Adaptation of Digital Twins as a methodology for management and development of Secure Software Systems

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Abstract

System development is frequent nowadays, and maintaining an ideal degree of security and trustworthiness remains challenging. However, research shows that software developers usually lack the knowledge and skills required to design safe software systems. Such expertise ensures that, in addition to adhering to the safe software development lifecycle, the relevant security parameters are fulfilled. Engineers and developers are always concerned with monitoring, tracking, and implementing critical product requirements. However, as technology evolves, digitization brings several opportunities for more sustainable system engineering and administration. With the aid of digital twins, a dynamic digital representation of a physical system is updated and maintained to build a more detailed virtual replica of the system. For better administration and faster processing, we believe digital twins to be a superior approach to examine the enhanced output and specified structure of safe software systems and their implementation. This article discusses a methodology for designing and monitoring safe software with the use of digital twins. It also describes how it works and how it may be used to make software systems more secure.

Keywords: DTs (Digital Twins), RTM (real-time monitoring), (SSD) Secure Software Development, (DTT) Digital Twins Technology, SDLC (Software Development Life Cycle), SSDLC (Secure Software development Life Cycle)

1. Introduction

As we progress into the digitalization age, emerging technologies such as smart manufacturing, machine learning, and product visualization will have a tremendous impact on enhancing product production and efficiency. There has recently been a significant amount of discussion on how real and virtual places interact. Digital twins are employed for more than simply representation; they may also predict how a product will behave and function once developed. Throughout a product's life cycle, design, production, and visualization all have a major impact on the development or manufacturing process. Furthermore, because of its ability to connect vast amounts of data for fast simulation, the digital twin offers the potential for real-time process and product development [1]. A good product, however, is regarded as being generated by providing a full connection between the product's physical model and virtual model, working in both ways to collect information from both models and give a more clear and concise view of the product's development [2]. There are increasing software vulnerabilities and security issues as Internet services and real-time interaction-based smart devices proliferate. Because of the complexity of software systems and the large number of connected users, creating secure software is becoming more challenging [3, 4]. Hackers target users of these systems and attempt to gain unauthorized access to their computers by introducing malicious software such as worms, trap doors, and spyware, among other things [5].

Organizational security strategies have traditionally been concentrated on system security, and most of them routinely spend large sums of money on different security instruments. The development of safe software remains difficult for many developers, who confront several problems from the beginning to the end of the process. In the current context, development methodologies and processes are evolving rapidly, with a shift toward a more visual representation of the whole process. Digital twins are a helpful simulation tool for understanding a more realistic simulation in many systems and processes since they are based on expert knowledge and information gathered from existing systems [6]. One of the most important activities in the process of creating and maintaining safe software is encouraging the organization, administration, and monitoring of data about the specifications for the creation by testing and affixing security patches to make it more dependable and secure [7]. By providing rational project planning and resource allocation, minimizing cost overruns and rework components, and aiming to enhance customer and stakeholder satisfaction, proactive management may assist us in achieving increased preventability [8]. At the moment, modelling and simulation are widely used to enhance system design, implementation, and maintenance [9].

The rest of the paper is described as: Section 2 contains background study for the formation of fundamental base and for problem identification. In section 3, the discussions of need of secure software development. Adaptation of DTTs for improved SSD in section 4. In section 5, discussion, results and conclusion is made on the basis of observations and theories discussed.

2. Background Study

The concept of digital twins is not new; Grieves first discussed them in his 2003 course on "product lifecycle management." Although the concept was not defined at the time, a digital twin prologue that covered physical things, virtual products, and their links was recommended [10].

In 2021, Mengnan Liu et al., conducts. The concept's evolution, the primary enabling technologies for three aspects, and fifteen possible sorts of industrial applications in each lifecycle phase are all outlined. Based on this, findings and suggestions for future digital twin research are presented as a sequence of life phases [11].

In 2020, Aidan Fuller et al. claim to have offered a comprehensive review of the primary enabling technologies, issues, and continuing research on digital twins. They also claim to have performed a research on the easy integration of data and facts in either direction between real and virtual devices. Furthermore, applications of digital twins using Internet of Things and artificial intelligence technologies assist us in learning how to properly integrate digital twins with a number of current trending technologies [12]. The author performed a reiteration of an earlier research that investigated the efficiency of security needs templates to assist in the identification of security requirements. The primary goal of this task was to conduct an analysis of this methodology and see how well the earlier results translate into the present context [13].

