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AUGMENTED INTELLIGENCE: HUMAN-AI COLLABORATION IN THE ERA OF DIGITAL TRANSFORMATION

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Abstract—**Augmented Intelligence (AI) combines human and artificial intelligence to enhance decision-making. This paper reviews AI concepts, applications, and collaboration models like human-in-the-loop AI and cognitive computing AI. It examines AI's role in improving human judgment, handling large datasets, and making routine decisions. The paper explores AI's impact on sectors like healthcare through use cases in blood glucose monitoring. It applies the McKinsey 4D framework to implement AI for glucose monitoring. The paper also discusses emerging models like Hybrid Augmented Intelligence (HAI) that integrate human cognition within AI systems for optimal performance. Overall, it underscores AI's potential in complementing human capabilities and driving innovation across industries with responsible design.**

Keywords— **Augmented intelligence, blood glucose monitoring, cognitive computing, digital transformation, hybrid augmented intelligence, human-AI collaboration, human-in-the-loop, Industry 4.0, McKinsey 4D framework**

I. INTRODUCTION

Augmented Intelligence (AI) is a type of AI that is designed to enhance human intelligence rather than replace it. It uses machine learning and predictive analytics of data sets to improve human decision-making and actions taken in response to improved decisions. Augmented Intelligence is also known as Intelligence Amplification (IA) or Cognitive Augmentation. Augmented Intelligence has been part of our lives for years, and examples of primitive AI include the abacus and calculator, which allow faster processing of data and decisions based on that data [1]. As the Internet of Things (IoT) and smart object connectivity expands, we can expect to see augmented intelligence in almost all aspects of life.

Augmented Intelligence is used in various applications, such as healthcare, education, and finance. For example, in healthcare, augmented intelligence can help pathologists make more accurate diagnoses by combining input from both the AI system and pathologists. In education, augmented intelligence can improve human decision-making by processing vast amounts of educational data that would be overwhelming for a human decision-maker and by removing elements like bias, tiredness, and attention that might taint or misinterpret data.

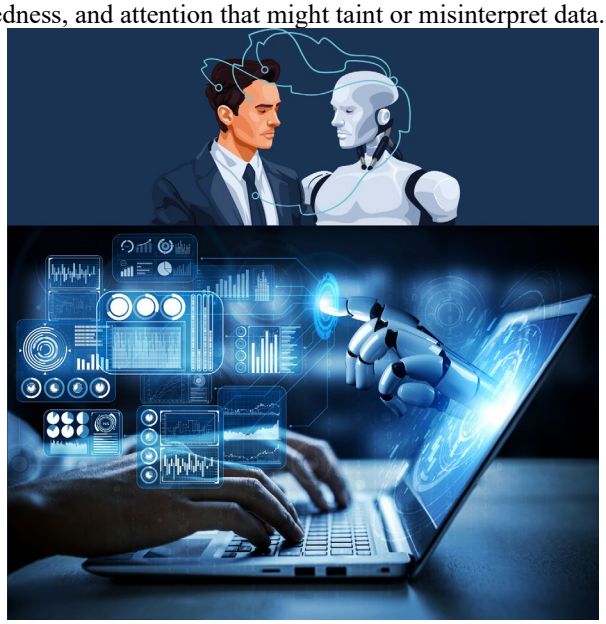

Figure 1: Augmented Intelligence

There is no one clear definition of augmented intelligence, probably due to the complexity of this phenomenon and its novelty in scientific research. However, it is generally agreed that augmented intelligence is a design pattern for a human-centered partnership model of people and AI working together to enhance cognitive performance, including learning, decision-making, and new experiences.

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II. LITERATURE REVIEW

Artificial Intelligence (AI) and Augmented Intelligence – which is also known as Intelligence Amplification (IA) are two different approaches to achieving the same objective. AI is designed to perform tasks autonomously, while IA is designed to work alongside humans to enhance and supplement human intelligence [2].

