

Artificial Intelligence and Its Scope in the Treatment of Diabetes

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Abstract

The science of artificial intelligence is rapidly expanding, and its application to the global diabetes pandemic could revolutionize how this chronic disease is diagnosed and managed. AI has been used to design algorithms to assist prediction models for the risk of diabetes or its complications. During the last 10 years, the combination of continuous glucose monitoring and data from insulin pumps has revolutionized the management of diabetes. More recently, wristbands or watches have been able to track a wide range of physiological characteristics and functions, including heart rate, sleep duration, number of steps taken, and mobility. Future updates will provide more information, including barometric pressure, hydration, and geolocation. When these variables are analyzed, they can support the decision-making of patients and medical professionals. There has been a growing interest in developing and using artificial intelligence (AI) methods for decision assistance and knowledge acquisition in recent years. Comparable new situations have emerged in various medical domains. The industry is considering a significant potential for the application of artificial intelligence (AI), which is now being applied to generate personal health histories. However, cost and privacy concerns have not yet been resolved.

Keywords

Artificial Intelligence, Diabetes, Expert Systems, RBR, CBR, FL, CNN

1. Introduction

By definition, artificial intelligence (AI) is the capacity of computers to do activities that traditionally require human intelligence [1] [2]. Determining what constitutes intelligence is also not easy. "Intelligence" refers to a set of capabilities, including understanding, learning, and reasoning, that enable a person to make

choices and find solutions to issues. AI attempts to mimic these aspects of the human intellect using various techniques. To better ease comprehension, the purpose of this study is to compile a list of the AI technologies that are most commonly used and provide a brief explanation of each. Over the past several decades, many AI approaches and techniques have been applied to the field of medicine and health in general. Typical uses of artificial intelligence in medicine include, among other things, diagnosis, categorization, treatment, and robots. Neural networks and fuzzy logic (FL) are the two types of artificial intelligence technologies that have seen the most widespread use.

On the other hand, this evaluation also considers several additional methods and approaches, all chosen because of their importance [1]. Diabetes mellitus is a persistent disorder that can be found almost everywhere and has a wealth of data and a variety of possible consequences. As a result, artificial intelligence could be instrumental in treating diabetes [1]. In addition, over the years, various AI models have been developed that can detect glucose and other biochemical constituents, generally measured in such patients. As an illustration, different wearable devices such as smartwatches, continuous glucose monitoring systems (CGMS), and insulin pumps are convenient alternatives to conventional methods. Artificial intelligence has played an important role in diagnosing and treating DM, but it is also widely used for data analysis and its management. Digitosome is the term that accounts for scientific information and digital technologies, as advised by authors, and highlights its importance for the recognition of digital biomarkers and risks associated with DM [3].

When given enough instruction, artificial intelligence (AI) can perform tasks like the human mind. Because AI can be digitalized, it is gaining popularity in the healthcare industry. The digital storage of patient information provides medical professionals with a means of facilitating patients' access to improved care in the years to come. As a result, the potential of a physician and hospital staff is increased. This technological advancement has led to treatment options for cancers and genetic defects. Physicians may make informed clinical decisions about diseases. It does this by automatically analyzing a significant quantity of patient data to create the data and predict the patient's prognosis. As a result, this new research and development method can potentially improve the healthcare system [4]-[6]. AI ensures patients do not have to be readmitted to the hospital by providing the right information. It will automatically follow up on any outstanding invoices and other management-related information about the hospital's administration. AI helps to move information around, and the accuracy of clinical data is also improved. It is to everyone's advantage to carry out modern treatments with the utmost precision. This makes solving the difficult issue easy for people [4] [7] [8]. The application of AI technology is beneficial in the diagnosis of diabetes and high blood pressure, as well as in treating these conditions in much less time and at a lower cost. It clearly explains the progression of the current condition using the information and makes therapy suggestions. By providing reminders of routine

responsibilities, this technology eases the workload of medical professionals. Better medical knowledge, practice-based learning, communication skills, patient care, and overall progress are all things doctors may accomplish. With the help of electronic health records, it is easy to miss the training given to medical students. The appropriate use of this technology may result in increased protection for patients. [4] [9] [10].

