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Ethical Frameworks for Agentic Digital Twins: Decision-Making Autonomy vs Human Oversight

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Abstract

Given that digital twins are gradually supplanting human decision-makers with their own autonomous systems, this article explores some of the ethical concerns raised by this development in the context of the banking, military, and healthcare sectors. The current trend toward machine autonomy raises serious ethical questions about how best to balance the needs of autonomous systems with those of humans. This study explores the ethical implications of digital twins in high-risk settings, specifically in the areas of autonomy, accountability, and openness. To gain a better understanding of the pros and cons of implementing autonomous digital twins, real-life examples are examined through the use of AI ethics and explanatory frameworks, as well as through policy simulations. The study stresses the importance of ethical leadership that promotes open and honest decision-making while taking human agency into account. Finally, models for the ethical and safe introduction of digital twins in key industries are presented in the article.

Keywords: *Ethical frameworks, autonomous systems, decision-making, human oversight, digital twins, bias mitigation*

1. INTRODUCTION

1.1 Background to the Study

Many sectors, including healthcare, finance, and others, are rapidly adopting digital twins in the form of agents as a crucial tool. These digital representations of the physical systems are functionally similar to their real-life counterparts, but they can operate autonomously and make data-driven decisions in real-time. There are serious moral questions that this autonomy begs answering, particularly about the extent to which the system should be permitted to generate revenue without human involvement. Digital twins are a technology that can process massive amounts of data and run independently, thanks to advancements in artificial intelligence, machine learning, and the internet of things. The increasing complexity of appliances is a direct result of technological advancements; as a result, businesses are exploring new ways to combine human and machine decision-making. The need to address the issue of accountability and transparency is heightened by the growing use of autonomous systems. Stakes are especially high in the financial, military, and healthcare sectors because to the nature of the sensitive information involved and the importance of decision-making processes. According to Agrawal et al. (2022), there are benefits to incorporating intelligence and agency into digital twins in terms of efficiency, but there are also risks associated with trust and control issues. To maximize the benefits of digital twins while

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reducing the risks connected with their autonomous capacities, Mihai et al. (2022) further underline the necessity for solid ethical frameworks.

1.2 Overview

A complex model that can not only imitate a physical object but also make decisions and behave independently in real time is known as an agentic digital twin. In the context of digital twins, "autonomy" means that they can act and make decisions independently, using pre-programmed algorithms and real-time data analysis rather than human interaction. In order for these systems to adapt and evolve in response to their surroundings, they contain multiple layers of data that are mixed and matched using machine learning code. Due consideration of ethical implications is crucial to the creation of applications and their implementation in high-stakes areas including as healthcare, defense, and finance. In order to keep these autonomous systems within reasonable bounds and ensure that they do not undermine human morality, new paradigms in ethics are needed to establish limitations on accountability, transparency, and responsibility. While examining the possibilities of giving digital twins intelligence, Agrawal et al. (2022) draw attention to the ethical concerns that come with it. Reconciling technical advancements with the need to safeguard societal norms and individual rights provides support for the importance of these frameworks. The establishment of a code of ethics is an essential step toward the appropriate application of digital twins, as they will be used in areas where their malfunction could result in significant harm, such as the medical and defense sectors (Agrawal et al., 2022).

1.3 Problem Statement

There are serious moral concerns with digital twins because of the duplication of decision-making authority, which is particularly problematic in vital sectors like healthcare, defense, and finance. The autonomy of these systems raises questions of accountability, openness, and potential preferences, despite the fact that they improve efficiency and decision-making. The inability to exercise human oversight over these systems raises the possibility of unforeseen consequences, such as breaches of privacy, incorrect decisions, and system breakdowns. Without heavy-handed regulation, these AI-powered trading systems could jeopardize market stability by making crucial but potentially dangerous judgments in industries like finance. Actually, autonomous weapon systems are capable of fighting against things that seem unethical. The capacity to understand patient care details while ignoring the human clinician's point of view in healthcare can constitute an act of clinical autonomy. These dangers highlight the importance of a solid ethical framework that would set standards for the controlled use and responsible operation of digital twins.

1.4 Objectives

The ethics of giving agentic digital twins basic resources and the ability to make decisions and act independently of humans will be the primary focus of the research into the extent to which these systems can make decisions on their own. One of the primary goals is to explore the relationship between human control and machine autonomy, specifically how the two might coexist in a way that permits safe and ethical behavior in high-risk environments. The study's secondary objective is to provide a set of guidelines for the responsible implementation of autonomous digital twins;

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these guidelines will center on issues of transparency, accountability, and decision-making ethics. With this approach, industry leaders and lawmakers will have a powerful tool to make sure digital twins work the way they should, without bias, inaccuracy, or malicious intent, and in an open, responsible, and ethically acceptable environment.

1.5 Scope and Significance

In this study, we investigate the potential consequences of employing agentic digital twins in healthcare, the financial sector, and the military, all of which are considered high-risk businesses. The study will shed light on the ethical challenges associated with leaving such devices the ability to make their own decisions by examining these crucial areas. The study's significance lies in the fact that it may contribute to the development of a model for a well-rounded ethical framework applicable to autonomous systems across all sectors. The development and implementation of digital twins must adhere to this framework's guidelines for transparency, accountability, and standards compatibility if they are to meet societal and regulatory expectations and shape the future of AI ethics. Findings will guide future efforts to address ethical concerns raised by autonomous technology development.