The key difference between AI and IA is that AI automates tasks requiring human intelligence, while IA enhances human decision-making. AI systems make decisions based on data sets and predefined rules, while IA uses machine learning and predictive analytics of data sets to improve human decision-making and actions taken in response to improved decisions. Take a look at Figure 2:

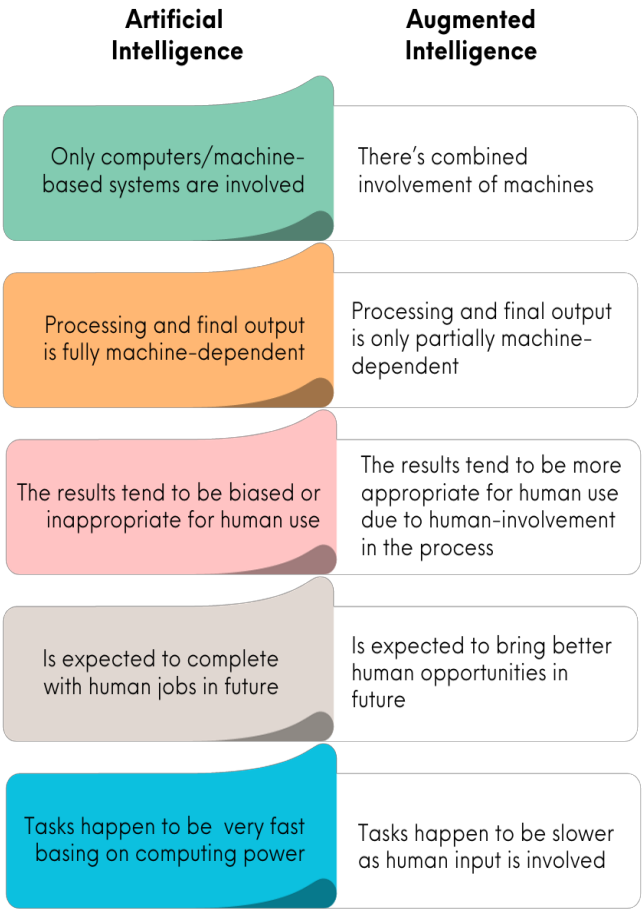

Figure 2: Difference between AI & IA

AI is intended to operate without human assistance, while IA is designed to complement and enhance human intelligence rather than replace it. AI is intended to take mundane and repetitive tasks from humans, while IA focuses on helping humans perform tasks faster and smarter.

AI is designed to replace human intelligence, while IA is designed to enhance and supplement human intelligence.

As organizations strive to harness the power of Augmented Intelligence and undergo digital transformations, a wealth of research has been conducted to explore their implications and potential. These papers delve into various facets of Augmented Intelligence and digital transformation. We not only highlight their key findings but also identify specific research gaps that persist across these studies. Furthermore, we shed light on the challenges that accompany the adoption of these transformative technologies [3][4]. While these papers provide valuable insights into the broader context of Augmented Intelligence and digital transformation, our examination also underscores the need for more targeted research, particularly in industries such as healthcare, manufacturing, and medical fields, where unique opportunities and challenges abound [5][6].

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Table 1. Research Papers on Augmented Intelligence and Digital Transformation

Research Area	Findings	Challenges
Digital Transformation through Artificial Intelligence [7]	AI enables digital transformation and changes the way work is done.	The study does not identify any specific challenges.
Digital Transformation and Business [8]	Technological skills are essential for digital transformation, but employees must also be motivated to use these skills.	The study does not identify any specific challenges.
AI and Digital Economy Impact on Legal System [9]	AI and digital transformation will be integrated into various applications.	The implementation must be carried out in conformity with both standard regulations and the new realities.
Factors Influencing Firms' Digital Transformation [10]	The study provides a systematic literature review of digital transformation at the individual, firm, and macro levels.	Limited understanding of factors influencing digital transformation in healthcare, manufacturing, and medical fields.
Digital Transformation in Business and Management [11]	The study maps the thematic evolution of current research on digital transformation in business and management.	Limited exploration of digital transformation's impact on healthcare, manufacturing, and medical fields.
Technology Advances in 2023 [12]	AI is one of the primary catalysts involved in enhancing capabilities, especially in computing.	The study does not identify any specific challenges.
Impact of AI and Digital Economy on Vietnam's Legal System [13]	AI and digital transformation will be integrated into various applications.	The implementation must be carried out in conformity with both standard regulations and the new realities.
Digital Technologies for a New Future [14]	Digital technologies are facilitating innovation and creating new business models.	Limited examination of digital technologies shaping the future of healthcare, manufacturing, and medical fields.
Augmented Analytics Driven by AI [15]	AI enhances analysis, reduces time, and supports data preparation, visualization, modeling, and generation of insights.	Most business problems cannot be solved purely by machines.
Digital Transformation and AI Applied to Business [16]	The study discusses the legal regulations, economic impact, and perspective of digital transformation and AI applied to business.	Limited exploration of the economic impact of AI in healthcare, manufacturing, and medical fields.