Artificial intelligence (AI) is rapidly transforming healthcare, and its application in diabetes management holds immense promise [11] [12]. AI offers the potential for personalized, predictive, and precise diabetes management, leading to better patient outcomes and reduced healthcare costs [13]-[18]. This manuscript aims to provide a comprehensive overview of the role of AI in diabetes management, including its significance, objectives, and research questions. AI enables personalized treatment plans by analyzing individual patient data. Predictive modeling helps identify people at risk of developing diabetes or its complications. AI-powered systems can provide patients and healthcare providers with continuous monitoring and real-time feedback [9]-[11]. This review will examine the various applications of AI in diabetes care, such as AI-driven decision support systems for healthcare providers [10], automated insulin delivery systems [11], predictive models for diabetes complications [12], and integration of wearable technology and continuous glucose monitoring (CGM) [10]-[12].

Furthermore, this manuscript also aims to analyze the challenges and limitations of AI in diabetes management, including concerns about data privacy and security [13], the potential for algorithm bias [14] [15], and interoperability issues between different AI systems [16]. This review will explore the potential of AI to revolutionize diabetes management in the coming years by discussing future directions for AI in diabetes management, such as the integration of CGM data with other health data sources [12], personalized medication and lifestyle recommendations [11], and AI-powered virtual assistants for the education and support [17] [18]. Finally, this review will address the following research questions: How is AI currently used to improve diabetes management? What are the key challenges and limitations of applying AI in this context? What are the potential future directions and emerging trends in AI-driven diabetes management?

1.1. Definition of AI and Its Importance in Diabetes

Artificial intelligence (AI) is the capacity of computers to perform. Artificial intelligence (AI) is defined as the capacity of computers to perform activities that traditionally require human intellect [1] [2]. While determining what constitutes intelligence is complex, it generally refers to capabilities such as understanding, learning, and reasoning, which enable decision-making and problem-solving. AI aims to replicate these aspects of human intelligence through various techniques.

Diabetes mellitus is a chronic disorder with global prevalence, characterized by extensive data and numerous potential complications [3]. Consequently, AI has significant potential in diabetes management [1] [3]. Over the years, various AI

models have been developed to detect glucose and other biochemical markers typically monitored in diabetic patients. Wearable devices such as smartwatches, continuous glucose monitoring systems (CGMS), and insulin pumps are convenient alternatives to traditional methods. AI has contributed significantly to diagnosing and treating diabetes and is widely used for data analysis and management. The concept of the “digitosome” encompasses scientific information and digital technologies, underscoring its importance in identifying digital biomarkers and risks associated with diabetes [3].

1.2. Artificial Intelligence’s Potential in Transforming Healthcare

Artificial intelligence (AI) has the potential to transform healthcare care by performing tasks that traditionally require human intellect. As AI can be digitized, it is becoming increasingly popular in the healthcare industry. The digital storage of patient information allows medical professionals to provide better care, enhancing the capabilities of physicians and hospital staff [5]. This technological advancement has led to new treatment options for diseases such as cancers and genetic defects, allowing physicians to make more informed clinical decisions [5] [6]. AI can analyze large amounts of patient data to predict patient outcomes, thus potentially improving the healthcare system [5] [6] [8].

AI also ensures that patients receive the right information to avoid hospital re-admissions. It can automatically follow up on outstanding invoices and other administrative tasks, improving the flow of health information and the accuracy of clinical data [5] [8] [9]. This technology simplifies the resolution of complex issues that challenge humans. AI has proven beneficial in diagnosing and treating conditions such as diabetes and high blood pressure more efficiently and cost-effectively [5] [10] [11]. Provides clear explanations of disease progression and suggests therapy based on current information. By offering reminders for routine tasks, AI reduces the workload of medical professionals, allowing them to achieve better medical knowledge, practice-based learning, communication skills, patient care, and general progress [5] [10]. Additionally, using electronic health records can enhance the training of medical students, ultimately increasing patient safety.

2. Background Study

Diabetes, a chronic metabolic disorder, is a leading cause of healthcare costs worldwide and a significant public health concern. The International Diabetes Federation (IDF) estimates that 463 million people between the ages of 20 and 79 have diabetes, with an additional 374 million having impaired glucose tolerance. These numbers are projected to rise to 693 million by 2045, representing a 10% global prevalence. The worldwide obesity pandemic and sedentary lifestyles contribute significantly to the development of type 2 diabetes, as they overwhelm the body’s natural ability to regulate blood sugar [19]-[21].