In 2018, Martin Kunath et al. presented the conceptual foundations and potential applications of a digital twin for a manufacturing system-based decision support system for the order management process. The digitalization of the manufacturing system is a potential solution for resolving these issues, such as adapting to evolving customer needs, rising resource costs, and increasing unpredictability [14].

In 2016, James Nutaro, Glenn, describe a model to withstand the rigors of reliability analysis and supervisory control, for which similar models are used to determine failure probabilities and rates, which are the basis for the models developed for this demonstration [15] and peviously Michael Grieves published a white paper in 2014 that outlined how the enabling technologies of DTs have expanded enormously while encountering challenges in a range of application, similarly, the other authors also provide a comprehensive analysis of the digital twin concept model, as well as the fulfilment needs and application scenarios [16, 17].

In table 1, various literature studies along with objectives of formulation of research that helps to build up the gap and creating the new insights in the topic.

Table 1: Description of selected literatures related to study

S. No.	Authors Name	Paper Title	Year	Objectives
1.	Michael Grieves	Digital twin: Manufacturing excellence through virtual factory replication	2014	Introduce DTs and Comparing a DT to its Engineering Design" to better understand what was created against what was intended [17].
2.	James Nutaro et.al,	Towards improving software security by using simulation to inform requirements and conceptual design	2016	Proposed employing modelling and simulation early in the life cycle of a system to increase security and save costs [18].
3.	Kazi Masudul Alam et. al.	C2PS: A Digital Twin Architecture Reference Model for the Cloud-based Cyber-Physical Systems	2017	A digital twin architecture reference model for the C2PS, a cloud-based CPS, in which the model aids in distinguishing varying degrees of fundamental and hybrid computation-interaction modes [19].
4.	Ron Bitton et. al.	Deriving a Cost-Effective	2018	Describes a technique for producing a

		Digital Twin of an ICS to Facilitate Security Evaluation		DT that is focused on security testing, is network-specific, economical, and extremely dependable [20].
5.	Charles Weir et. al.	Interventions for long-term software security creating a light weight program of assurance techniques for developers	2019	Since the interventions may be successful with teams that have little or no security knowledge, they are used by many development teams, enhancing software security globally [21].
6.	Fei Tao et.al	Digital Twin in Industry: State-of-the-Art	2019	This study examines the state-of-the-art of DT research with regard to essential DT components and current development and main applications of DT in industry [22].
7.	Mengnan Liu et al.,	Review of digital twin about concepts, technologies, and industrial applications	2020	A complete and in-depth assessment of various literatures in order to analyses the digital twin from the perspective of concepts, technology, and industrial applications [13].
8.	David Jones et. al.	Characterizing the Digital Twin: A systematic literature review	2020	The characterization of the DT, the identification of knowledge gaps, and the necessary topics for research consideration are all presented by a thorough examination of the literature [23].
9.	Shaun West et al.	Digital twin providing new opportunities for value co-creation through supporting decision-making	2021	Suggest to the use of DTs to improve the significance of co-creation by assisting decision-making [6].

On the basis of real-time sensing, expert systems, and historical data, the digital twin is a sophisticated simulation tool that offers a virtual world that helps to clearly copy things and recommend the most viable and right answer to the product development or manufacturing process [5]. Since then, the implications of DTs have been more obvious, as their popularity and study application areas in this field have grown significantly. The notion of digital twins is one of the common approaches being used by developers and various industries to connect actual and virtual things with extensive data and information gathering [24].

DTs also provide simulation, perception, and value-added services to aid in the product development process. By digitally duplicating issues and problems, digital twins help us grasp them. A product has real-time information set for efficient processing. Using DTT for SSD to enhance the development process, diagnostics, and representation of societal expectations in the product development organizational context necessitates much research and effort in this area.

3. The significance of safe software development

The most important of these features is the incorporation of security activities into the application development process (creation of security requirements, security design analysis, developer guidelines, code review, penetration testing, and so on). To ensure that security operations do not stymie application development, the appropriate amount of security engagement in development is determined by the importance of the application to the company.

The developing system's replica creation aids in understanding the difficulties, challenges, and adjustments required in the programme. Real-time data services may be used to visualize the main requirements, security components, and their execution utilizing digital twins [19, 25]. We provide a framework for comprehending the adaption of SSD's standard approach to real-time development process monitoring.

3.1 Software evaluation and feature optimization: As previously said, DT can visualize, automate, and adapt to future components for further deployment in many other systems for items that are now in use. To limit the chances of failure and rejection, it is essential to keep note of all positive and negative aspects of a product evaluation. To enhance the construction of complete system models that optimize product visualizations and also aid in controlling and guiding the problems in a software document, a better approach for idea generation, processing, selection, and administration is necessary. Furthermore, optimization facilitates the adoption of certain alterations for a quick and effective production process.

