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Integrating AI into DevOps pipelines: Continuous integration, continuous delivery, and automation in infrastructural management: Projections for future

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Abstract

This paper explores the transformative role of Artificial Intelligence (AI) in enhancing DevOps pipelines, focusing on Continuous Integration (CI), Continuous Delivery (CD), and automation in infrastructural management. As organizations increasingly adopt DevOps methodologies to streamline software development and delivery processes, the integration of AI technologies offers significant potential for improving efficiency, quality, and responsiveness. This study reviews current practices in CI/CD and examines how AI-driven tools can automate repetitive tasks, optimize resource allocation, and facilitate predictive analytics for proactive decision-making. Additionally, the paper discusses the challenges and considerations associated with AI integration in DevOps, including cultural shifts, data governance, and the need for skilled personnel. Projections for future developments highlight the potential for AI to create smarter, more adaptive DevOps environments that align with evolving industry demands. By identifying key trends and innovations, this research provides a comprehensive overview of the future landscape of DevOps, positioning AI as a critical enabler of agility and performance.

Keywords: Artificial Intelligence; DevOps; Continuous Integration (CI); Continuous Delivery (CD); Automation; Infrastructural Management

1. Introduction

DevOps is a software development paradigm that focuses on the communication and integration of cross-functional teams and aims to enhance the efficiency of the software delivery process with CI and CD.

This methodology helps to develop and operations teams work together, which helps to deliver shorter cycles and better-quality software. However, traditional DevOps practices often face challenges such as:

- Manual Tasks: Routine tasks such as code reviews, testing, and infrastructure provisioning are often repetitive and error-prone if done manually.
- Slow Feedback Loops: If undetected early enough, such problems will take more time to resolve and, hence, slow down development.
- Limited Insights: The absence of extensive data analysis makes it difficult to take anticipatory action and fine-tune the systems.

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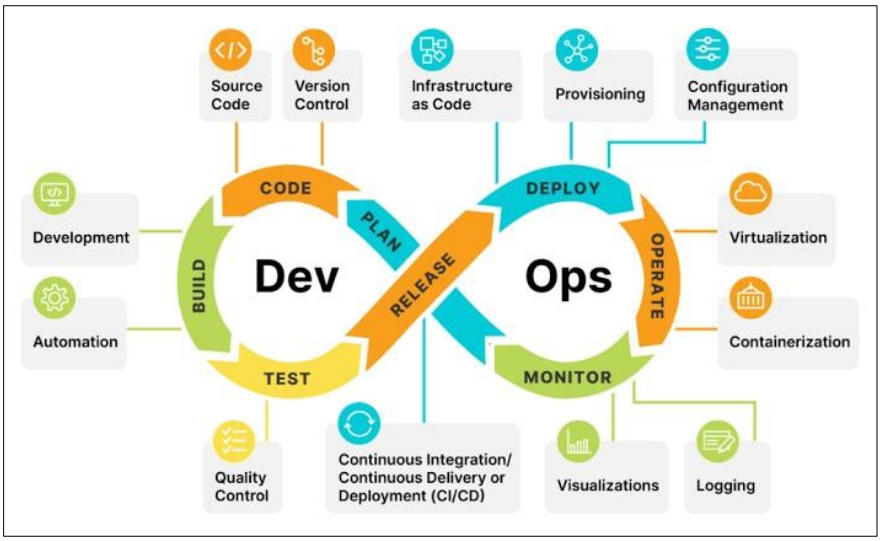

Figure 1 Continuous Integration

This results in identifying artificial intelligence (AI) as an influential technology that can help deal with these difficulties. AI's ability to analyze large amounts of data, automate complex tasks, and provide predictive insights can revolutionize DevOps workflows, resulting in:

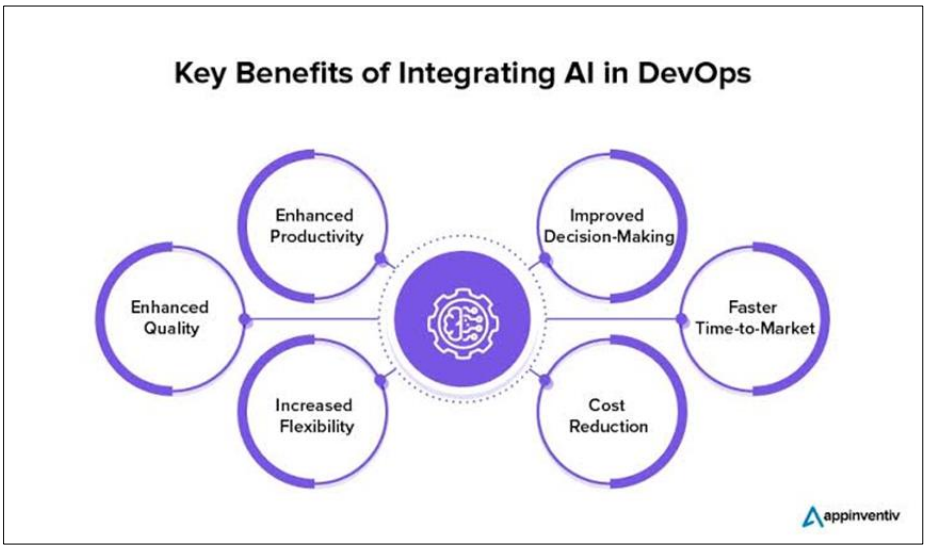

Figure 2 Key Benefits of Integrating AI in DevOps

- Increased Efficiency: AI can help reduce time-consuming and repetitive tasks so developers and operations teams can work on more critical issues.
- Faster Delivery Cycles: AI in automation and optimization can bring changes that help make development and deployment quicker and less time-consuming, allowing speedier release of software updates.
- Improved Quality: Automated code review and testing can help detect and fix problems early in software development, thus increasing product quality.
- Enhanced Agility: AI makes it easier for organizations to be more reactive to changes in market conditions and customer requirements, thus making them more responsive.

This paper will discuss the use of AI in DevOps processes, focusing on continuous integration, continuous delivery, and automated infrastructure. We will also discuss individual AI tools and techniques, their advantages, current problems, and prospects for using AI in DevOps.

1.1. AI-Powered Continuous Integration (CI)

The CI pillar refers to developers' continuous integration of code by developers in a main branch. After this, build and test automation occurs; successful builds are containerized, and release candidates are signed.

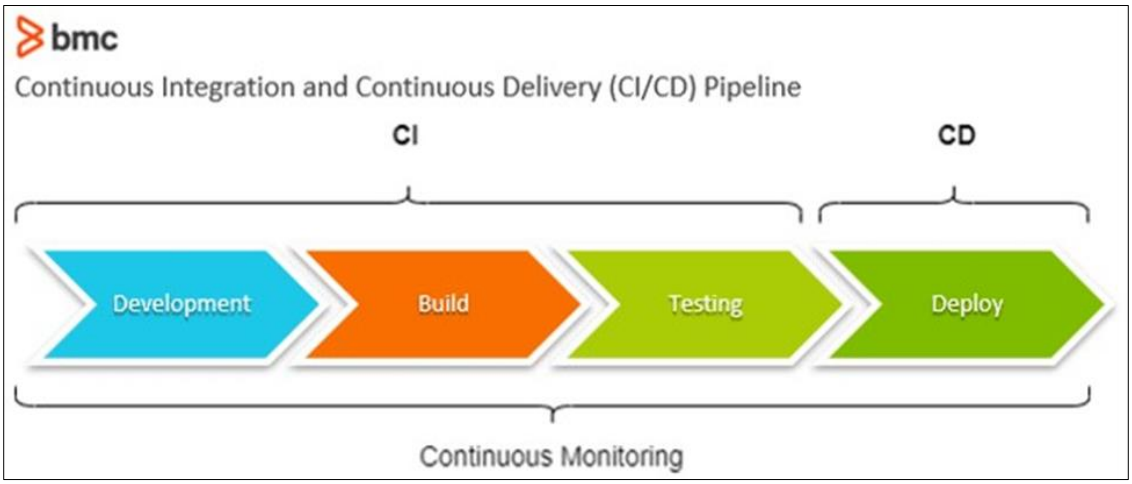

Figure 3 Continous Integration and Continous Delivery (CI/CD) Pipeline

The three main objectives of CI are to detect problems at the earliest opportunity, prevent integration issues, and provide good-quality, secure release candidates. This section explains how AI can improve every stage of the CI phase of DevOps CI/CD integration.

1.2. Code Branching

Large teams face issues managing multiple branches in DevOps, merge conflicts, and tracking problems.