There is a pandemic of diabetes worldwide. 12% of global health costs are attributed to the estimated 425 million people who have diabetes; however, only one

in two of these people receives a diagnosis and treatment [22]. The worldwide obesity pandemic and a sedentary lifestyle, which exceed the body's natural ability to regulate blood sugar and require exogenous insulin, are the main causes of type 2 diabetes [23]. Gestational diabetic mothers give birth to millions of babies each year. Insulin therapy is necessary for the rest of a child's life if they are born with type 1 diabetes mellitus, in which the body cannot make insulin [24]. Diabetes virtually doubles the risk of heart attack and all-cause mortality, makes people more likely to need hospitalization, have long-term problems, and incur greater expenditures. It is also the main cause of kidney failure, lower limb amputations, and adult-onset blindness in the United States [25]. Insulin therapy is necessary for the rest of a child's life if they are born with type 1 diabetes mellitus, in which the body cannot make insulin.

Diabetes virtually doubles the risk of heart attack and all-cause mortality, makes people more likely to need hospitalization, have long-term problems, and incur greater expenditures. It is also the main cause of kidney failure, lower limb amputations, and adult-onset blindness in the United States.

The complications associated with DM can be classified as macrovascular and microvascular complications. The former includes cardiovascular diseases, and the latter consists of diabetic nephropathy, diabetic retinopathy, and diabetic neuropathy [26]. One study listed the percentage of the different cardiovascular diseases caused in DM patients, which are 34% for stroke, 22% for myocardial infarction (MI), and 56% for isolated systolic hypertension [27]. Einarson and his research team highlighted the prevalence of CVD diseases in DM patients. They conducted a study with 4,549,481 patients with DM and resulted that 32.2% had CVD problems, 29.1% had atherosclerosis, 21.2% had coronary heart disease, 14.9% had heart failure, 14.6% suffered from angina pectoris, 10% myocardial infarction, and 7.6% patients were diagnosed with stroke. On the contrary, cardiovascular diseases were prevalent in diabetic patients and were responsible for 9.9% of mortality rates in patients with DM [28].

In addition, diabetic nephropathy is the major etiological factor for renal failure in DM patients. This disease is irreversible, and the patient needs to undergo therapies such as dialysis if they are affected by it. The diagnostic factors associated with this complication include an imbalance in creatinine levels and the presence of proteins in the urine. Prophylactic action can be taken by managing blood glucose levels and taking renin-angiotensin-aldosterone inhibitors. Diabetic nephropathy, if not managed, can lead to severe complications. Research indicates that mortality in patients with diabetes who also have nephropathy is 30 times higher compared to those with diabetes but without nephropathy. A cross-sectional study conducted in China found that out of 15,856 DM patients, 38% suffered renal failure due to nephropathy, and a multicenter research study from India stated the composite prevalence was 62.3% [29] [30].

Diabetic retinopathy (DR) is also a serious complication observed in patients with DM. It is characterized in multiple ways based on elevated vascular flow and

vascular leakage due to the prevalence of vascular lesions, cell inflammation, edema in tissues, expression, and cytokines, reactive glia, apoptosis of inner retinal cells, and neovascularization. This condition causes blurred vision in patients and can also lead to blindness. A meta-analysis by Jonas and colleagues proved that DR caused blindness and visual impairment in 0.8 million people out of 32.4 million blind people worldwide [31]. Lastly, another microvascular complication, diabetic neuropathy, is also well prevalent in DM patients, and about 30% of DM patients suffer from painful diabetic neuropathy [32]. It is characterized by needle-stinging pain and significant burning sensation in the hands and limbs.

Currently, there is no complete cure, but it can be prevented by managing blood sugar levels and administering multivitamins. Proper management of diabetic neuropathy is important as it can lead to foot ulcers and amputation [33]. Multiple software and devices are developed using artificial intelligence, which has not only helped reduce severity but also helps to understand the diseased state better. It can be used to prevent and treat complications, such as diabetes.

3. AI Applications in Diabetes Management

AI is applied in diabetes management in various ways, including prediction models, decision support systems, and wearable technology.

3.1. Prediction Models

AI algorithms can analyze data from various sources, such as electronic health records, genetic data, and lifestyle information, to predict the risk of developing diabetes or its complications. This enables healthcare professionals to identify individuals who may benefit from early interventions and preventive measures.

