AI-Enhanced Automation for DevOps: Employing a Model-Driven Strategy to Facilitate Continuous Advancement in Cyber-Physical Systems

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Abstract: ***The primary objective of this paper is to examine the role of AI-augmented Automation in DevOps in enhancing the modeling of Cyber-Physical Systems (CPS). With the increasing complexity in the development and operation of CPS, there is a need for a more efficient engineering methodology. This paper aims to provide a deeper understanding of a model-based framework for effectively supporting the software and system engineering of large and complex CPS through the use of AI augmentation. In recent years, DevOps has gained popularity, promoting closer collaboration between developers and operations personnel for system development and integration. While AI technology has the potential to be beneficial in this context, its widespread use is currently limited. However, AI is anticipated to have a significant role in automating processes for major corporations in the future. The ultimate goal of this project is to create an integrated AI-augmented framework for the continuous automatic development of CPS, utilizing a model-based approach. The paper will extensively cover Model-Driven Engineering (MDE) concepts and methodologies to provide a model-based framework with the relevant approaches and associated technology.***

Keywords: Artificial Intelligence (AI), Internet of Things (IoT), Artificial Neural Networks, Machine Learning, DevOps

1. Introduction

Several application sectors in the field of artificial intelligence have gained significant attention, including the Internet of Things, Web of Things, and "Smart Systems" settings. As Cyber-Physical Systems (CPS) standards continue to evolve, AI approaches, models, and tools face various challenges. Engineers must consider non-functional criteria such as memory and CPU resource limitations, energy consumption, technology and human safety, delay-tolerant communications, and autonomous decision-making [2]. CPS represents a novel system that integrates computing, communication, and control to monitor and control the physical environment through coordinated interactions with sensors and actuators. The objective is to establish a consistent language and taxonomy within the CPS domain to foster unified communication [2]. This model aims to define a modeling language and facilitate communication among engineering process stakeholders to encapsulate essential CPS concepts. In the realm of Cyber-Physical Systems, computational algorithms seamlessly integrate with physical components, employing multiple decision-making entities known as multi-agents. CPS applications, often referred to as Smart Factories, are increasingly adopting artificial intelligence (AI) to enhance automation. Deep learning is proving beneficial in areas such as factory planning, scheduling, and maintenance, enabling more efficient decision-making in complex data environments [3]. To achieve these advancements, a model-based framework utilizing Model-Driven Engineering (MDE) principles is being developed. This framework facilitates the analysis of data acquired during both design and runtime phases, resulting in AI-enhanced solutions that can be tested in real-world scenarios, particularly in advanced CPS settings. Employing DevOps practices, the framework bridges IT operations and software development, aiming to enable AI for IT operations (AIOps) and automate decision-making processes. The project emphasizes the importance of building AI systems with accountability and explainability [4]. The project also involves research to explore how continuous deployment and operations management influence businesses. The AI-enhanced framework allows DevOps teams to analyze live and historical event streams, extract valuable insights for continuous improvement, accelerate deployments, enhance communication, and reduce downtime through proactive detection [5]. Overall, the project focuses on advancing AI for IT operations to automate decision-making and streamline system development tasks.

2. Problem Statement

In The primary focus of this paper is to enhance our comprehension of how AI augmentation can effectively address the challenges presented by Cyber-Physical Systems (CPS). CPS examples found in Industry 4.0, healthcare, autonomous vehicles, and smart grids represent highly interconnected systems, often embedded, where software enables increasingly sophisticated functionalities [6]. Despite the growth in scale and complexity of CPSs, they encounter novel issues upon real-world deployment. Utilizing artificial intelligence (AI) approaches undoubtedly holds significant potential to positively impact the entire development process. The paper's approach allows for the examination and analysis of specialized AI-augmented solutions within the project's architecture before their validation in real-world industrial environments, which frequently involve intricate CPSs of varying sizes [6]. Many major corporations have already recognized the future potential of automating work processes through AI. While an increasing number of companies are making substantial investments in software development, it's essential to note that AI is still in its early stages as a tool for development and design.