III. AUGMENTED INTELLIGENCE AND HUMAN DECISION-MAKING

Augmented intelligence improves human decision-making in two ways:

- By providing human decision-makers with actionable insights. Augmented Intelligence analyzes large amounts of data that would overwhelm a human decision-maker and removes factors that can color or misinterpret data, including bias, fatigue, and distraction. Augmented Intelligence can accelerate data processing and pinpoint trends that humans might overlook or not consider while still including human employees in the data analysis process [17].
- By making routine decisions autonomously. Augmented Intelligence can make routine decisions autonomously,

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freeing up human decision-makers to focus on more complex decisions [18].

Augmented Intelligence is designed to enhance human abilities through the power of machine-generated insights. When used together properly, augmented intelligence and human intelligence are greater than the sum of their parts. Augmented Intelligence improves human decision-making by handling large amounts of data that would overwhelm a human decision-maker, removing factors that can color or misinterpret data, and making routine decisions autonomously.

IV. GENERATIVE AI AND HUMAN EXPERTISE COLLABORATION

The collaboration between Generative AI and human expertise is important in various domains and industries, as it harnesses the strengths of both artificial intelligence and human intelligence to achieve superior outcomes. This synergy between AI and human expertise has the potential to drive innovation, enhance decision-making processes, and address complex challenges more effectively.

One significant aspect of this collaboration is the ability of Generative AI to augment human creativity and productivity. AI can generate a wide range of ideas, designs, or solutions rapidly, providing a valuable source of inspiration to human experts. For instance, in creative fields like art and design, AI tools can assist artists and designers by generating initial concepts, saving them time, and allowing them to explore a broader spectrum of possibilities. Human experts can then refine and customize these AI-generated outputs to align with their unique vision, style, or requirements. This collaboration amplifies the creative capacity of individuals and teams [19].

In addition to creativity, Generative AI can also enhance the efficiency of problem-solving. AI algorithms can analyze vast datasets and generate insights that would be challenging for humans to derive manually. For example, in healthcare, AI can assist medical professionals in diagnosing diseases by analyzing medical images and patient data [20][21]. The AI can highlight potential issues or patterns, enabling doctors to make more informed decisions faster. This collaborative approach between AI and human expertise not only improves diagnostic accuracy but also enables healthcare professionals to focus on patient care and empathy, aspects where human judgment and communication are irreplaceable.

Figure 3: Generative AI & Human Collaboration

Generative AI can facilitate knowledge discovery and synthesis. It can sift through enormous volumes of data from various sources, extract relevant information, and generate summaries or reports. This is invaluable in research and data-intensive fields, as it saves human experts from the laborious task of manually reviewing and synthesizing information. AI-driven text summarization, for instance, can help researchers quickly identify key findings and trends within scientific papers, expediting the process of literature review and hypothesis generation [22].

However, it's crucial to note that Generative AI is not a panacea and has limitations. Human expertise is indispensable in providing context, nuance, and ethical considerations that AI may lack. While AI can generate content, it often requires human oversight to ensure quality, relevance, and alignment with ethical standards [23]. Moreover, human experts bring years of experience and intuition to the table, enabling them to make value judgments, adapt to unexpected situations, and exercise discretion – qualities that AI currently struggles to replicate.

The collaboration between Generative AI and human expertise is also essential in addressing the ethical and societal implications of AI applications. Human experts can guide the development of AI algorithms to ensure they adhere to ethical guidelines, fairness principles, and legal regulations. They can identify potential biases, unintended consequences, and ethical dilemmas that may arise from AI-driven decisions. By working together, AI and human experts can create responsible AI systems that respect human values and rights [24].

This partnership enhances creativity, efficiency, and knowledge synthesis, ultimately leading to more innovative solutions and improved decision-making. While AI can automate tasks and generate content, human expertise provides the essential context, judgment, and ethical guidance necessary for responsible and meaningful AI applications across various domains. The ongoing collaboration between

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AI and human expertise holds the promise of shaping a future where the combination of artificial and human intelligence drives progress and innovation in unprecedented ways.