3.2. Decision Support Systems

AI-powered decision support systems can assist healthcare professionals in making informed treatment decisions. These systems can analyze patient data and provide personalized recommendations for medication, lifestyle changes, and other interventions.

3.3. Wearable Technology

Wearable devices, such as continuous glucose monitors (CGMs), insulin pumps, and smartwatches, can collect real-time data on blood glucose levels, activity levels, and other physiological parameters. AI algorithms can analyze this data to provide personalized insights and recommendations for patients and healthcare professionals.

3.4. Evolution of CGM Technology

CGM technology has advanced significantly over the past decade, with improvements in sensor accuracy, size, and wearability. The development of “flash” CGM systems has eliminated the need for routine fingerstick calibration, making it eas-

ier for patients to monitor their blood glucose levels. However, challenges remain, such as sensor calibration, accuracy in hypoglycemia, and cost-effectiveness.

3.5. Automated Insulin Delivery Systems

AI is also being used in automated insulin delivery systems (AID) or “artificial pancreas” technology. These systems use AI algorithms to analyze CGM data and automatically adjust insulin delivery to maintain optimal blood glucose levels.

3.6. Prediction and Prevention of Complications

AI can be used to predict and prevent diabetes complications, such as retinopathy, nephropathy, and cardiovascular diseases. AI algorithms can analyze data from various sources, such as retinal images, blood tests, and physiological parameters, to identify individuals at high risk of developing these complications.

3.7. Artificial Intelligence in the Treatment of Secondary Diseases Associated with Diabetes Mellitus

AI is being used to develop and improve the treatment of secondary diseases associated with diabetes mellitus. **Table 1** summarizes different AI tools used for micro and macrovascular complications. These tools offer various functionalities, including disease detection, severity measurement, classification, diagnosis, prediction, and data processing.

Table 1. Different AI tools used for micro and macrovascular complications.

Disease complication	AI Tool	AIM	Reference
Diabetic Neuropathy	SVM, KNN	Detection of the prevalence of diabetic foot and to measure its severity.	[34]
Diabetic Neuropathy	Machine Learning	Classification of Diabetic foot thermograms	[35]
Diabetic Neuropathy	GaNDLF	Data processing and data augmentation	[36]
Diabetic Retinopathy	Fundus imaging modalities	Diagnosis using color retinal fundus images	[37]
Diabetic Retinopathy	CNN	Obtaining fundus photographs, radiological films, and pathological studies	[38]
Diabetic Retinopathy	Machine Learning	Clinical Diagnosis	[39]
Diabetic Nephropathy	Machine learning tool	Prediction of DKD stage	[40]
Diabetic Nephropathy	CNN	Classification, detection and segmentation of disease	[41]
Diabetic Nephropathy	Multi-instance Learning	Solve Multiple instance problems at Musk Data set	[42]
Cardiovascular diseases	SKLEARN	Machine learning prediction tool for heart disease	[43]

4. Diabetes Retinopathy (DR)

Artificial intelligence models are regularly used to detect abnormalities in patients with DR. As an illustration, Open Indirect Ophthalmoscopes by LVPEI and MIT have an inert feature to detect DR by Machine Learning. In addition, a 3-D printed smartphone fundus camera and Kavya Kopparapus's Eyagnosis app are being used in famous eye hospitals worldwide. The US FDA has authorized IDx-DR, a device that analyzes digital retinal images using an AI algorithm to help in the early diagnosis of retinopathy. A software known as Scikit-learn utilizes computer languages such as Python as a platform for working [44]. Fundus screening is one of the most common methods for early diagnosis and therapy to decrease the problems associated with this disease. However, with an increase in screening rates, technical difficulties led to that can be easily solved by AI-based grading systems.

These systems are more economical for long-term use and are less time-consuming. Wong and colleagues [45] developed a model to classify DR stages based on the presence of microaneurysms and hemorrhages. Imani and colleagues [46] proposed an alternative technique of identifying exudation and blood vessels using morphological component analysis and adaptive thresholding to provide information about the vessel map. Yazid and colleagues [47] also employed inverse surface thresholding to detect hard and soft exudates. In recent times, a scientific study conducted by Eye Nuk used retinal images that were obtained with the help of fundus cameras, proving that Eye Art's sensitivity for DR screening was 91.7 to 91.5% [48]. An automated teleretinal DR screening program, IRIS (intelligent retinal imaging system), can differentiate nonmydriatic retinal images from the reference standard pictures [49]. Lastly, various AI-based technologies such as Retina fundus imaging modalities, Ultra wide-field imaging, Smartphone-based, and machine learning have helped capture and identify the diseased components that have improved the prophylaxis of diabetic retinopathy [50].