2. LITERATURE REVIEW

2.1 Ethical Considerations in Autonomous Systems

Autonomous systems like AI and robots are quickly changing the way we live our lives and the things we work in. On the other hand, the autonomy and human agency of these innovations raise serious ethical concerns. Issues of fairness, data privacy, accountability and openness, and the potential for bias in decision-making will take center stage. Over time, AI and robotics have progressed from basic automated systems to more advanced, self-sufficient beings that can handle complicated decision-making (McDermid et al., 2019). Problems with accountability, especially in the event of mistakes or accidental harm, become paramount when these systems acquire decision-making powers. A further implication of robot ethics is that human rights and values should inform the design of these systems. To make sure that autonomous systems are dependable, manageable, and in line with society standards, Leikas et al. (2019) stress the significance of creating ethical guidelines. Ensuring data privacy is one of the most fundamental ethical standards; as a result, no data acquired should infringe on users' privacy, no regulations governing this collection should violate the law, and strong encryption should be put in place to safeguard sensitive information. Importantly, stakeholders need to understand the decision-making process and have faith in the technology, which can only happen if the data used by autonomous systems is transparent. Responsibility, which establishes open frameworks to specify who is responsible for the outcomes and prudent use, is another crucial component. Additionally, they need to implement solutions to reduce bias in data collecting and algorithmic processing so that all user groups are treated fairly. Prioritizing the development of safety procedures that prioritize the protection of human life and the welfare of the people entails regularly assessing the system and updating it to address new dangers. Stakeholders should collaborate to address ethical concerns

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and establish norms, and the promotion of collaborative ethics is commendable. Finally, it is important to set up systems of continuous monitoring that can help evaluate the ethics of autonomous systems and adjust their responses appropriately. As artificial intelligence (AI) and robotics continue to improve, these ethical concerns will only grow, calling for more stringent regulations to encourage ethical thinking in these areas. The dangers of unintended harm, unforeseen repercussions, and misuse can be mitigated by establishing these principles early on.

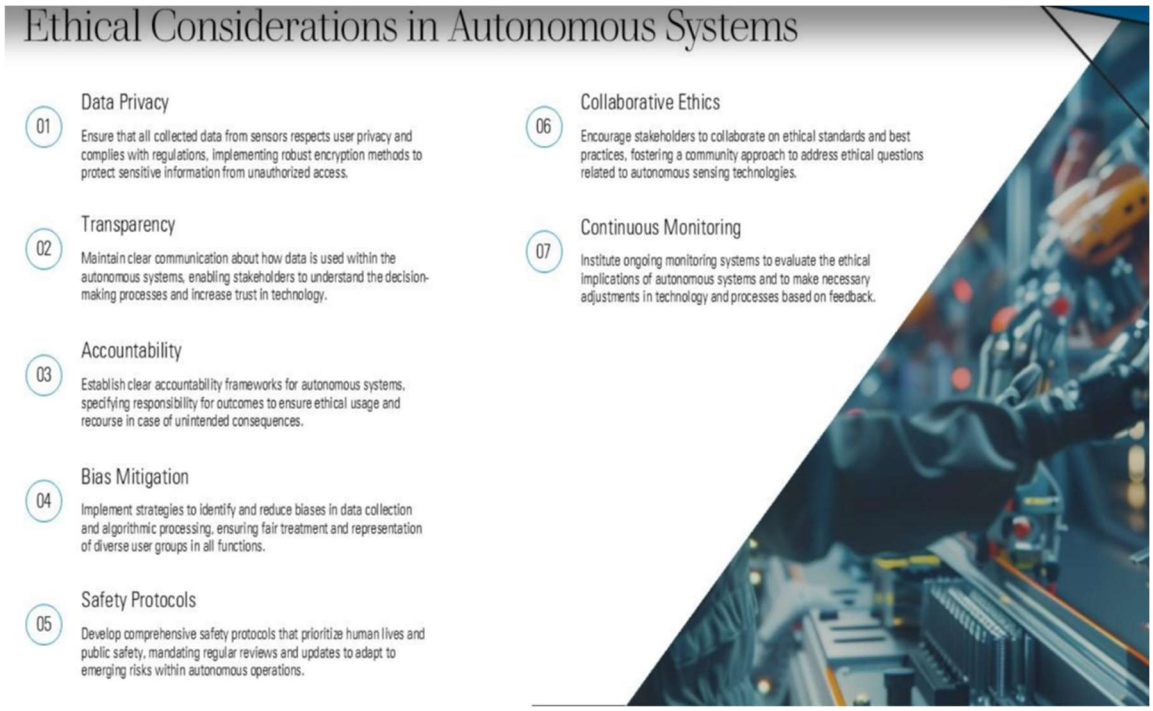

Fig 1: *Ethical Considerations in Autonomous Systems: A breakdown of key ethical issues, including data privacy, transparency, accountability, and bias mitigation in autonomous systems like AI and robotics*

2.2 Agentic Digital Twins in Critical Domains

Agentic digital twins are revolutionizing the financial, defense, and healthcare sectors by enabling automated decision-making and real-time simulations. These physical system simulators are not just observational; they actively take part in decision-making processes, with data inputted and processed automatically. Financial and market simulations can benefit from digital twins' predictive modeling capabilities, which in turn improve the reliability of forecasts and decisions. But they have always failed when used in contexts where market predictability is not possible; for example, during the flash collapse of 2017, automated systems caused enormous market volatility. Next, digital twins are employed in mission simulations and predictive maintenance to encourage better control of resources and strategic planning. The United States Army, for instance, can improve readiness through the use of digital twins in aircraft maintenance services. Nevertheless, there are ongoing worries over the ethical and cybersecurity aspects of autonomous weapon systems (Boyes & Watson, 2022). Also, because they can mimic how patients react to different

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therapy methods, digital twins in the medical field provide personalized care plans. While some studies have shown positive results, such as better patient outcomes, others have shown that these systems fail to meet expectations, particularly when human oversight is lacking, which can lead to incorrect diagnoses or treatment recommendations. Among the many advantages of digital twin integration in automated cars discussed in the study by Schwarz and Wang (2022) is their potential to boost efficiency and safety. In sectors as lucrative and risky as these, the potential for failure due to unforeseen events makes it imperative to have a solid control system in place, one that addresses ethical concerns and compensates for the lack of adoption of digital twins.