AI Solution: It should also be noted that AI can help with branch management and even offer merging suggestions. AI systems can also assist developers in identifying the best branching strategies to minimize or avoid confusion.

AI Tool Example: IntelliCode by Microsoft is a tool that provides developers with AI assistance during software development; it may prove useful in branch management.

1.3. Code Commits

The idea of commits is good for maintaining the codebase, but they are also problematic because they create confusion and constantly employ different policies.

AI Solution: This also means that AI can look at the code's commit history and recommend best practices. It can also give feedback on changes made to the code in real time before the commits.

AI Tool Example: Kite is an AI coding assistant that assists with code improvements before committing to changes.

1.4. Merges

Some code changes can always create conflicts, especially when working on large, complicated projects.

AI Solution: AI tools can alert developers of likely merge conflicts and suggest ways to resolve them before they occur by learning the code's structures and patterns of changes.

AI Tool Examples: DeepCode and Sider are AI-based tools that scan and analyze code before merging to avoid merge conflicts.

1.5. Static Scanning

It can be tedious and time-consuming, sometimes leading to false results.

AI Solution: Integration with AI can improve static analysis tools. AI can learn from previous scans to make the analysis accurate and even suggest corrections for the problem that was found.

AI Tool Example: DeepCode scans through code, identifies issues with the code, and then suggests possible solutions in case of a problem based on past scans.

1.6. Builds

A project can experience build failures due to several causes, such as poor-quality code and wrong configurations.

AI Solution: Using past data and patterns, AI can predict build failures. It can also help automate the build process and handle configurations to avoid mistakes.

AI Tool Example: CircleCI Insights offers success prediction building using machine learning, which helps prevent failure.

1.7. Looking for Quality Errors and Security Issues

This can be a slow process, and it may flood the teams with potential issues to face.

AI Solution: It can improve the speed and efficiency of scan operation by identifying issues that were seen in the previous scan and prioritizing them according to their severity.

AI Tool Example: ShiftLeft looks for security risks and employs Artificial Intelligence to filter through the risks it finds.

1.8. Unit Testing

Creating and updating a set of unit tests requires a lot of time and effort, and these tests must be more comprehensive.

AI Solution: With code analysis, AI can help create unit tests that are more coverage-efficient than hand-made tests and completed quickly.

AI Tool Example: Diffblue Cover's next feature is to generate unit tests using Artificial Intelligence to increase coverage and speed.

1.9. Containerization

Unintended configurations of the containers may cause application failures and various security breaches.

AI Solution: AI can enhance and optimize the configuration process of containers.

AI Tool Example: Magalix uses historical data and current needs to define ideal containers and highlight possible misconfigurations.

1.10. Functional Integration Testing

These tests are demanding regarding the resources and time required to perform them.

AI Solution: AI can create functional integration tests based on the system's behavior, which thus requires minimal maintenance efforts.

AI Tool Example: Test. AI employs AI to produce and perform functional tests, thus reducing the need to develop test cases.

1.11. E-signatures in an Artifact Repository

This process can be time-consuming and is always vulnerable to human intervention.

AI Solution: AI can also implement the assured signing of artifacts, which ensures that only the validated code is signed, reducing the chances of human error.

AI Tool Example: There aren't many specific AI tools for this task, but existing automated DevOps tools such as JFrog Artifactory or Sonatype Nexus could incorporate AI to make the signing process as smooth as possible.

2. Benefits of Integrating AI-driven CI Toolchains

Transitioning to AI-driven CI toolchains offers several advantages for organizations

- Enhanced Efficiency: Several sub-processes of the CI process can also be automated, such as code reviews, tests, and environment configuration. This automation helps reduce the time taken for these tasks and enhances the CI process and software delivery.
- Improved Quality: Code reviews can be effectively automated, and AI can look through the code and find problems that humans might miss. This results in better quality code, a reduced number of defects, and more stability of the software.
- Predictive Analytics: Historical data can also be used by AI to predict future occurrences, like build failures. This enables the teams to prevent problem situations, which helps reduce the occurrence of failures and improve the CI process's dependability.
- Better Decision Making: AI offers relevant information obtained after analyzing data that is helpful in teams' decision-making processes. This comprises the identification of the most suitable release candidates or candidates for scaling and timing, as well as the most effective means of scaling resources.
- Consistency and Standardization: Implementing CI using Artificial Intelligence increases the adoption of rules and standards and mitigates the reliance on developers' subjective decisions. This leads to a better and uniform development process.

