches, which rely on formal mathematical assertions of correctness, are the most thorough V and V methodology.
- **Semi-formal**

4.7. Methods that adhere to formal frameworks are called semi-formal methods. Unfortunately, these systems rely on human deductive reasoning and interpretation to extract outcomes due to inadequate semantics.

- **Informal:**
- **Informal V and V approaches do not follow established concepts or mathematical underpinnings in analysis.**

Dimension3

This dimension defines the components on which V and V operations rely or can be carried out at three levels (notice that an amalgamation of elements can also be considered as an ensemble or part of a system).

- **Software**

Software refers to software elements that interact with a system's physical components.

- **Hardware**

Hardware is the tangible element of a computing system.

- **Model**

The model is a thorough representation of a system.

Any code-written functions for software that need to be examined and verified are known as software pieces. This includes software component integrations as well as any software-in-the-loop system (Ahamed et al., 2018). Testing and verification are necessary for hardware components such as processor chips, cameras, connectors, sensors, device-in-the-loop, and hardware integrations. When we talk about models, we mean applying a V and V process to any element—like Simulink models—that is described as a framework.

Dimension4

Evaluation Tool This dimension specifies the tool used for assessing a system or part of the IV-G standards. During testing, a variety of tools were created and released by commercial vendors, which were well received by the market. There are numerous approaches for characterizing a tool, including the number of processing resources required, the extent of robotics, whether it is standard-compliant, and the level of uptime. Certain instruments may be free to use, with documentation made available for free to the public. Some instruments are proprietary, thus there may be costs associated with using and extending them. However, some of this expenditure may be ascribed to certification under various SCP standards. The assessment instruments have the following levels

- **Open Source**

Open source is code in its entirety that is made available for modification and distribution.

Proprietary

Exclusive software or tools are sometimes known as non-free or closed-source software.

Dimension5

Evaluation Early phases of testing procedures to confirm that the system is constructed appropriately are where stage V and V operations are often carried out at different stages of the design process. On the other hand, validation procedures are usually

required in the later phases to ensure that the system delivers the desired services. Development strategies that are predicated on the widely used V-model (Awais et al., 2023) are typical. Verification, sometimes in the form of testing, is the focus of the activities carried out on the right side of the V-structure, aside from verification duties like reviews, assessments, and tests conducted on the outcomes of each phase on the left side. Conversely, validation tests are carried out to ensure that the system accurately executes its intended functions and complies with applicable safety, security, and privacy requirements. In short, the purpose of this aspect is to help determine the evaluation activities carried out at various phases of growth. These levels have been established for this purpose:

4.8. Concept In this stage, product feasibility is evaluated

- **Requirement Analysis/engineering**

The process of assessing customer expectations regarding a new or changed product.

- **System Design**

The process of establishing a system's architecture, components, interfaces, and data to suit certain requirements.

- **Architecture Design**

The process of defining a set of software and hardware parts, as well as their connections, to build a system.

- **Detailed Design**

The process of enhancing and expanding the fundamental design of an element or system until it is ready to be implemented.

- **Implementation**

Programming for computers is used to convert an engineering norm or procedure into a software/hardware element or another computer system.

- **Unit Challenging**

Checking whether or not components meet their functions. Evaluating both the functional and the non-functional needs for comprehensive system testing.

- **Acceptance testing**

As part of the edit delivery process, they check to see if their furnishings sofa specifications or contracts have been followed.

- **Operation**

These mature after the system has been delivered and is functioning.

- **Risk analysis**

The process of understanding the nature of perils and estimating their level of risk.

- **Other**

Stages not addressed in the preceding tiers. The layers were influenced through the V-model phases, however, the structure is not used in the same way. The "Other" layer has been introduced to facilitate the concern of additional doings in the "Risk Analysis" layer.

5. Conclusion

A multi-domain framework for characterizing and classifying V and V processes, concluding that different methods and tools can be fully classified by virtue of the dimensions and artifacts of the VALU3S framework. A digital library has also been established to provide users with information on tools and techniques as well as a working example of the framework. The VALU3S architecture served as the foundation for the creation of the content categories, and the repository was constructed on top of Plane CMS. There are 52 assessment scenarios, 12 use cases, 29 implements, and 55 V and V methodologies in the online repository. 43 Valu3S project members supplied 23 standards, and 193 test cases connected to 155 requests. The digital repository makes it simple for researchers and practitioners to learn about and access relevant V and V resources.

References

Ahamed, M., Tewolde, G., & Kwon, J. (2018). *Software-in-the-Loop Modeling and Simulation Framework for Autonomous Vehicles* (p. 0310).

Awais, M., Tahir, M., Farid, R., Zubair, S., Iqbal, M. waseem, & Hamid, K. (2023). *Guide-A Tool To Detect The Gui Elements To Enhance The Efficiency Of Testing*. *42*, 55–69.

de la Vara, J. L., Ruiz, A., Attwood, K., Espinoza, H., Panesar-Walawege, R. K., López, Á., del Río, I., & Kelly, T. (2016). Model-based specification of safety compliance needs for critical systems: A holistic generic metamodel. *Information and Software Technology*, *72*, 16–30.