5. Diabetic Nephropathy

Artificial intelligence has significantly impacted the diagnosis and treatment of diabetic nephropathy and other renal diseases. Functional magnetic resonance imaging (fMRI) in association with fuzzy C means (FCM) clustering algorithms in plan-do-check-action (PDCA) have been used to evaluate the effect of DN in patients. This incorporation of technologies was studied by Du and colleagues with 64 DN patients who were divided into two groups: the research group (n = 32) and the control group (n = 32), and different measures such as curative effect, nursing satisfaction, and patient quality were observed. The study resulted in significantly higher fMRI activation points with the FCM algorithm [51].

Furthermore, a contemporary predictive model for diabetic kidney disease was built by Makino and colleagues [52] using artificial intelligence. This system processed natural language and organized longitudinal data with big data machine learning in order of electronic medical records (EMR) of 64,059 diabetic patients.

All preliminary factors were determined using AI, and convolutional autoencoders evaluated the patterns. Moreover, this AI model consisted of more than 3073 features and used logistic regression analysis to generate time series data [52]. Furthermore, six machine learning techniques are also implemented to determine complications associated with DN. These techniques include linear discriminant analysis, support vector machine (SVM), logistic regression, K-nearest neighborhood, naive Bayes, and artificial neural networks. Combined with principal component analysis, these techniques have shown great precision in improving the accuracy of disease diagnosis and treatment [53].

6. Cardiovascular Diseases

These consist of all the macrovascular complications associated with DM. Any individual with DM has a high risk of suffering from CVD, and therefore, regular check-ups and the incorporation of newer technologies like AI are essential. One of the most common medical procedures to determine heart activity is the Electrocardiogram (ECG). Siontis and colleagues successfully fused this medical procedure with artificial intelligence. A deep learning convolutional neural network (CNN) is a complex AI method that can detect signals and information that are generally missed after human interpretation; thus, this particular technology is commonly used for the identification of atrial fibrillation, hypertrophic cardiomyopathy, left ventricular dysfunction, and also for the determination of age, sex and race of any individual [54].

Additionally, other commonly used AI-based models include artificial neural networks (ANN), Multi-layer perceptron (MLP), and probabilistic neural networks (PNN). MLP is easy to understand and based on mathematical theories, whereas ANN provides better predictive ability and greater accuracy. This accuracy of ANN was highlighted in the Baldassare study, which was conducted in a total of 949 patients and 54 variables. The study aimed to differentiate patients based on their history of vascular events, such as vascular risk factors (VRF) and carotid ultrasound variables (UV). The result recorded an 80.8% diagnostic ability and 79.2% precision [55].

7. Peripheral Diabetic Neuropathy (PDN)

The most prevalent issue associated with PDN is the diabetic foot. Several AI tools have been developed to treat this condition because it is difficult to diagnose it early stage. The AI methodologies with sensor-based technologies are equipped to identify the extent of the disease. Special platforms are also developed, which consist of sensory components on which the patient is asked to walk. The software measures the locomotion movement and the stimulus of nerves when in contact with the needles.

In addition, the ANN method was used to detect the Diabetic foot risk associated with 5 SNPs in the TLR4 gene [56]. Additionally, Troitskaya used the MLP technique for prophylactic purposes [57]. Although diabetic foot can be consid-

ered a major concern of DN, monitoring neuronal activity in other bodies is also very important [58]. As an illustration, the corneal subbasal nerve plexus is extensively used to diagnose PDN. Subsequently, studying corneal confocal microscopy gives us a four-year chance of the incidence of PDN. Thus, prediction can be made by conducting non-invasive ophthalmic imaging techniques, which enables us to determine the peripheral and central neurodegenerative diseases. This process also comes with disadvantages, as it is more time-consuming and less economical, but we can at least achieve a better diagnosis for the patient's well-being [59]-[61].

Thus, AI enables informed and empowered patient participation. Healthcare systems are significantly affected by digital solutions because they change patient behavior, comorbidities, time spent receiving care, and the need for frequent healthcare visits [3]. AI has improved both patient transfer inside hospitals and patient flow to hospitals [62].