2.1. Difficulties of CI to AI Transformation

Shifting from traditional continuous integration (CI) to AI-driven CI comes with several challenges:

- Integration with Existing Systems: Integrating AI into an already existing CI toolchain is challenging. Executive management must be assured that adopting AI will not disrupt the current systems' operational environment.
- Skillset and Understanding: Applying AI means understanding how it works and its benefits and drawbacks. Organizations and their teams require proper training for implementing AI and especially for analyzing the results provided by such tools.
- Data Privacy and Security: AI tools usually work with large amounts of data, which might be confidential and/or proprietary. Organizations must also ensure that the use of these tools does not compromise the security and privacy of the data.
- Cost: AI tools may cost a lot of money to acquire and integrate into the organization since they may require extra hardware. The second criterion that organizations should use is the return on investment (ROI) in an effort to establish whether the value that is being derived is worth the cost.

Tool Maturity: Most AI tools currently used in DevOps are still developing and have yet to grow. Organizations must evaluate the degree of the tool's maturity and stability before adopting it.

Over-Reliance on AI: Despite the potential that utilizing AI in CI activities leads to over-reliance on it without proper knowledge, it causes wrong interpretations and errors. AI needs to be integrated with some form of control by humans or at least monitored by them.

2.2. AI-Powered Continuous Delivery

Continuous delivery (CD) is the pillar that deals with the process of building, testing, and staging the code change for Production. This is followed by continuous deployment, in which the approved releases are deployed continuously to the production environment. The purpose of CD practices is to reduce the disruption of releases and deployments and increase their frequency to increase speed.

2.3. Continuous Delivery and Deployment

The continuous delivery (CD) pillars mean that the changes are built, tested, and ready for production release in an automated manner. This may be succeeded by continuous deployment, which involves pushing approved releases to the production environment. CD practice is aimed at minimizing the disruption of release and deployment and increasing their frequency, that is, speed.

2.4. Continuous Delivery Use Cases

Orchestration of Test Environments: This involves the necessary arrangements and dispositions, versioning, and configuration of a range of environments for a team, and the test team in particular, when it comes to setting up and tearing down environments. Tools such as Harness and IBM's UrbanCode will be helpful in creating and tearing down the test environment and managing configurations as code.

Execution of Various Tests: This includes system acceptance tests, regression tests, performance tests, user acceptance tests, and security tests. SOAtest from Parasoft may help create test scenarios, check for gaps in coverage, and independently modify the test cases for new code.

Performance Monitoring of Release Candidates: Measures are required to compare the performance of the release candidates, find out which part of the program consumes the most time, and measure the performance against previous versions. Dynatrace provides a dynamic baseline of application performance based on artificial intelligence and allows teams to know when performance is low.

Automation of Artifact Acceptance Policies: Clear guidelines are required on when exactly an artifact is ready for release, and these should be implemented. Other tools, such as Harness, use machine learning to examine past deployments and test outcomes to determine future deployment trends and even approve them on autopilot.

2.5. Continuous Deployment Use Cases

Orchestration of Deployment Environments: To meet these demands, teams must address deployment environments, get them, version them, configure them, and handle data. Spinnaker is an open-source tool based on AI for managing multi-cloud deployment.

Execution of Deployment Strategies: This includes the gradual rollouts of Blue-Green, Canary, and Feature Flag. LaunchDarkly can manage feature flags, analyze usage data, and gradually release features using AI.

Testing in Production: It is crucial to apply the new releases in the live production environment. Sentry uses AI to track application usage in real time, thus instantly triggering teams to solve problems.

Restoring Production to a Previous Version: If a new release has a problem, the teams may be required to switch to the stable one quickly. StackStorm is an event-driven automation system with AI that helps define the sequence for building applications or simply rolling back an application to a previous state in case of failure.

Updating Documentation and Configuration Management Databases: Records must always be up to date. Guru uses artificial intelligence to update and maintain its records, keeping the document up-to-date.