V. HYBRID-AUGMENTED INTELLIGENCE

Hybrid-augmented intelligence (HAI) is a new form of AI that combines human cognitive capabilities or human-like cognitive models with AI systems to develop a more effective and efficient AI model. The need to introduce human cognitive capabilities or human-like cognitive models into AI systems is due to the open-ended nature of problems that humans are facing, which machines are unable to completely replace [25]. Here are some ways in which HAI can empower individuals and organizations to innovate, create, and drive digital transformation with a human touch:

1. **Collaboration and Cognition:** HAI can be divided into two basic models: human-in-the-loop augmented intelligence with human-computer collaboration and cognitive computing-based augmented intelligence, in which a cognitive model is embedded in the machine learning system. This collaboration between humans and machines can harness the strengths of both, leading to more effective decision-making and problem-solving in complex scenarios.
2. **Optimal Results:** While AI can support and enhance executive functioning tasks, the combination of human intelligence and AI capabilities holds the potential for achieving optimal results. Human cognitive skills, such as creativity, emotional intelligence, and critical thinking, complement AI models' analytical and computational power.
3. **Revolutionizing the Way, We Work:** HAI can revolutionize the way we work, learn, and make decisions by involving a partnership between humans and machines, where each party contributes their unique strengths and capabilities.
4. **Meta- and Omni-Human:** The emergence of the metaverse(s) and omniverse has transformed the landscape of human-computer interaction, ushering in a new era of HAI that aims to optimally leverage the capabilities of both human and artificial intelligence.
5. **Synergistic Human-AI Interactions:** HAI highlights how humans and AI can augment their capabilities and intelligence through synergistic human-AI interactions.

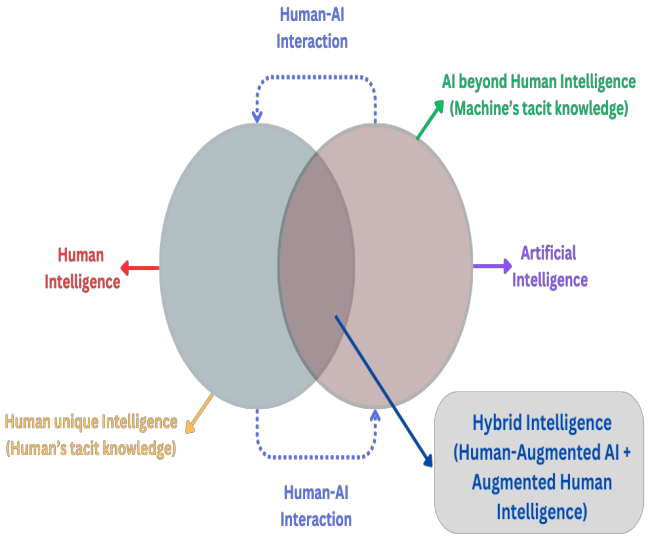

Figure 4: Hybrid-Augmented Intelligence

HAI is a new form of AI that combines human cognitive capabilities or human-like cognitive models with AI systems to develop a more effective and efficient AI model. HAI can empower individuals and organizations to innovate, create, and drive digital transformation with a human touch by involving collaboration and cognition, achieving optimal results, revolutionizing the way we work, and leveraging synergistic human-AI interactions [26].

VI. HYBRID-AUGMENTED INTELLIGENCE MODELS

Hybrid-augmented intelligence (HAI) can be divided into two basic models:

Human-in-the-Loop Augmented Intelligence with Human-Computer Collaboration:
This model involves a partnership between humans and machines, where each party contributes their unique strengths and capabilities. In this model, humans are involved in the decision-making process, and the machine provides support and enhances the decision-making process. The human-in-the-loop model is particularly useful in complex scenarios where human judgment is required [25]. Take a look at **Figure 5:**