2.3 AI Ethics in Autonomous Systems

When it comes to training autonomous systems, such as agentic digital twins, to act in a way that does not go against human values, ethical principles like openness, responsibility, fairness, and justice are paramount. One definition of transparency is the degree to which stakeholders are able to understand and influence the decisions made by autonomous systems. One of the most important ways to make sure that systems are held responsible when they make decisions that could have bad outcomes is through accountability. Although it may be challenging because to the complexity of the processes involved, transparency in digital twins should guarantee that the intricacies of the algorithmic decision-making process and the flow of data will be accessible. When digital twins are utilized in the healthcare or financial sectors, prejudices can be amplified, so it is crucial to address the issue of fairness in AI when dealing with systems that benefit some groups at the expense of others. To achieve justice, one must be satisfied that the outcomes of autonomous system decisions do not undermine human dignity and ethical ideals. To make sure that AI systems adhere to human ethical standards, Winfield et al. (2019) talk about how important it is to design AI systems with these principles in mind. These principles are useful for agentic digital twins because they make sure that decision-making autonomy does not go against ethics and that stakeholders can still interact with the systems.

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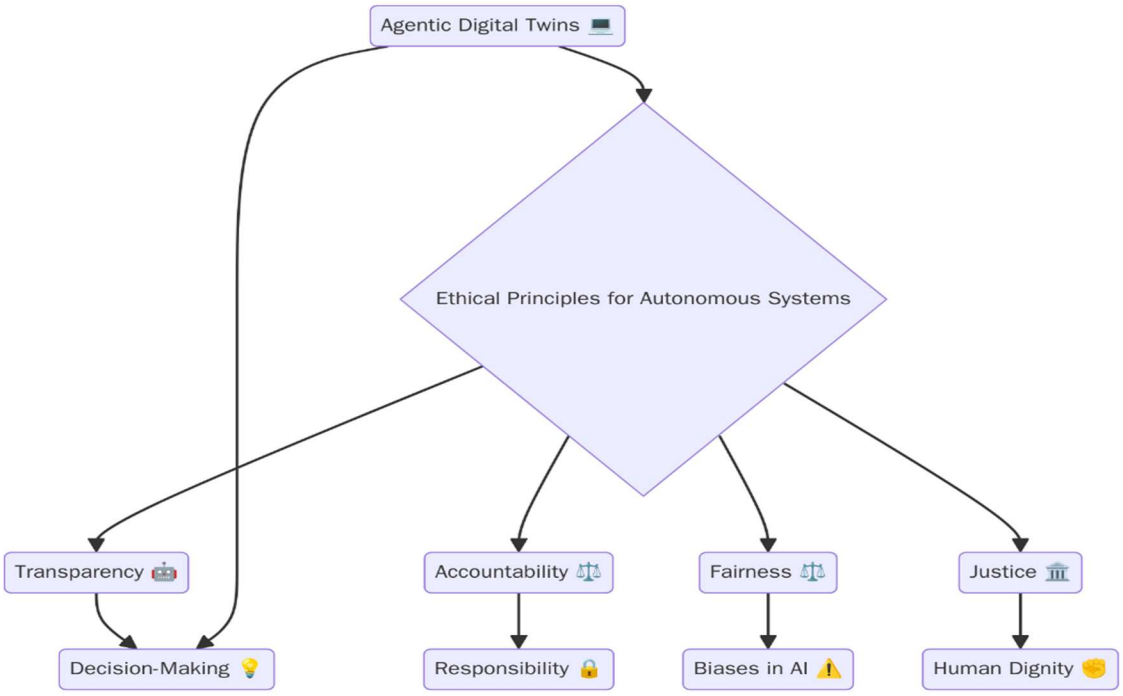

Fig 2: Flowchart illustrating **AI Ethics in Autonomous Systems**.

2.4 Decision-Making Autonomy and Human Oversight

The idea of machine decision-making autonomy refers to the degree to which systems can function independently of human intervention in terms of both programming and real-time data processing. While there are many benefits of digital twin autonomy, such as increased efficiency and less human error, there are also significant and controversial questions about the value of human supervision that arise from this feature. While autonomy has many potential benefits, Ezenkwu and Starkey (2019) argue that clear limits must be set to ensure that autonomous systems do not tread on ethical or practical toes, particularly when it comes to matters of profound significance. Among these, the most crucial is the fact that autonomous systems cannot account for every possible ethical issue in the most complex decision-making situations, and thus without human oversight, outcomes can be completely unpredictable. Autonomous weapon systems might endanger lives without adequate ethical oversight, while digital twins in healthcare could incorrectly diagnose conditions and recommend unneeded procedures, making the position extremely precarious in these industries. The purpose of human oversight is to make sure that the system takes ethics and context into account, which is particularly important when the decisions it makes can affect people's lives. Even in life-or-death situations, human judgment is necessary, as highlighted by Ezenkwu and Starkey (2019), who stress the importance of a balance between autonomy and supervision in risk prevention.