2.6. Benefits of Automated Deployment

- Reduced Deployment Time: Automated deployment makes it easy, resulting in less time to deploy new features or update the program. This enables the teams to release changes to Production often and quickly.
- Increased Reliability: It is a fact that automation reduces human interference and thus makes the deployment process more accurate. Thus, operationalization entails that the processes involved in implementing the change are very well structured to minimize the risks of errors during the deployment phase.
- Improved Scalability: Automated deployment systems can also adjust to a higher volume of work to meet the increasing demand. Since demand increases, one can easily tweak automated processes without much interference from individuals, satisfying the need for applications to support more users and data.
- Faster Rollbacks: When there is a problem, the automated systems allow immediate revert to previous, more stable versions and hence less user disruption.
- Enhanced Collaboration: Automated deployment ensures that all the team members understand how to go about the deployment process since it is laid down. This transparency aids in the synchronization of development, operations, and quality assurance teams.
- Consistent Environments: Automation helps maintain standardization of deployment environments, reducing the 'it works on my machine' scenario, which is detrimental to stability across the various environments.
- Increased Focus on Development: By automating the mundane deployment processes, the developers can code more and enhance the features, increasing productivity and innovation.
- Better Monitoring and Feedback: Automated deployment solutions may also include monitoring features that indicate the success of the deployment, enabling teams to fix problems that arise in good time.

2.7. Challenges in Transforming to CD to Incorporate AI

Organizations may encounter several challenges when transitioning their existing CI/CD pipelines to integrate continuous delivery, continuous deployment, and AI tools, along with potential solutions:

Limited Understanding of AI Capabilities: One of the significant issues is the general ignorance of what the AI is capable of and what it cannot offer. Some team members may be expecting less than what is possible to achieve or fearing job loss. This is why training and workshops should be conducted regularly to explain how AI can complement their work, not eliminate it. Cutting misunderstandings regarding the goals and benefits of AI integration will also help.

Data Privacy and Security Issues: Using AI tools sometimes requires dealing with large volumes of information, some of which may be considered confidential. However, another issue is connected with the insecurity of AI tools. Businesses should have a good data management policy in place and choose the most secure AI tools.

Integration Complexity: Some of the applied tools will not fit well in the current systems and frameworks, which will cause program technical debt and pipeline problems. There is a need to focus on AI tools that have high integration perspectives. The support team of the tool or consultants can be hired to resolve any hitches during the tool's integration and achieve stability.

Resistance to Change: Process changes might be met with opposition, mainly from the current team and personnel. Some best practices that help change management include continuous communication, training, and support during change.

Cost of AI Tools and Training: AI tools can be costly, and when one hires team members to ensure they are conversant with the tools, the expenses increase. One must conduct a cost-benefit analysis to know whether the change is worthwhile. Ensure you source cost-effective AI tools, especially regarding the features offered, and consider gradually integrating the tool to spread the costs over time.

Dependence on Vendor Support: Because of the complexity involved in using artificial intelligence, organizations may depend on vendors. This can be a problem if the vendor needs to be more responsive or stop supporting the product. One should select vendors with a proven track record of customer support and consider tools with good community support.

2.8. AI-Powered Automated Infrastructure Management

Incorporating Artificial Intelligence (AI) in infrastructure advancement is an efficiency, sustainability, and safety innovation. With the rate of urbanization and demands for smarter infrastructure, AI offers unique approaches to solving these issues. These range from predictive maintenance to autonomous construction of structures or intelligent traffic flow. This section focuses on ten revolutionary applications of AI in infrastructure development to show how technology improves existing procedures and revolutionizes construction, city planning, and environmental conservation.

3. Ways AI is Transforming Infrastructure Development

3.1. Predictive Maintenance

AI-based predictive maintenance is a significant shift in infrastructure advancement. Since AI can access large datasets from sensors within the infrastructural parts, it can predict failure occurrences before they occur. This preventive measure increases the durability of structures vital to organizations' functioning while decreasing the number of operations prone to breakdowns and the costs incurred in the process. It changes the approach to maintenance from a breakdown-oriented one to a more proactive one.

Examples Include:

- Bridges are one of the significant critical infrastructures where vibration analysis has widely been used.
- Roadway condition monitoring
- Equipment failure prediction
- Energy consumption optimization
- Pipeline leak detection

3.2. Autonomous Construction Equipment

Autonomous construction machinery is one of the ways AI is changing the construction of infrastructures. This technology uses artificial intelligence and robotics to control excavators and bulldozers. Some of the advantages of AI in construction include reducing the time taken to complete projects through automation of repetitive or risky tasks, allowing operations to run continuously, cutting labor costs, and increasing accuracy to eliminate wastage of materials.