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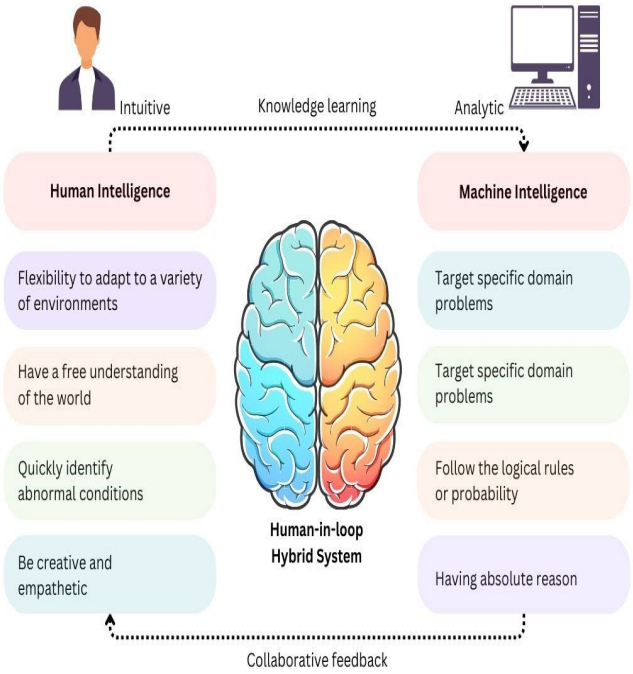

Figure 5: Human-in-the-loop with AI

Cognitive Computing-Based Augmented Intelligence

This model involves embedding a cognitive model in the machine learning system. The cognitive model is designed to mimic human cognitive processes, such as perception, reasoning, and decision-making. This model is particularly useful in situations where the decision-making process is repetitive and requires a high level of accuracy. Take a look at **Figure 6:**

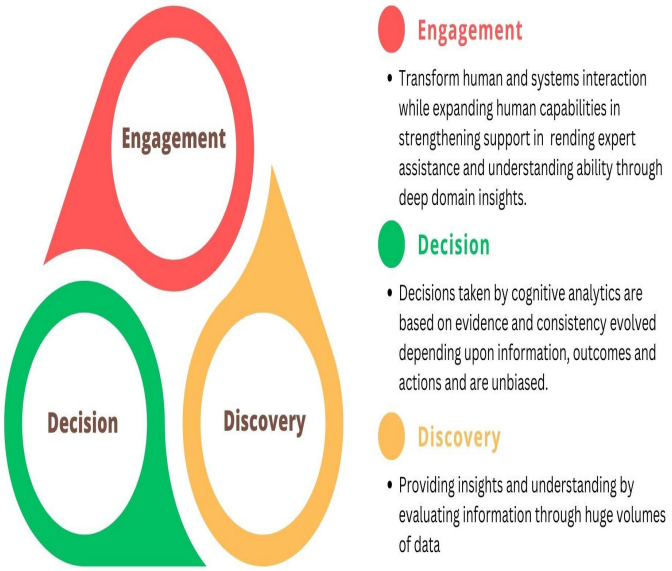

Figure 6: Cognitive Computing-based AI

In both models, the goal is to combine the strengths of human and machine intelligence to achieve optimal results. The human-in-the-loop model emphasizes collaboration and cognition, while the cognitive computing-based model emphasizes the integration of human-like cognitive models into AI systems.

VII. HYBRID-AUGMENTED INTELLIGENCE IN BLOOD GLUCOSE MONITORING

Hybrid-augmented intelligence (HAI) can be used in blood glucose monitors to improve decision-making processes. Here are some ways in which HAI can be used in blood glucose monitors:

1. **Continuous Glucose Monitoring (CGM):** HAI can be used in CGM systems to improve glucose control, reduce hypo and hyperglycemia, and increase time in range (TIR). By analyzing data from various sources, including sensors and other monitoring devices, HAI can predict when glucose levels are likely to fluctuate and recommend appropriate actions to prevent adverse events.
2. **Diagnosis of Diabetes:** HAI can be used to diagnose diabetes by analyzing data from various sources, including electronic health records (EHRs) and wearable devices. By analyzing this data, HAI can identify patterns and trends that can inform diagnosis and treatment.
3. **Glucose Management:** HAI can be used to manage glucose levels by analyzing data from various sources, including glucose meters, insulin pens, insulin pumps, and activity bands. By analyzing this data, HAI can provide personalized recommendations for insulin delivery, meal ingestion, exercise, and other factors that affect glucose levels.
4. **Self-Management:** HAI can be used to support self-management of diabetes by analyzing data from various sources, including self-reported events, glucose monitoring, and heart rates. By analyzing this data, HAI can provide personalized recommendations for insulin delivery, meal ingestion, exercise, and other factors that affect glucose levels.