3. Literature Review

Merging Blockchain Within the domains of DevOps and CPS engineering, a significant aspect involves the integration of artificial intelligence, especially machine learning. In regulated industries, the adoption of these concepts has enabled systems to autonomously make decisions and take actions, often with minimal human intervention [6,7]. Consequently, it becomes imperative to formulate a response strategy to ensure the safe and beneficial utilization of artificial intelligence technologies. This strategy needs to address both the ramifications of computer-based decision-making and the ethical challenges that may arise. It should also consider the legal definition of artificial intelligence [7]. The overarching objective of the CPS engineering process is to develop systems in a responsible manner, instilling public confidence in their functionality. This entails supporting two critical aspects: explainability [7], which involves the ability to elucidate and defend decisions, and responsibility [7,8], which encompasses justifying actions and choices made by stakeholders involved in the CPS engineering process. For a successful digital transformation, AIOps plays a crucial role. Forward-thinking executives leverage AIOps to imbue IT data with meaning, facilitating automation and yielding enhanced business outcomes through operational transformation. Gartner [7], [8] coined the term AIOps to characterize solutions employing AI/ML methodologies to address DevOps challenges. The proliferation of technologies within IT infrastructure leads to increasingly intricate interdependencies. This complexity is compounded as the IT infrastructure serves a growing array of corporate services and applications. Given the rapid and frequent updates to these elements and the underlying infrastructure, human capacity falls short in keeping pace with these changes, necessitating machine assistance. AIOps creates real-time, context-rich data repositories to reduce noise in existing performance and fault management systems, ultimately streamlining automation and reducing resolution time. Integrating AIOps [9] into the DevOps pipeline poses a significant challenge while aiming to enhance continuous deployment and operations management. AIOps employs data analysis and predictive modeling to automate standard operational processes with AI assistance. Combining AIOps with machine learning harnesses extensive data for accelerated root-cause analysis (RCA) and reduced mean time to repair (MTTR) [9]. By providing intelligent, actionable insights, AIOps enables continuous improvement in IT operations, leading to time and cost savings. In conjunction with Model-Driven Engineering (MDE), AIOps serves as a valuable complementary tool for the development of Cyber-Physical Systems (CPS), given its efficiency and adaptability [9]. Over the past two decades, Model-Driven Engineering (MDE) has gained significant popularity as a valuable tool for software developers. One of its primary advantages lies in elevating the level of abstraction, which facilitates the handling of complex systems like Cyber-Physical Systems (CPSs) [10]. The increasing utilization of models as deliberate abstractions of systems and their environments has given rise to new challenges, such as the concept of digital twinning, particularly in industrial applications. Initially, MDE was primarily employed for code generation from abstract, platform-independent descriptions at a high level. However, its scope has evolved over time to encompass a broader spectrum of intricate software engineering tasks, including model-based software testing, verification, and measurement [10]. MDE's contribution to projects manifests in three key ways: enhancing abstraction principles and approaches, streamlining automation of operations, and facilitating the integration of new technologies throughout the design and development processes. In the context of the AIDOaRt project, MDE plays a pivotal role in transforming and managing diverse data originating from various engineering processes, thereby contributing to explicit modeling within different project domains [10,11]. Business leaders recognize that transitioning to model-driven techniques holds the promise of heightened productivity and improved software quality. Consequently, MDE is the chosen software engineering paradigm for developing the AIDOaRt framework.

To enhance the essential Infrastructure and Platform of various Cyber-Physical Systems (CPS) under development, it is imperative to create and utilize complementary AI-augmented features tailored to the specific demands [11]. As part of the project's objectives, an AI-enhanced Toolkit will be established to significantly enhance the capabilities required for various CPS development activities. To facilitate the different stages of the development lifecycle, specific AI support toolkits will be incorporated.

AI for Requirements: Artificial intelligence, particularly machine learning algorithms, will play a crucial role in early design stages by aiding in requirement elicitation, providing suggestions, and ensuring consistency checks. Furthermore, AI will improve analysis and support operations in later development phases, incorporating earlier requirement documents into the elicitation process. AI will also offer suggestions for various demands based on publicly available information.

Deployment Considerations: It's important to note that this paper does not extensively address deployment operations [12]. However, the Core Infrastructure and its AI-augmented Toolkit will provide assistance in this regard, focusing on the application domain, associated standards, and norms.

AI for Monitoring: Artificial intelligence forms the foundation for run-time property verification, failure detection, predictive maintenance, and other monitoring tasks. Leveraging AI and machine learning techniques, these responsibilities involve detecting performance and system defects through trace analysis and historical data [14].

AI for Modeling: During the modeling phase, AI-based tools and techniques will facilitate better decision-making, strategy design, and suggestions. An AI-based assistant will support researchers in developing complex mixed-criticality systems, identifying relevant qualities, and offering new model-based ideas. AI and machine learning technologies will aid in generating and updating extensive model views using diverse modeling approaches, contributing to model improvement and verification, especially in security applications [14].

AI for Coding: AI will be employed to create coding tools that enable individuals with limited or no programming skills to build applications. These tools will primarily focus on learning code generation patterns from samples using machine learning and artificial intelligence [15].