Examples Include:

- Excavators
- Bulldozers
- Cranes
- Drone used in surveying the site

3.3. Intelligent Traffic Management Systems

Artificial intelligence in traffic management has become one of the most innovative ways of creating a more intelligent city by managing traffic flow and safety. These systems use cameras, sensors, and GPS data to detect conditions, anticipate traffic congestion, and control real-time traffic signals. When traffic patterns have been identified, traffic management can be enhanced by city planners, thus making transportation systems in cities safer and more efficient.

Examples Include:

- Traffic flow optimization
- Traffic signal retiming
- Incident identification and control
- Real-time traffic condition information

3.4. Structural Health Monitoring

AI applied to Structural Health Monitoring (SHM) is a revolutionary approach to managing the integrity of infrastructure assets. AI enables data collected from sensors to evaluate and identify the existence of any abnormalities that may be associated with defects. This continuous monitoring helps aid the early detection of such problems as cracks or corrosion and facilitates early maintenance improvements, ensuring the safety and durability of the structure.

Examples Include:

- Bridge monitoring
- Building integrity analysis
- Tunnel safety assessments
- Dam Surveillance

3.5. Smart energy systems

Intelligent energy is an emerging system in which AI is instrumental in designing and implementing systems to produce, distribute, and use energy efficiently. Through proper analysis, AI optimizes the utilization of renewable power sources and the demand for power. For instance, intelligent grids apply artificial intelligence to manage supply and demand, minimize energy losses, and apply dynamic tariffs to save resources.

Examples Include:

- Smart grids
- Renewable energy integration
- Dynamic energy pricing
- Demand response management

3.6. Digital Twins for Urban Planning

Digital twins can be named one of AI's breakthrough advances in urban planning. Such virtual models allow planners to evaluate different development scenarios before practical application. Thus, with the help of data from IoT devices and

GIS, AI can forecast the consequences of infrastructure changes, which will help to make the right decisions to create a more sustainable urban landscape.

Examples Include:

- City-wide simulation models
- Infrastructure scenario testing
- Environmental impact analysis
- Resource allocation optimization

3.7. AI-Enhanced Project Management

AI is changing how infrastructure projects are managed by making work more efficient, less time-consuming, and precise. Decision support systems look at past data and anticipated timeframes to determine consequences, vulnerabilities, and ways to address them. This allows project managers to make the right decisions for the project and enhance the overall workflow, thus improving the overall delivery of the project.

Examples Include:

- Risk assessment
- Resource allocation optimization
- Project timeline forecasting
- Automated task management

3.8. Advanced Material Optimization

AI is also at the forefront of material choice and improvement for infrastructure development. By evaluating material properties and environmental characteristics, AI determines which materials are most suitable for specific applications, increasing the product's longevity and eco-friendliness. This method, material informatics, assists in developing more robust green materials and thereby decreases resource usage.

Examples Include:

- High-performance concrete development
- Sustainable material selection
- Corrosion-resistant alloys
- Energy-efficient building materials

4. Advantages of AI-Powered Infrastructure as Code (IaC)

- Faster Infrastructure Provisioning: With the help of AI, the IaC is much quicker in provisioning since setup and configuration are automated. This fast deployment enables teams to commence new environments quickly; this decreases the time taken to bring applications to the market.
- Improved Infrastructure Security: The effectiveness of AI is that it can detect weak points in configurations and compare them with the standards that correspond to security. It also assists in eliminating the risks before the potential attackers can leverage them.
- Reduced Operational Costs: AI-powered IaC can also reduce the cost of operation by minimizing the amount of time and resources consumed by repeating routines. People within organizations can use resources better and in a way that avoids unnecessary spending.
- Enhanced Consistency and Standardization: AI ensures that infrastructure configurations are standard across the environments. This standardization minimizes the chances of creating errors and inconsistencies, making the systems more accurate.
- Predictive Resource Management: AI can also monitor customers' usage patterns and predict the required resources for the organization's growth so that it can plan its infrastructure accordingly. This capability assists in sustaining performance while at the same time reducing costs.
- Simplified Maintenance and Updates: AI makes managing and updating the infrastructure accessible since patching and configuration changes are automated. This will, in a way, help reduce the amount of time spent and minimize errors that may be encountered while making the changes.