People living with diabetes can interact and gain knowledge from one another through online networks and support groups. Both patients and caregivers find this collaborative approach to learning more about the numerous facets interesting, and it has a good effect on the patient's well-being and desired results [63]. A cost-effective approach to reducing ocular problems and avoidable blindness related to diabetes is early diagnosis of diabetic retinopathy using AI. Continuous glucose monitors (CGM) can potentially lower the cost of treating diabetes-related medical problems [64]. By enabling earlier and more effective treatment, image-based screening of diabetic foot ulcers and retinal abnormalities can improve quality of life and save delays in referral to specialist treatment [65].

8. Role of Artificial Intelligence in the Real-Day World

Artificial intelligence (AI) is a field of study and a group of computing technologies modeled after—but frequently works differently—how people use their neurological systems and bodies to detect, learn, reason, and act [66]. Since the field started sixty years ago, there have been considerable advancements, even if the growth rate has been uneven and unexpected. In the twenty-first century, artificial intelligence enables a constellation of widely used technologies that significantly affect people's daily lives. Video games, which are already a larger segment of the entertainment market than Hollywood, are driven, for example, by computer vision and AI planning [66]. Speech comprehension is now possible on smartphones and in kitchens thanks to deep learning, a type of machine learning based on layered representations of variables known as neural networks. Deep learning algorithms may be widely used in various pattern recognition applications. A machine defeated the Jeopardy champion thanks to natural language processing (NLP) and knowledge representation and reasoning, and these technologies are giving Web searches new strength.

Robotics and artificial intelligence (AI) will also be used globally in businesses with difficulty attracting talent. When AI augments or replaces human work, problems will arise for the economy and society. The nature and direction of these

developments are likely to be significantly influenced by the design and policy choices made soon, so AI researchers, developers, social scientists, and policymakers must strike a balance between the need to innovate and the need to ensure that the economic and social benefits of AI are widely distributed throughout society [66]. Mistakes that hinder AI's progress or push it underground will occur if society views these technologies primarily with dread and distrust, slowing crucial work on assuring the security and dependability of AI systems has the potential to revolutionize various sectors in the coming decades, offering significant societal benefits if embraced openly. While agriculture, food processing, fulfillment centers, and manufacturing rely on younger workforces, AI-powered automation could reshape these sectors. For instance, delivery services may increasingly utilize flying drones, autonomous trucks, and stair-climbing robots to fulfill online orders [66]. This shift could lead to increased efficiency and convenience but also necessitates careful consideration of its impact on employment and the workforce.

Artificial intelligence has allowed us to utilize our natural resources to their full potential. As an illustration, an artificial neural network (ANN) is a contemporary tool-based model that has facilitated a better understanding of various solar energy devices and also helped to predict the efficiency of its parts like the solar-assisted heat pumps, solar air and water heaters, solar collectors, photovoltaic systems, solar stills, solar cookers, and solar dryers. This has not only helped to improve the quality provided by these systems but is also an initiative to promote green energy [66].

Wind energy is one of the most crucial forms of renewable energy, and incorporating AI to obtain a better yield is very important. Marugan and colleagues, with this ideology, conducted a survey that focused on the benefits of using ANN in wind energy systems. Statistical analysis reported error prediction, machine design optimization, and the use of ANN in the prediction [67].

AI has been a boon for all sectors and has enabled us to predict and reach great heights, but it also has its set of disadvantages. The Research Panel found little reason to be concerned that AI poses an immediate threat to humans, in contrast to some of the most amazing forecasts for AI in the popular press. If not used wisely, AI has the potential to take over human civilization by decreasing employment requirements and making people lazy and dependent.

AI can also be an addictive tool for children, which, when overexploited, can harm their well-being. Kids are surrounded by a world of technology and artificial intelligence (AI), which has reduced their excitement for outdoor activities, making them inactive and ignorant. It also directly affects their creativity and makes them dependent, hampering their mental growth.