AI for Testing: AI-based tools and methods will be developed for testing at various levels, utilizing artificial intelligence and machine learning technologies to acquire, evaluate, and monitor data models for reliable unit tests. Pattern recognition algorithms will be utilized to identify high-quality test suites, particularly those with a higher likelihood of detecting failures [15,16].

4. Future of AI Augmentation

Finance The future outlook for AI augmentation in the United States appears optimistic, driven by recent technological advancements that support the growth of Cyber-Physical Systems (CPS). These developments have brought us closer to the widespread adoption of CPS, contributing to the promising future of AI augmentation. Key factors shaping this future include the versatility of sensors, spanning macro to nano sizes, capable of detecting a wide range of natural phenomena and various materials, including physical variables, chemicals, fluids, solids, and biological substances. Additionally, the proliferation of alternative energy sources and energy collection methods, global access to satellite and wireless communications, and the increasing number of internet users are contributing to the growth of AI. Furthermore, the rapid advancement and affordability of computing and storage devices are driving progress in AI. A skilled workforce and a solid foundation in CPS are fueling this growth, even though some challenges exist. The deployment of fully self-driving vehicles is anticipated to offer safer and more efficient transportation, particularly benefiting elderly individuals by enhancing their independence and self-esteem. Notably, advancements like Carnegie Mellon University's self-driving car in the DARPA Urban Challenge showcase the potential of AI-driven technologies in practical applications. Looking ahead, AI-powered DevOps systems will play a crucial role in analyzing corporate objectives and providing recommendations for infrastructure design and regulations. As the number of CPSs increases, engineers will need to revamp their educational programs, giving rise to a new field of engineering that integrates cyber and physical components. Essential learning outcomes for engineers will encompass control theory, physical/mechanical properties, and software expertise [16,17,18].

5. Economic Advantages in the US

The United States, which used to dominate the global microelectronics sector, has faced challenges due to its dependence on foreign suppliers for advanced semiconductor manufacturing, crucial for AI-powered military systems and various industries. The potential of artificial intelligence (AI) to transform business operations is widely recognized by CEOs. The deployment of AI augmentation in DevOps and the modeling of complex predictive systems are predicted to yield significant economic benefits, particularly in technology and industrial sectors (CPSs). The manufacturing industry has witnessed a global increase in the use of robots, with a 13% annual growth rate since 2011, particularly in automotive and electronic manufacturing. In the United States, robot sales increased by 6% [18]. The concept of smart factories, which utilize digitally connected machines, is expanding, leading to reduced product development time, faster reusability of items, decreased product failures, and minimized machine downtime. Smart factories rely on continuous data streams from networked operations and production systems, enabling seamless communication and adaptability. Recent polls indicate that forward-thinking companies prioritize revenue-generating applications of AI over cost-saving measures. The United States is closing the technological gap with other nations, driven by international initiatives aimed at acquiring American expertise and dual-purpose technology.

6. Conclusion

This research delved into the application of AI augmentation within the DevOps framework to develop Cyber-Physical Systems (CPS). The growing demand for intelligent devices capable of interacting with their surroundings is propelled by advancements in analytics, artificial intelligence (AI), and communication technologies. Examples include autonomous vehicles that analyze and engage with their environment and smart applications that optimize energy consumption for cost savings. Beyond enhancing quality of life, CPS serves as the foundation for intelligent infrastructure, products, and services set to transform the world. The integration of artificial intelligence into DevOps, particularly through the AI-augmented toolkit's AIOps operations, supports various common engineering tasks, including requirements gathering, monitoring, modeling, coding, testing, and related activities. Leveraging Model-Driven Engineering (MDE) concepts and methodologies enables the creation of a model-based framework. This framework facilitates the examination and analysis of data collected during both the design and runtime phases, resulting in AI-enhanced solutions suitable for testing in real-world scenarios involving complex CPSs. These activities generate valuable feedback, insights, and actionable steps at different stages of the DevOps lifecycle.

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Author Profile

Sarthak Srivastava is a seasoned Senior DevOps Engineer with over five years of experience in the field. Currently affiliated with Visa Inc, a leading global financial services corporation, Sarthak has played a pivotal role in optimizing DevOps engineering practices within the fintech industry. With a Master of Science degree in Computer Science, Sarthak brings a strong academic foundation to his work. Sarthak's expertise lies in the intersection of DevOps, testing, and automation. Through his specialization in optimizing testing strategies and leveraging automation techniques, he has successfully streamlined the software development lifecycle, ensuring the delivery of highquality solutions. His knowledge spans various domains within DevOps, including continuous integration and delivery, infrastructure automation, cloud computing, and security best practices.