- Better Compliance and Auditability: As a result, IaC can be powered by artificial intelligence to ensure that the set complies with various industries' regulations and organizational policies are met. This capability makes audit easier and guarantees that infrastructures are as standard as required.
- Enhanced Collaboration: With the help of code-based, AI IaC helps achieve the DevOps culture's aims by integrating the development and operational teams.
- Rapid Testing and Validation: AI can also help in automated testing and validation of the infrastructure code to determine if the configurations work as expected before deployment. This cuts the possibility of problems arising in the course of production.
- Dynamic Infrastructure Optimization: Through constant performance analysis, AI can make real-time adjustments to infrastructure resources, improving the performance of the systems in place.

4.1. Some of the Potential Issues in Adopting AI / Machine Learning in DevOps Processes

- Data Privacy: Integrating AI in DevOps means it will take significant quantities of data, which may contain personal information. Data security and protection and meeting the requirements of the laws, including GDPR, are major concerns. To effectively use technology, organizations must have robust data governance measures to safeguard users' data simultaneously.
- Model Explainability: AI models tend to function as 'black boxes,' and this causes a lot of issues as teams are not able to understand how these decisions are being made. In the DevOps practice, such opacity reduces trust and accountability, mainly when AI makes decisions regarding releases and incidents. Making the models explain their decisions is crucial to gaining the users' trust.
- Ethical Considerations: Several issues applications of AI in DevOps such as bias I,n data, and decision making. It is also essential to ensure that the models do not bring bias into the results already present in society. To sustain the highest level of credibility and public trust, organizations should practice ethical AI.
- Integration Complexity: Even though AI tools are still relatively new to DevOps, some challenges come with using them. Some of the issues that businesses may encounter include compatibility issues, issues with the tools and the integration, and possible drastic changes in how things are being done. Implementing the two concepts involves time and, in most cases, calls for a change in personnel.
- Skill Gaps: The integration of AI in DevOps is a success if done by a team with unique skills that may not be already in place. AI should be accompanied by the personnel's training and development to enable them to understand how to use the AI tools.
- Infrastructure Limitations: Some organizations may lack the necessary infrastructure that is required for the implementation of AI technologies. The integration of AI into a system requires an upgrade of systems, which is expensive and takes a lot of time to rule out the integration of AI.

4.2. Future Developments of AI in DevOps.

- Development of More Sophisticated AI Models: Development of More Sophisticated AI Models: The future development of AI in the DevOps environment will likely demonstrate more sophisticated models for more accurate solutions to complex problems. Such models may have profound learning and reinforcement learning to enhance decision-making in DevOps pipelines.
- Integration with Emerging Technologies: AI is expected to intertwine further with other progressing technologies, including edge and quantum computing. AI can also benefit from edge computing because it facilitates the processing of big data closer to the source, thus increasing the real-time processing efficiency. AI is one of the fields for which quantum computing is promising, as it will allow for processing significantly more significant amounts of data and tackling tasks that classical computers cannot solve.
- Creation of New AI-Powered DevOps Tools: Because of the constant progress in AI, it is possible to assume that more and more tools adapted for DevOps will be created. These may encompass tools for automating other, more complicated tasks, improving interdisciplinary cooperation and coordination, and gaining more detailed information on system usage and security issues.
- Enhanced Collaboration through AI: AI tools of the future may help the development and operation of teams to understand each other's work. They may help with automating the communication process. This could result in the development of efficient processes and enhancement in the general efficiency of project delivery.
- Continuous Learning and Adaptation: AI systems will continue to be integrated with capabilities for lifelong learning to enable them to learn and evolve in the progress of the DevOps environment. This will augment the flexibility and the overall robustness of the DevOps pipeline.
- Focus on Sustainability: As more attention is paid to environmental conservation, AI helps enhance the efficient use of resources in DevOps and the conservation of resources in infrastructural operations. Future AI solutions

could have sustainability features that would help sustain future developments and implementations of software.

5. Conclusion

The absorption of AI technology into the DevOps pipeline has several advantages, including effectiveness, cost control, and flexibility. Since the application of AI in organizations results in the automation of processes and real-time analysis, this makes the organizations' flow responsive to change. However, the right approach must be taken in developing and deploying AI where data privacy, ethical factors, and transparency in decision-making are given the deserved attention. Thus, organizations should follow these principles to ensure the developed AI solutions are trusted. Hence, the business must search for and adopt AI technologies for its DevOps.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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