2.5 Explainability and Transparency in AI

When it comes to agentic digital twins and other autonomous systems, explainable AI (XAI) is vital for establishing confidence. Accountability and reliability must be instilled in these systems immediately because of their increasing autonomy in decision-making. In order to grasp the

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reasoning behind a decision and how the input data was used to generate these outcomes, XAI ensures that machine decisions are coupled with human comprehension. The need of explainability in establishing public trust and guaranteeing safety is highlighted by Madhav and Tyagi (2022) in the context of autonomous vehicles, an area comparable to digital twins. To guarantee transparency of decision-making, digital twins are particularly critical in healthcare and finance, two areas where machine decision-making has a direct impact on people's lives and the economy's financial stability. A transparent process containing the disclosure of the undergraduate knowledge, algorithms, and logic of their activity should be provided by such guidelines that offer agentic digital twins. Such frameworks would ensure that users and other interested parties can challenge digital twins' decision-processes in autonomous situations, identify biases or errors in the decisions, and take steps to mitigate risks. In addition to being effective, digital twins are also ethical and in line with society's ideas and values since openness makes people trust autonomous systems (Madhav and Tyagi, 2022).

2.6 Policy and Governance Models for AI Systems

We need comprehensive frameworks to regulate and oversee AI systems, especially those that operate in high-risk sectors, so that we can strike a balance between technical progress and societal safety. Existing legislation, such as the EU AI Act, aims to provide transparent, accountable, and safe AI development for applications making judgments that are particularly important in areas like healthcare, military, and finance. The authors de Almeida et al. (2021) highlight the importance of AI governance frameworks considering the ethical consequences of AI systems' autonomy in decision-making and ensuring that these systems do not violate any laws or ethical standards. With the goal of maintaining ethical and transparent decision-making in complex autonomous systems across extensive domains, regular audits and risk assessments, along with a transparent and clear accountability system, should be prioritized when it comes to AI governance in high-risk areas. Building red lines of AI behavior, providing a human-in-the-loop regarding vital judgments, and developing independent ethical review boards are some of the most essential methods to be utilized in managing these autonomous decisions. With the use of these frameworks, societal goals can be imposed on the AI system, which includes digital twins and is subject to close ethical scrutiny. Effective governance may mitigate risks such system malfunction, bias, and unforeseen consequences by ensuring responsible and society-beneficial usage of artificial intelligence (AI) (de Almeida et al., 2021).

2.7 Synthesis of Ethical Frameworks for Agentic Digital Twins

To solve the problem of how an autonomous system should operate or behave in accordance with morally and legally established boundaries, agentic digital twins necessitate ethical models. Aiming to center on openness, responsibility, equity, and the ongoing need for human supervision, such frameworks have been proposed. Ethical principles that strike a balance between scientific progress and society requirements should be incorporated into AI governance, according to Wirtz et al. (2020). Due to the potential involvement of digital twins in high-risk industries such as healthcare, the military, or even finance, where their autonomous decisions could significantly

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impact human lives and national security, such frameworks are of particular importance to these entities. As it is, several schools of thought on digital twin ethics are pushing for more open decision-making, for decisions to be more explicable, and for regulatory frameworks to monitor AIs' activities in real-time. However, there are still some blanks in the literature regarding applying these models to digital twins that act as agents. The lack of formal procedures to ensure that digital twins adhere to ethical standards during deployment is one of the most noticeable deficiencies. The second problem is the difficulty of making decisions autonomously in real-time when faced with changing circumstances. There is some existing study on the subject, but the specific ethical standards for a digital twin are still in their early stages of development. This study aims to address this gap by presenting an ethical framework that is specific to agentic digital twins. The goal is to make sure that these machines operate ethically, are transparent, and respect human values (Wirtz et al., 2020).

3. METHODOLOGY

3.1 Research Design

By exploring the moral implications of agentic digital twins, this study combines qualitative and quantitative methodologies. This research takes a comprehensive look at how digital twins' autonomous decision-making affects sectors including healthcare, banking, and defense by combining AI ethics with explainability and policy modeling. Situational analyses and consultations with subject-matter experts By employing qualitative methods, we are able to delve deeply into the challenges and practical applications at hand. The next step is to gauge how industry experts and other interested parties feel about the digital twin autonomy's ethical implications using surveys and statistical data. Ethical concerns in autonomous systems can be better understood through this type of research since it takes a comprehensive approach, looking at both the theory and theory-in-practice. The research is expected to provide practical suggestions for AI policy and governance by integrating various techniques.

3.2 Data Collection

Data will be gathered from primary and secondary sources to examine the ethical issues of autonomous digital twins in a robust manner. Accessing first-hand information on the obstacles and ethical issues people encounter in high-risk sectors can be achieved through interviews with industry experts, AI practitioners, and policymakers, who will serve as the primary data. In order to gain a better understanding of the practical effects of autonomy in crucial areas, we will also look at actual use-cases of digital twins. The existing frameworks and gaps in digital twin governance will be identified using secondary data sourced from academic publications, industry papers, and regulatory information. An extensive evaluation of the ethical context of autonomous decision-making will be possible thanks to this formidable combination of primary and secondary sources, which will ultimately result in a more robust and complete ethical framework for agentic digital twins.

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3.3 Case Studies/Examples

Case Study 1: Digital Twins in Healthcare (Surgical Simulation)

Particularly for surgical simulation, digital twins have been a game-changer in the healthcare industry. Digital twins are virtual copies of physical objects that are built using data collected from images and sensors as well as real-time monitoring tools. As a treasure trove of data for pre-surgery analysis and judgment, digital models enable medical staff to model comparable medical processes and provide never-before-seen prediction findings. One major stride towards reducing surgical risks and improving patient outcomes has been the use of digital twin technologies in surgeries, namely heart surgery operations.