Goncharov, S., Neves, R., & Proença, J. (2020). Implementing Hybrid Semantics: From Functional to Imperative. In V. K. I. Pun, V. Stolz, & A. Simao (Eds.), *Theoretical Aspects of Computing – ICTAC 2020* (pp. 262–282). Springer International Publishing.

Hamid, K., Ibrar, M., Delshadi, A. M., Hussain, M., Iqbal, M. W., Hameed, A., & Noor, M. (2024). ML-based Meta-Model Usability Evaluation of Mobile Medical Apps. *International Journal of Advanced Computer Science and Applications (IJACSA)*, *15*(1), Article 1.

Hamid, K., Iqbal, M. waseem, Aqeel, M., Liu, X., & Arif, M. (2023). *Analysis of Techniques for Detection and Removal of Zero-Day Attacks (ZDA)* (pp. 248–262).

Hamid, K., Iqbal, M. waseem, Aqeel, M., Rana, T., & Arif, M. (2023). *Cyber Security: Analysis for Detection and Removal of Zero-Day Attacks (ZDA)* (pp. 172–196).

Hamid, K., Iqbal, M. waseem, Ashraf, M. U., & Gardezi, A. (2022). Intelligent Systems and Photovoltaic Cells Empowered Topologically by Sudoku Networks. *Computers, Materials & Continua*, *74*, 4221–4238.

Hamid, K., Iqbal, M. waseem, Muhammad, H., Fuzail, Z., & Nazir, Z. (2022). ANOVA Based Usability Evaluation Of Kid's Mobile Apps Empowered Learning Process. *Qingdao Daxue Xuebao(Gongcheng Jishuban)/Journal of Qingdao University (Engineering and Technology Edition)*, *41*, 142–169.

Hamid, K., Iqbal, M. waseem, Nazir, Z., Muhammad, H., & Fuzail, Z. (2022). Usability Empowered By User's Adaptive Features In Smart Phones: The Rsm Approach. *Tianjin Daxue Xuebao (Ziran Kexue Yu Gongcheng Jishu Ban)/Journal of Tianjin University Science and Technology*, *55*, 285–304. https://doi.org/10.17605/OSF.IO/6RUZ5

Hamid, K., Muhammad, H., Iqbal, M. waseem, Bukhari, S., Nazir, A., & Bhatti, S. (2022). ML-Based Usability Evaluation Of Educational Mobile Apps For Grown-Ups And Adults. *Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)*, *41*, 352–370.

Hamid, K., Muhammad, H., Iqbal, M. waseem, Hamza, M., Bhatti, S., Bukhari, S., & Bahadad, A. (2022). Extendable Banhatti Sombor Indices For Modeling Certain Computer Networks. *Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)*, *41*, 69–87.

Ibrahim, A., Al-Rajab, M., Hamid, K., Aqeel, M., Muneer, S., Parveen, M., & Saleem, M. (2023). *Usability Evaluation of Kids' Learning Apps* (p. 10). *IEEE Standard for System and Software—ProQuest*. (n.d.). Retrieved April 28, 2024.

Iqbal, M. W., Hamid, K., Ibrar, M., & Delshadi, A. (2024). Meta-Analysis and Investigation of Usability Attributes for Evaluating Operating Systems. *Migration Letters*, *21*, 1363–1380.

Rasool, N., Khan, S., Haseeb, U., Zubair, S., Iqbal, M. waseem, & Hamid, K. (2023). Scrum And The Agile Procedure's Impact On Software Project Management. *Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)*, *42*, 380–392.

Salahat, M., Said, R., Hamid, K., Haseeb, U., Ghani, E., Abualkishik, A., Iqbal, M. waseem, & Inairat, M. (2023). *Software Testing Issues Improvement in Quality Assurance* (p. 6).

Schumann, J., & Goseva-Popstojanova, K. (2019). *Verification and Validation Approaches for Model-Based Software Engineering* (p. 518).

Syed, W., Ahmed, A., Zubair, S., Iqbal, M. waseem, Arif, S., & Hamid, K. (2023). *Fuzzy-Based Expert System For Test Case Generation On Web Graphical User Interface For Usability Test Improvement*. *42*, 549–565.

Verification and Validation of Automated Systems' Safety and Security | VALU3S Project | Results | H2020. (n.d.). CORDIS | European Commission. Retrieved April 28, 2024.

Verification and Validation: Overview. (n.d.). AcqNotes. Retrieved April 28, 2024.

Yang, Y., Mclaughlin, K., Littler, T., Sezer, S., Im, E. G., Yao, Z., Pranggono, B., & Wang, H. (2012). Man-in-the-Middle Attack Test-bed Investigating Cyber-security Vulnerabilities in Smart Grid SCADA Systems. In *IET Conference Publications* (Vol. 2012, p. 8).

Zafar, Z., Hamid, K., Kafayat, M., Iqbal, M. waseem, Nazir, Z., & Ghani, A. (2023). AI-Based Cryptographical Framework Empowered Network Security. *Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)*, *42*, 497–510.