3.2 Asset management: This is a critical component of product manufacturing because it is the systematic practice of preserving, monitoring, organizing, and managing the value of assets in a manner that maintains performance and minimizes hazards throughout the product manufacturing method [23]. Digital twins help predict future changes by replicating functions and comparing previous data to the most current.

3.3 Real-time Monitoring: Real-time monitoring allows the process to operate in real time. It is feasible to analyze and measure throughput in a variety of situations with DTs [22]. They are also useful for collecting data on a regular basis and visualizing it in order to categorize the correct production sequence. Real-time monitoring in product development procedures uses contemporaneous or current data with actual occurrences of operations to replicate client interactions with the product.

3.4 Performance prediction: Predictable factors such as throughput, quality constraints, resource consumption, and demands allow us to better understand the created output.

For performance prediction utilizing DTs, a model-based prediction technique is employed, in which prediction models are developed using features parameters and extracting information is tested for the built-in performance model [25].

3.5 Perception and forecasting: The digital twin outperforms the product development life cycle. Digital twins are designed to foresee the behaviour of physical items under various environmental circumstances and in the future, as well as to understand how physical products act under diverse development settings.

4. Development through Digital Twins

The product development process includes several adjustments before, during, and after the product is delivered. Working continuously in the correct direction to attain the specified goals might be time-consuming at times, but by using DTT, we can generate a visualization of the ultimate output, which also helps in handling difficulties faster than conventional approaches. However, the following is a description of adapting DTs for safe software development, as we can see that a parallel development process with security objective determination aids in attaining objectives in a timely way and generates a more dependable system.

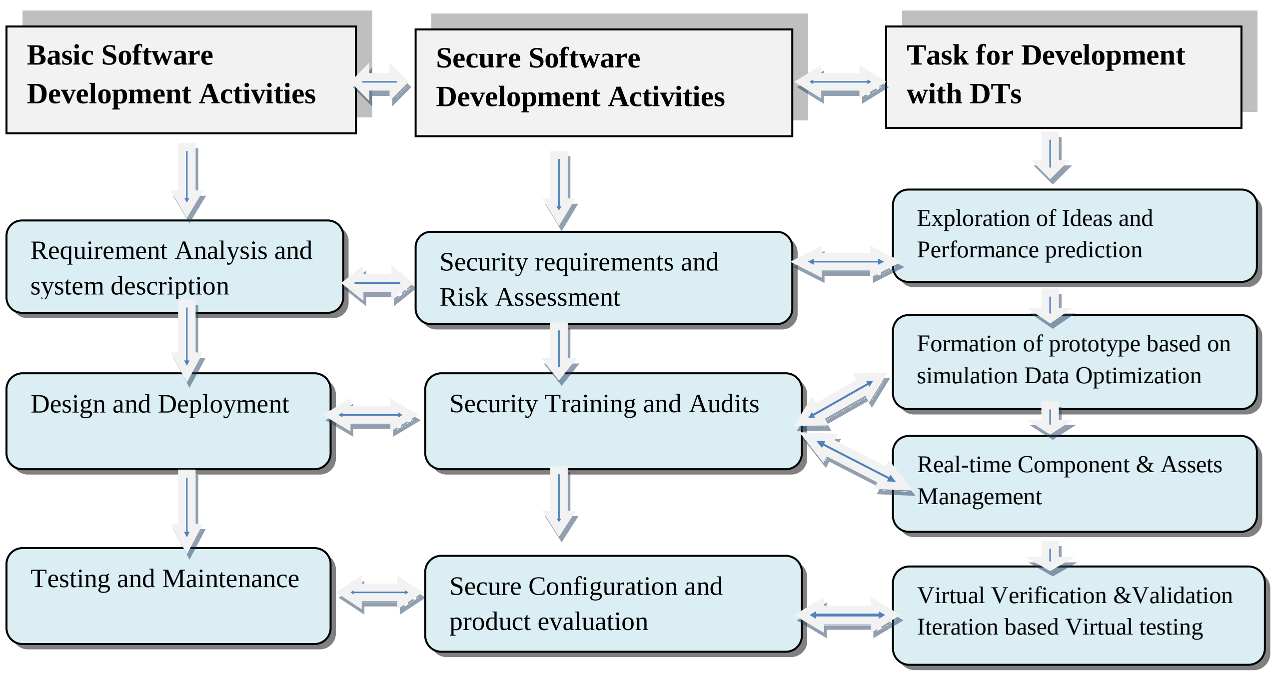

***Fig 1:** A framework for Development and management of software development security tasks through simulation based DTTs.*