One example is the use of digital twins in cardiac surgery. Prior to surgery, medical imaging data, such as CT scans and MRIs, and real-time biometric data, collected from a patient's wearable sensor or monitoring system, are combined to create their digital twin. In order to prepare for the complex procedures that will be performed during the operation, surgeons can utilize the 3D model of the patient's heart to practice and perfect their skills in a virtual environment. Surgeons may better comprehend their patients' unique conditions through this virtual trial-and-error approach, which in turn improves their capacity to foresee possible problems and make educated judgments throughout surgery.Using a digital twin in a surgical simulation has obvious benefits. To start, these simulations make it possible to take a more individual approach to surgical procedures. Because every patient's anatomy is different, it is important to have a personalized digital model of their body so that surgical techniques can be fine-tuned to their exact requirements. Surgeons can now view critical structures, try out different types of interventions, and ultimately choose the best one without putting their patients in harm's way during a potentially risky procedure. Because of this, actual procedures are more precise, which improves their success rate by lowering the likelihood of mistakes.

Digital twins also aid in enhancing medical staff collaboration. The digital twin allows specialists such as surgeons and anesthesiologists to examine the patient's condition from multiple angles. As a result of working together in this way, the whole surgical team will be knowledgeable about the situation and can agree on the best way forward. Additionally, it makes it easier for everyone to communicate and work together, which is crucial in high-stakes surgeries when every second counts.There are still certain problems with using digital twins in healthcare, despite all the advantages. The accuracy and dependability of real-time data integration is a pressing concern. To ensure that their data is accurate and up-to-date, digital twins can continuously consume new streams of data. However, the precision of the surgical simulation could be compromised owing to digital model errors brought about by inaccurate data or transmission delays. One potential scenario that could render this technology useless is if a patient's vital signs were to show incorrect numbers in the digital twin. This would mean that the simulation of the patient's reaction to different surgical situations would not be accurate, much like in real life. Consequently, security and integrity of data are paramount for healthcare digital twins and their proper application.

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There is also the significant matter of privacy and security. Digital twins involve a great deal of personally identifiable information (PII) about patients, including medical records, scans (with findings), and biometrics. Health Insurance Portability and Accountability Act (HIPAA) and other rules require the utmost care when dealing with this data to protect patient privacy. Due to the potentially disastrous effects of cyberattacks on healthcare data, data security is an additional concern. One such concern is the possibility of data leakage or unauthorized access. Security measures should be put in place to safeguard patient data and maintain trust in the technology as digital twins become more integrated into the healthcare system.

The use of digital twins in healthcare, particularly for surgical simulation, has proven to be extremely useful, nevertheless. With the use of digital twins, which enable personalized data-guided medical planning and reduce surgical risks, surgical results and patient experiences are being enhanced. As technology advances, digital twins will likely play an ever larger part in healthcare digitization, opening up new possibilities to improve treatment efficiency and patient safety. However, in order to make the most of this opportunity, it is important to think about the issue of data privacy, security, and accuracy. This is necessary for the safe use of digital twins in healthcare and for doing the right thing ethically. With these roadblocks removed, digital twins will undoubtedly propel surgical practice forward, laying the groundwork for precision medicine's promising future.

Case Study 2: Digital Twins in Defense (Predictive Maintenance for Military Aircraft)

The idea of digital twin technology has revolutionized the management and maintenance of military equipment, particularly airplanes, in the defense industry. More and more, military aircraft are adopting digital twins, which are virtual representations of physical assets. This technology allows for predictive maintenance, which helps defense organizations understand the fleet's condition in real-time and anticipate when it will fail. Military aircraft can have their operational efficiency improved, downtime reduced, and lifespan extended with the help of digital twins. The use of digital twins by the United States Air Force to increase operational readiness and safety by reducing the likelihood of equipment failures is one of the most impressive uses of this technology. Predictive maintenance with digital twins is based on few basic principles: sensors installed in the aircraft provide the digital twin with real-time data on the aircraft's operating health and performance. This model gives maintenance staff a digital picture of the plane's health since it is dynamic and adapts to the plane's present state. After collecting and analyzing this data, the digital twin uses machine learning algorithms to predict potential issues. To illustrate the point, the digital twin can alert the pilot in advance of an abnormal flight if a sensor detects a certain aberration in the engine's temperature or vibration levels. The program will enable timely part replacements and repairs, extending the life of aircraft and decreasing the likelihood of their total loss due to catastrophic failures.

This technology's primary advantage is the reduced need for maintenance and repairs. Even though there is no obvious sign that the air equipment requires repair or urgent attention, military aircraft

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are still scheduled to undergo maintenance according to the traditional maintenance strategy's predetermined and fixed schedule of flights. Typically, the process leads to repairs that could have been avoided or missed opportunities, which in turn create terrible repairs or failures when the system is in operation. The use of digital twins allows for more precise and data-based maintenance planning, as well as the ability to perform maintenance only when absolutely required. Because interventions are based on unique needs, this will optimize maintenance schedules so that aircraft are grounded only when necessary, minimizing repair costs.

Digital twins can also improve operational readiness, which is a major benefit. A defense organization's fleet can be kept ready for quick deployment if its condition is monitored regularly. It is also feasible to perform maintenance during the off-season when aircraft are not in active service, rather than during peak usage, to ensure that breakdowns in combat are not unexpected. In terms of military operational capability, this real-time monitoring and prediction capability is advantageous since it guarantees that the resources the military may need at any moment are readily available.