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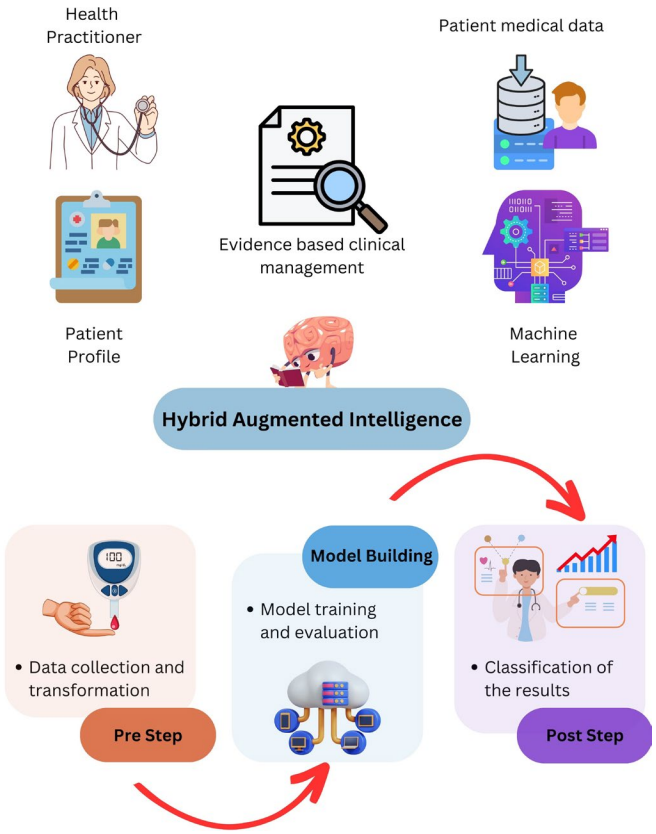

Figure 6: Hybrid-Augmented Intelligence in Blood Glucose Monitoring

As shown in **Figure 7**, HAI can be used in blood glucose monitors to improve decision-making processes by analyzing data from various sources, including CGM systems, EHRs, wearable devices, glucose meters, insulin pens, insulin pumps, activity bands, and self-reported events. By analyzing this data, HAI can provide personalized recommendations for insulin delivery, meal ingestion, exercise, and other factors that affect glucose levels.

HAI System Example in Diabetes Management

There are several examples of hybrid-augmented intelligence (HAI) systems used in diabetes management [27]. Here are some specific examples:

1. **Diabetes Management System:** Contreras et al developed a diabetes management system to integrate a series of AI models and tools with an engine to manage diabetes patient care flows.
2. **Continuous Glucose Monitoring (CGM) Sensors:** HAI can be used in CGM systems to improve glucose control, reduce hypo and hyperglycemia, and increase time in range (TIR). Advanced methodologies using AI and CGM sensors for decision support in advanced T1D management have been reviewed.
3. **Artificial Intelligence Algorithms for Treatment of Diabetes:** AI algorithms can provide actionable insights for clinical decision-making and managing chronic diseases. Leveraging Artificial Intelligence to Improve Chronic Disease Care: Methods and Application to Pharmacotherapy Decision Support for Type-2 Diabetes Mellitus is an example of an AI-powered diabetes care device.
4. **Intelligent Diabetes Mellitus Detection System:** HAI can be used to design an intelligent diabetes mellitus detection system using a hybrid feature selection based XGBoost classifier. The Hybrid FS-based XGBoost system achieves a high accuracy of 99.93 % for non-invasive diabetes detection with fewer features and less computational effort [28].
5. **Decision Support Systems for Type 1 Diabetes:** HAI can be used in decision support systems for type 1 diabetes. An artificial intelligence decision support system for the management of type 1 diabetes is an example of an AI-powered diabetes care device.

In summary, HAI systems have been used in diabetes management to improve glucose control, reduce hypo- and hyperglycemia, increase time in range (TIR), provide actionable insights for clinical decision-making, design intelligent diabetes mellitus detection systems, and develop decision support systems for type 1 diabetes [29].