Figure 1 illustrates a method for incorporating safe software development utilising digital twins while accelerating the fundamental process of software development. The aforementioned framework begins the work with the elicitation of requirements, creates real-time adjustments and updates, and then moves processes through each step employing DTTs in parallel to visualize full scenarios. The following list of fundamental SDLC tasks and simulation-based activities are included in this framework:

4.1 ***Requirement analysis and description:*** Following the collection of data or needs, the pertinent and necessary requirements for the particular development process are developed. Unwanted, unnecessary, and extraneous needs are avoided.

4.2 ***Designing and Deployment:*** The modelling, manufacturing, structuring, or designing of the product is started based on the analysis and documentation of requirements. Developers then attempt to implement all the described functionalities, codes, and sustaining standards in accordance with the documented plan.

4.3 ***Testing and Maintenance:*** After the codes generated, then testing is initiated by formation of test cases to identify the issues or errors in the software development. And making software reliable to adapt particular changes and maintenance if required.

4.4 ***Security requirements identification***: security requirements are identified from various sources such as previous systems, feedbacks, review of documents related to SSD. To achieve secure systems, is important to have a list of desired requirements to be completed.

4.5 ***Security Training and Audits:*** By determining the specific security needs, examining them to discover any faults and potential improvement areas. Additionally, the development team and testing team collaborate to confirm security at every level.

4.6 ***End-product evaluation and Configuration:*** After implementation and design, the finished product is produced for testing and verification based on the SRS document [24]. It is also validated by end users and a team from the organization's inspection department before launch to ensure that the developed product's functionality and design are as desired and to make any necessary changes.

4.7 ***Pre-selection of security objectives***: It is important to have a general understanding of details for any kind of development. Data exploration and visualisation using a variety of tools, graphs, and pie charts to create the final data necessary

4.8 ***Exploration of pre-selected ideas:*** Identification and extraction of ideas previously selected and the formation of outline of goals necessary to be achieved to be done for the development.

4.9 Formation of Simulation based prototype and Data Optimization: After brainstorming methods for obtaining enduring, valuable data, optimization approaches are applied to make the criteria more precise. Additionally, a virtual, simulation-based, or event-based prototype may be produced. Data optimization helps with various adaptations for a quick and effective production process.

4.10 Real-time asset and component management: The virtual prototype makes the needed modifications and improvements for the product clear. The actual physical product design is subsequently started, along with risk and performance monitoring that is done so as to keep costs under control [6].

4.11 Virtual verification and validation: The following development procedure is based on virtual verification and validation, where engineers or developers utilize CAD (computer-aided design) and CAE (computer-aided engineering) to use a 3-dimensional edition of the product to test and verify its appropriate functioning. The release of the finished product follows.

4.12 Iteration based virtual testing and finalizes the product: By meeting the security objectives and progressing to finalize and market the product, DTT enables several iterations that enhance the development of the software system as a whole.

The management plan takes the SDLC to a different level and strengthens it. Specific aspects of our Management SSDLC solution include configurable catalogue of security controls to handle security threats, needs, and technologies, measurement metrics for security control efficacy, and general security controls for information systems for effective risk management.

5. Discussion and conclusion

The development of a more potent, safe, and dependable product is impacted by many developers' attempts to digitalize diverse technologies. The use of digital twin technology in conventional software development is beneficial in a variety of ways, including:

- Better handling of requirements
- less Time and efforts
- Make the system adaptable so it can handle changes.
- Swift and efficient delivery

By using the aforementioned framework, one may be better able to comprehend the security goals that must be met early on and make continuous monitoring effective for putting the required adjustments into the development process. In this paper, we suggested a digital twin-based integrated and secure development architecture. We give security advice and security investigation situations by using the SSDLC's security practices and operations. To maintain the system secure, we combine software development and management tasks. To do this, we use a simulation tool to provide a better solution to the relevant issues and to aid in real-time improvement and future modification. Future work will demonstrate how DTs may be used to enhance requirement gathering, get rid of extraneous data concerning inaccurate demands, and prevent security breaches that might cause system failures. By performing a comprehensive study and working in this field to improve the development process, diagnostics, and representation of societal demands in the organizational environment of product creation, we made an effort to construct a framework or life cycle model. To better serve users and developers, we will focus on network-based system dependability and security challenges in the future.

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