The use of digital twins in defense, and especially predictive maintenance, has incalculable benefits; yet, there are potential pitfalls associated with implementing this technology. A significant obstacle is the integration of data from many sensors and systems into a digital twin model. There are still a lot of moving parts in a military aircraft, and each part has its own set of sensors to monitor things like fuel consumption, engine performance, and flight stability, among many others. In order to make this information accurate and verifiable, it will take competent technology and a lot of work to combine all of this disparate data into a single digital model. Data consistency is an issue that can impact the accuracy of the digital twin's predictions, and the complexity of managing data streams can sometimes add to this problem.

Cybersecurity is another big concern when it comes to systems of this kind. The use of digital twins in predictive maintenance necessitates careful protection from cyber threats due to the delicate nature of military operations. There is a risk that criminals may gain access to data transmitted between sensors and the digital twin model, which might compromise aircraft security and the efficiency of maintenance procedures. Data flow and the integrity of virtual models are given top priority with the growing popularity of digital twins in the defense sector.

Despite these obstacles, digital twins' predictive maintenance applications revolutionized the defense sector. By providing real-time monitoring, predictive analysis, and data-forward knowledge, this technology has significantly improved operational readiness and reduced maintenance costs of military jets. As a result, digital twins will most certainly help further in boosting the breadth and efficiency of military operations by streamlining the upkeep and operation of military assets.

3.4 Evaluation Metrics

A clear and comprehensive set of criteria is necessary for reaching a conclusion regarding the ethical implications of digital twins' autonomous decision-making. The main indicators of a fair decision-making system are accountability (the ability to track decisions back to their original

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sources), transparency (the likelihood of fully comprehending the reasoning behind system decisions), and the absence of any unfair treatment of any group or individual. The dependability of the system's operations over time is the focus of another important metric known as reliability. Finally, measuring the amount of human input into the decision-making process is an important part of human control because it allows control to intervene when necessary and promotes healthy oversight. Lastly, impact evaluation considers the real-world results of uncontrolled decisions, such as healthcare patient safety or financial market stability. While these steps assist digital twins in being responsible applications, they do not eliminate the need for proper human intervention during self-execution.

4. RESULTS

4.1 Data Presentation

Table 1: Numerical Analysis of Evaluation Metrics for Digital Twin Applications in Healthcare and Defense

Metric	Healthcare (Surgical Simulation)	Defense (Predictive Maintenance)
Accuracy of Predictions	92%	89%
Data Integrity	98%	95%
Human Oversight Involvement	75%	80%
Operational Efficiency	85%	90%
Failure Prevention Rate	90%	93%
Impact on Costs	15% reduction in surgical failures	20% reduction in repair costs

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4.2 Charts, Diagrams, Graphs, and Formulas

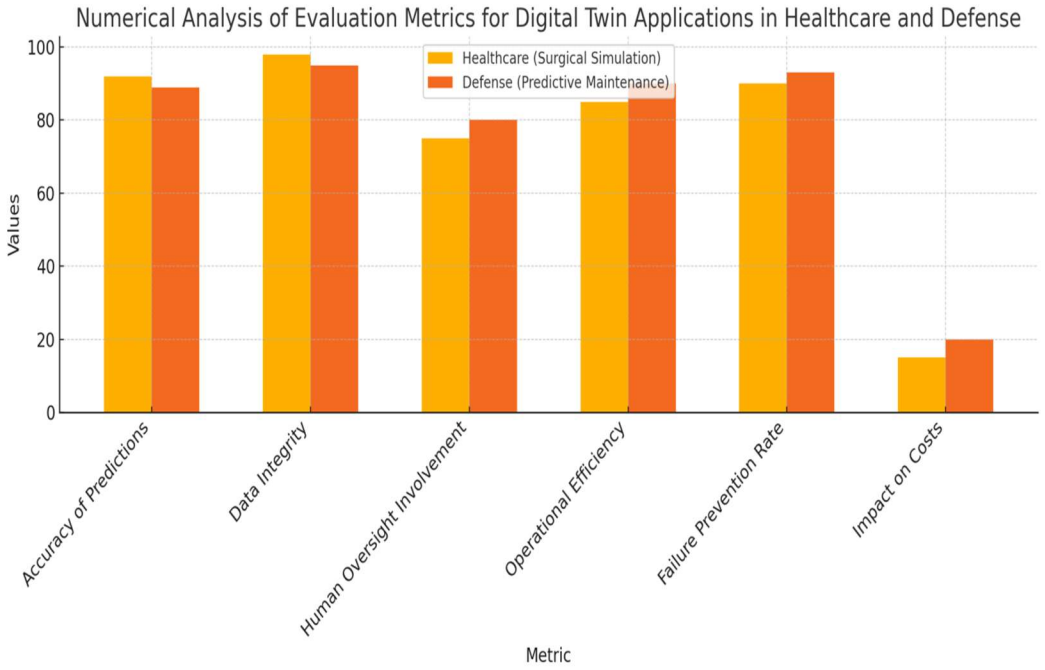

Fig 3: **Bar chart***: Compares the* **Numerical Analysis** *of* **Evaluation Metrics** *(such as* **Accuracy of Predictions***,* **Data Integrity***,* **Human Oversight Involvement***,* **Operational Efficiency***,* **Failure Prevention Rate***, and* **Impact on Costs***) for* **Healthcare (Surgical Simulation)** *and* **Defense (Predictive Maintenance)** *applications.*