VIII. HYBRID-AUGMENTED INTELLIGENCE IN BLOOD GLUCOSE MONITORING

As we delve deeper into the realm of digital transformation strategies and frameworks, our focus now shifts to a pivotal aspect of contemporary technological evolution: Human-AI Collaboration for Augmented Intelligence. Building upon the foundations of our earlier discussion, we aim to explore how organizations can effectively embrace this transformative approach. Our quest is to identify strategies and frameworks that not only harness the power of technology to enhance human capabilities but also prioritize ethical considerations and human-centric principles. To embark on this journey, we turn our attention to a well-established framework, the McKinsey 4D model [30].

The McKinsey 4D framework for digital transformation can be adapted and applied effectively to the context of augmented intelligence and human collaboration for blood glucose monitoring in healthcare. Here's how each stage of the framework can be utilized:

McKinsey 4D Framework

Discover:

- In the context of blood glucose monitoring, the "Discover" stage involves gaining a deep understanding of the current state of blood glucose management, including the challenges faced by patients and healthcare providers.

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- Identify the potential for augmented intelligence to improve blood glucose monitoring. This could involve studying existing technologies, patient data, and healthcare processes.
- Develop a comprehensive strategy for implementing augmented intelligence in blood glucose monitoring, considering factors such as patient engagement, data privacy, and regulatory compliance.

Design:

- The "Design" stage focuses on creating user-centric solutions. For blood glucose monitoring, this means designing user-friendly interfaces, mobile apps, or wearable devices that patients can easily use to track their blood glucose levels.
- Utilize augmented intelligence to design predictive models that can provide real-time insights and alerts to patients and healthcare providers based on blood glucose data.
- Incorporate feedback from patients and healthcare professionals to refine the design and ensure that it aligns with their needs and preferences.

Deliver:

- In the "Deliver" stage, implement the designed solutions. This may involve developing or partnering with technology providers to create the necessary software, hardware, or medical devices.
- Establish collaboration between healthcare providers and technology companies to ensure seamless integration of augmented intelligence into clinical workflows.
- Roll out the blood glucose monitoring system with augmented intelligence capabilities to a pilot group of patients and healthcare facilities to assess its effectiveness and gather real-world data.

De-risk:

- To "De-risk" the implementation of augmented intelligence in blood glucose monitoring, focusing on minimizing risks associated with data security, accuracy, and patient safety.
- Ensure compliance with healthcare regulations, such as HIPAA in the United States, to protect patient data.
- Continuously monitor and evaluate the performance of the augmented intelligence system to identify and address any issues promptly.

Figure 7: McKinsey 4D Framework

By applying the McKinsey 4D framework to augmented intelligence in blood glucose monitoring, healthcare organizations can enhance the accuracy of monitoring, improve patient outcomes, and streamline healthcare processes. Augmented intelligence can assist healthcare providers in making timely decisions based on patient data, and patients can benefit from personalized recommendations and alerts for managing their blood glucose levels effectively. Overall, this approach facilitates a collaborative ecosystem between technology and healthcare professionals, ultimately improving the quality of care for individuals with diabetes or other blood glucose-related conditions.

IX. CONCLUSION

In conclusion, Augmented Intelligence represents an evolution in artificial intelligence capabilities that prioritizes collaboration with human expertise. This paper has explored key AI concepts, models, applications, and frameworks that can drive innovation across diverse industries. While AI systems can rapidly process data and automate decisions, human cognition remains irreplaceable for judgment, ethics, and nuance. An effective augmented intelligence strategy combines the strengths of both.

Healthcare is one domain with immense potential for human-AI collaboration. As illustrated through blood glucose monitoring examples, AI can generate real-time insights to assist providers and patients. However, human expertise is vital for context and patient-centric care. Responsible development and application of AI can transform decision-making and service delivery across healthcare, manufacturing, research, and more. Hybrid augmented intelligence models that tightly integrate human and machine intelligence promise to achieve optimal outcomes.

Overall, augmented intelligence marks a promising new phase where artificial and human capabilities complement each other

in unprecedented ways. But realizing its full potential requires a focus on ethics, transparent design, and human-centric principles. With responsible implementation, augmented intelligence can usher in an era of amplified innovation and decision-making to advance sectors and address complex societal challenges. This evolution necessitates ongoing research and dialog between technologists, domain experts, policymakers and society.

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