Conversely, between now and 2030, the time frame this paper analyzes, increasingly practical uses of AI are anticipated to develop, potentially affecting our society and economy positively. In addition, many of these breakthroughs will lead to changes in how AI augments or replaces human labor, posing new problems for the economy and society. The nature and directions of such developments are

likely to be significantly influenced by application design and policy choices made in the near future, so AI researchers, developers, social scientists, and policymakers must strike a balance between the need to innovate and the need to ensure that the economic and social benefits of AI are widely distributed throughout society. Mistakes that hinder AI's progress or push it underground will occur if society views these technologies primarily with dread and distrust, slowing crucial work on assuring the security and dependability of AI systems. If society approaches AI with a more open attitude, the technologies that result from the area may significantly improve civilization over the next several decades.

9. Contextual Information about Diabetes

Diabetes has now reached the level of a pandemic. Diabetes affects an estimated 425 million people across the globe and is responsible for 12% of all healthcare costs globally; nonetheless, the condition is still misdiagnosed and undertreated in all other people [1]. The worldwide obesity pandemic and a sedentary lifestyle are the primary causes of type 2 diabetes. These factors cause the body's glucose control mechanisms to be overwhelmed, necessitating exogenous insulin use. There are around 2 million babies born each year to mothers who have gestational diabetes. Children born with type 1 diabetes mellitus, a form of the disease in which the body cannot manufacture insulin, need insulin treatment for the rest of their lives [5].

The worldwide obesity pandemic and a sedentary lifestyle are the primary causes of type 2 diabetes. There are around 6 million babies born each year to mothers with gestational diabetes. Children who are born with type 1 diabetes mellitus, a form of the disease in which the body is unable to manufacture insulin, need insulin treatment for the rest of their lives. The effectiveness of intensive treatment in delaying the development of diabetes-related problems, such as retinopathy, nephropathy, ketoacidosis, and neuropathy, as well as slowing the course of these diseases, has been shown through decades of well-designed trials [68].

It is sometimes difficult to provide optimal care to people with Diabetes (PWDs) because there is a lack of real-time, crucial health information required to make informed decisions about intense treatment and strict diabetes management. The influence of technology on the treatment of diabetic patients seems to be relatively modest, although technological improvements have made it possible to have unprecedented and affordable access to the knowledge necessary for many people in many other disciplines. The rapidly increasing body of medical knowledge adds another layer of difficulty to the already difficult task of providing up-to-date information on diabetes treatment [5]. Rapid advances in artificial intelligence (AI) have the potential to make organized and unstructured health data in real-time accessible for the treatment of patients with physical disabilities (PWD).

AI, or artificial intelligence, is defined as "the study of having computers execute activities that require intellect when done by people," according to the Turing Archive for the History of Computing [5] [58]. AI encompasses a wide variety of

techniques to emulate the human mind and carry out a variety of reasoning activities. Some examples of these tasks include visual perception, voice recognition, analytics, decision-making, and the translation of languages into one another. Cognitive systems use AI techniques to expand and scale human knowledge and skills. This is accomplished by allowing people to quickly use substantial information sources to find solutions to problems [5].

The Institute of Systems Biology's Leroy Hood is credited with pioneering the P4 medicine idea, which has since been expanded into the P7 concept [1] [69].

Some of the vision of components that make up the P7 for the future of healthcare are as follows:

1) Personalized. The practice of adapting or personalizing a patient's therapy to their specific needs is known as personalized medicine.

2) Predictive. We should be able to evaluate an individual's vulnerability to specific illnesses using the information included in their EHRs (electronic health records) and genetic data.

3) Precise. After data and information, decision analytic methods can be used to pinpoint a condition and propose appropriate treatment activities accurately.

4) Preventive. Machine learning and decision analysis tools can be used to design ways to avoid the start of the illness, which is preferable to treating a person after they have been infected.

5) Pervasive. Anytime, anywhere, and any location should be acceptable for medical attention.

6) Participatory. A patient's role in evaluating and managing his or her health should be collaborative.

7) Protective. The confidentiality of patient information must be protected by adopting the necessary precautions and safety measures. All of the ideas will use recent artificial intelligence (AI) breakthroughs.

10. How Does Artificial Intelligence Work?

AI, or artificial intelligence, is a subfield of computer science that focuses on developing intelligent software and hardware capable of doing tasks formerly reserved for humans. This results in various advances in all industries and sectors. This technology enables more intelligent production, support, customized advice, monitoring of potentially hazardous equipment, improved marketing, and improved customer service [4] [70] [71]. The programming of machines may make them behave in a manner that is similar to that of a human being. It has enormous potential for learning, thinking, perceptual development, and solving difficult situations. In medicine, this technology is intended to be used to perform complicated algorithmic and software-based analyses of complex medical data [4] [72] [73]. It has an impressive capacity to acquire knowledge through machine learning methods. This device can quickly analyze the treatment procedure, which may further improve patient results.