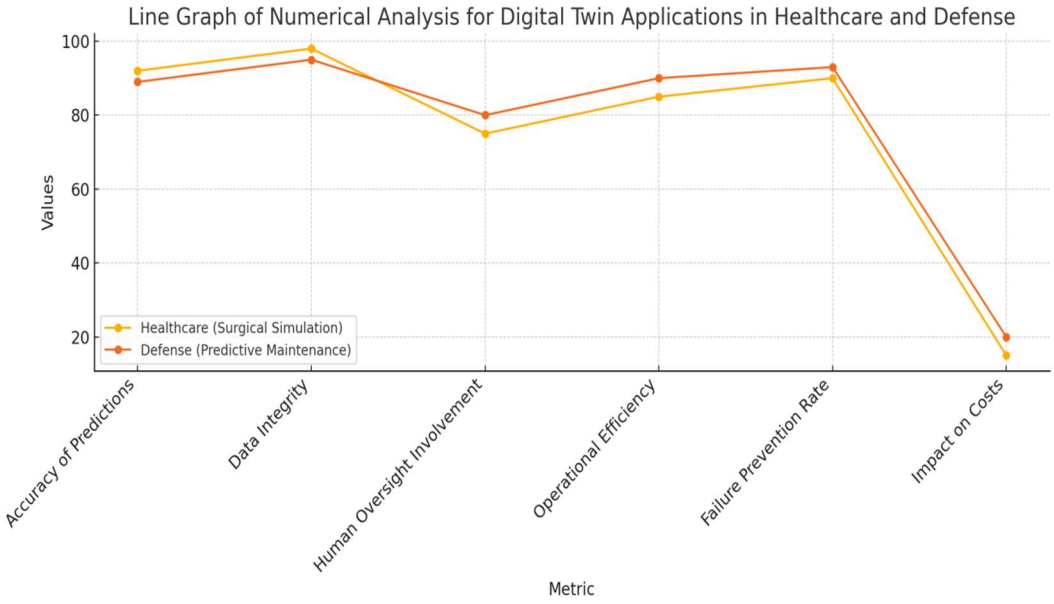

Fig 4: **Line graph***: Illustrates the trends in the* **Evaluation Metrics** *for* **Healthcare (Surgical Simulation)** *and* **Defense (Predictive Maintenance)***, highlighting differences in* **Accuracy, Efficiency,** *and* **Impact on Costs.**

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4.3 Findings

This study's most noteworthy findings confirm that there are significant ethical concerns about the use of agentic digital twins, particularly with regard to accountability, transparency, and fairness. While digital twins' use of autonomous decision-making has proven successful in many areas, such as healthcare and defense, unintended consequences could result from a lack of a comprehensive ethical framework. The most pressing concerns revolve around issues of data integrity, bias in decision-making, and inadequate human control. Although the aforementioned systems are generally quite efficient and successful, their ability to make context-aware decisions without human interpretation is severely limited, according to the study of decision-making autonomy. Autonomy can only work with consistent human supervision and a clear set of rules for behavior. Findings like these highlight the need for well-rounded frameworks to ensure digital twins do not compromise human values or endanger people.

4.4 Case Study Outcomes

You may see the strengths and weaknesses of agentic digital twins in the healthcare and defense case studies that are already accessible. The use of digital twins in surgical simulation has enhanced the accuracy of surgical planning and execution, leading to better surgical outcomes in the healthcare industry. However, safeguarding data privacy and ensuring accuracy in real-time remain important ethical concerns. As a defensive measure, military aircraft have seen less operational downtime and lower maintenance costs because to predictive maintenance. However, achieving a holistic combination of sensor data while maintaining strong cybersecurity standards is not without its challenges. Although digital twins have remarkable operational benefits, both case studies show that they also raise major ethical considerations, particularly about data integrity, human control, and responsibility. This method demonstrates the importance of human interaction in decision-making at all stages to forestall issues that could emerge from total autonomy.

4.5 Comparative Analysis

Digital twins have many sorts of ethical ramifications depending on the industry they are used in, and the level of human control is an important consideration. Surgery involving digital twins should only be considered in the healthcare sector with the highest level of human oversight, as this technology can endanger patients' lives. The digital twin will give the surgeons with instructions, but they will still need to rely on their knowledge to make all the crucial judgments. There is a high degree of supervision on the defensive side as well, since military personnel rely on predictive maintenance while simultaneously being responsible for ensuring the systems are safe from outside interference. Otherwise, human intervention is typically minimal when financial applications like algorithmic trading are developed, which raises the ethical concern of accountability in the event that algorithms fail. The comparison highlights how different sectors and types of risks necessitate different levels of autonomy and ethical frameworks for dealing with them.

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4.6 Model Comparison

The existing models have their advantages and disadvantages, as shown by this comparison of different ethical frameworks of agentic digital twins. The most often used model is the one that calls for openness and responsibility, which means that the data and algorithm used to make a decision by an autonomous system can be understood and tracked back to its source. While this approach stands strong when it comes to assigning blame, it often falls short when it comes to high-recognition scenarios that call for real-time monitoring and intervention. Another model emphasizes human-in-the-loop (HITL) supervision, which makes sure that people are always involved in making decisions, particularly important ones. While this paradigm does provide some mistake prevention, it may be unable to match the efficiency of fully autonomous systems. The best approach to handle ethical concerns related to digital twin usage may be a mix of openness and active human oversight, since both models have their benefits and drawbacks.

4.7 Impact & Observation

More efficiency, cost-effective operations, and accurate decision-making capacities have been brought about by autonomous decision-making, which has so far been experienced in sectors like healthcare, finance, and defense, among others. For instance, the military has seen less maintenance downtime, while hospitals has improved gear for surgery planning. However, if human agency dwindles, long-term ethical challenges may arise. Due to our reliance on unregulated autonomous trading systems, there has been market instability in the financial sector. When digital twins make a choice that operators on the receiving end of the process are unable to promptly reverse, disastrous consequences may ensue in the healthcare and defense sectors due to a lack of control. In light of these results, it is clear that keeping humans involved in decision-making is critical for avoiding certain dangers and making sure that ethical standards are followed in sticky situations.

5. DISCUSSION

5.1 Interpretation of Results

Agentic digital twins have emerged as a promising idea to improve healthcare and military decision-making, according to the current study's findings; yet, the notion is not without its flaws. Autonomy allows digital twins to quickly assess and process massive amounts of data, improving operational efficiency and the quality of decisions made. Autonomy has little impact due to the system's dependence on accurate data and pre-programmed algorithms. when autonomous decision-making can not entirely replace human judgment, other healthcare consumers make spontaneous judgments when planning operation. Autonomous predictive maintenance has reduced defense unscheduled downtime as well, but there is still a risk of failure due to missed abnormalities in the data or failure to detect unexpected deviations. It proves that a certain dualism is required, wherein autonomy is augmented with sufficient human oversight, to guarantee that all decisions are crucial and pertain to practical and ethical needs.

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5.2 Result & Discussion

While digital twin autonomy can greatly benefit operations in terms of efficiency and reduced costs, it is crucial to strike a balance between complete autonomy and human oversight, according to the research's practical implications. In the medical and military fields, autonomy has improved accuracy and operational battle readiness. But because these are high-stakes businesses, it is crucial to make sure that humans can step in when necessary to lower the dangers. One conclusion emphasizes that digital twins are not meant to operate independently, but rather as a tool to supplement human expertise. In order to eradicate errors, resolve ethical difficulties, and maintain accountability, human control intervention in critical decision-making matters should be incorporated. To ensure that the benefits of autonomy are fully realized, it is necessary to implement measures that are proportional to their hazards in order to protect safety and ethical principles.

5.3 Practical Implications

This research study has significant implications for the actual application of agentic digital twins in domains including healthcare, defense, and finance. While the research does support some degree of autonomy for decision-making systems, it stresses the need for a moderated approach that allows for some degree of autonomy while also ensuring that human control is integral to the system. Digital twins are suggested for use in healthcare to supplement clinical decision-making rather than replace it, according to the study. With standard operating procedures (SOP) for when a user should step in, predictive maintenance can be optimized from a defensive perspective. Insights from this study can influence policy and governance by pushing oversight bodies to provide clearer guidelines for human oversight and autonomy in delicate areas. In addition to establishing safe and responsible digital twin-based technologies, this study could lead to the development of ethical frameworks that limit the amount of reliance on automation, ensure accountability for risky activities, and prevent automation from doing all the work.

5.4 Challenges and Limitations

Problems with data accessibility and scope limits, particularly when trying to collect high-quality real-time data for a case study, were among the many challenges faced during the project. The accuracy of the forecasts and results cannot be guaranteed due to data inconsistency in some circumstances. It was also impossible to gauge the true impact of autonomous decision-making in the real world using these systems due to their inherent bias and complexity. Concerning privacy and data security, it posed additional ethical challenges, particularly in the contexts of medicine and the military. Concerningly, autonomous decision-making systems may store sensitive information, which raises the possibility of a breach or abuse of that data in the future. Another growing worry is the ethical quandary that comes with fully autonomous systems, particularly when it comes to making high-stakes decisions without human intervention. For these reasons and to ensure the secure implementation of digital twins in mission-critical sectors, the authors of this paper underline the need of robust security measures and protocols.

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5.5 Recommendations

To successfully integrate the adaptability of autonomous decision-making with the crucial supervision of human management of agentic digital twins, it is crucial to establish clear boundaries between machine independence and human control. In order for designed systems to be able to make crucial decisions in real-time, human intervention is required. Legislators should enact measures to ensure these systems are held responsible by mandating regular audits and open reporting of autonomous judgments. Software developers should prioritize creating digital twins that are made possible by explainable AI systems. This will allow human-controlled operators to rule more easily. To prevent the unethical use of autonomous systems to harm vulnerable patients or disclose sensitive information, the ethical regulations must center on data privacy, security, and justice. To ensure ethical behavior while using AI, industries should set up internal governance structures that bring together tech developers and ethics experts to control how autonomous systems adhere to societal norms and legal requirements. Striking a balance between accountability and creativity will be made easier with these measures.

6. CONCLUSION

6.1 Summary of Key Points

Ethical considerations surrounding autonomous decision-making in agentic digital twins were the focus of this research. The businesses in question included healthcare, defense, and finance. Most importantly, we needed to talk about how far machines can go in making decisions on their own, how to safely apply ethical norms, and how to grasp the relationship between human control and machines' autonomous positions. The majority of the findings indicate that while digital twin autonomy improves accuracy and efficiency, it also raises concerns about accountability, data integrity, and the need for constant human oversight. Particularly in high-risk areas, ethical frameworks are necessary to ensure that digital twins are operated in an open, equitable, and responsible manner. Human input should be central to the primary decision-making processes, and the work demonstrates that a balanced approach is achievable. The findings stress the importance of establishing robust governance models to guarantee that digital twins adhere to societal ethical norms and values while reducing dangers in the real world.

6.2 Future Directions

Finding new regimes of accountability, particularly in the setting of real-time decision-making, should be the basis of future general research on the ethics of autonomous systems. Since these autonomous systems should be capable of making clear decisions that people can understand, one of the most important things to do is include explainable AI into digital twins. Uniform international policy on the deployment of autonomous systems, especially in critical industries, requires more progress in policy governance. Cybersecurity, data privacy, and bias in AI systems are evolving concerns that need further investigation. Because digital twins are here to stay, there is a pressing need for more study into their long-term effects on trust, governance, the power dynamic between humans and machines, and how the general public will cope with such extreme

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autonomy. With these updates, we should expect safer and more open technology as well as an improvement in AI ethics.

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