11. Principal AI Research Objectives

By augmenting the human brain's capabilities, artificial intelligence (AI) facilitates the creation of novel medical techniques. This article focuses on the capabilities of this technology to improve healthcare education and the decision-making processes involved in these processes. Teaching and illustrating to medical students the many alternative methods available for diagnosing and treating diseases is beneficial. Artificial intelligence is effective in producing correct outcomes with the use of relevant data. Data are captured digitally, which helps reduce the number of continuous mistakes that occur in the healthcare industry [4] [74]. This technology is important to properly monitor a patient's heartbeat, analyze a patient's computed tomography, X-ray, or magnetic resonance imaging scan, and assist patients with exercise correctly. By revealing a more accurate image, which human eyes cannot do, revolutionary shifts in various abnormalities. It aids in preserving sensitive information that might harm the patient [75] [76]. Several types of fraud and errors in therapy are straightforward to identify. The primary purpose of this investigation is to discuss the great benefits of AI as well as its limitations.

12. AI Methodology

12.1. The Application of Expert Systems in Medicine

The term "expert system" (ES) refers to the artificial intelligence system used most often in clinical practice. They are systems that can collect expert knowledge, facts, and reasoning skills to assist care professionals daily. To help in decision-making and problem-solving, ES tries to imitate clinicians' competence by using inference techniques. Furthermore, ES can manage data to arrive at logically sound conclusions. Image interpretation, diagnosis assistance, and alert generation are some of the many functions that ES can accomplish.

12.2. The Following Are Important Aspects of an ES

1) A knowledge acquisition system, also known as a KA system, is a system that is used to acquire the information and the rules that the ES employs to answer the suggested issues. The expert may carry out this procedure, the knowledge engineer providing direct input, or based on a database that includes previous case studies and the results of those studies.

2) A knowledge base: This component maintains the information and rules about the unique challenge the ES is resolving.

3) An inference engine is a control system that applies the rules and information in a knowledge base to the data to perform the reasoning process [77].

12.3. Rule-Based Reasoning (RBR), Case-Based Reasoning (CBR), and Fuzzy Systems Are the Most Common ES Used in the Diabetes Domain

12.3.1. RBR

The RBR methodology relies on transferring knowledge from a specialist to a

computer. As a direct result of this, the computer must be able to discover answers to questions that would typically need the assistance of a specialist. Statements of the “if-then” form are used to convey knowledge in such a manner that allows the chain of reasoning to be analyzed and understood. The first step in acquiring new information is to interview the subject matter expert and the knowledge engineer who will ultimately be responsible for developing and validating the ES. It has been defined as the most available possibilities during these interviews, and the engineer encodes this information to become computer-interpretable [77].

12.3.2. CBR

CBR can identify answers to new challenges by modifying existing and successful solutions to similar situations. To assist in obtaining further instances, the characteristics of the case study need to be supplied. While this is happening, the characteristics must be discriminative enough to prevent the retrieval of case studies that can result in incorrect answers because they are too dissimilar. In contrast to RBR, CBR does not need an explicit domain model; all that is required is to identify new examples that include important characteristics. This is how CBR “learns.” CBR processes are often described using what is known as the “CBR working cycle,” which consists of the following five steps.

1) description of the current issue description; 2) search for a successful solution of a comparable case; 3) modification and reuse of the solution to the new problem; 4) assessment; and 5) storage of the confirmed solution; and one of the most significant drawbacks of CBR is that it requires the collection of enormous databases of case studies. These databases may include information irrelevant to the analysis, and retrieving these data may sometimes take an unnecessary amount of time.

12.3.3. FL

Expert knowledge that uses ambiguous terms can be represented in a manner that computers can understand by applying fuzzy expert systems. For example, a blood glucose range of more than 180 mg/dl is considered high, while a blood glucose range of less than 80 mg/dl is considered low. This categorization does not provide a great deal of assistance when making decisions. In the real world, a blood glucose reading of 181 mg/dl requires a different course of action than 281 mg/dl in most cases. In other words, in other words, a blood alcohol level of 181 mg/dl is considered high but is practically acceptable, but a blood alcohol level of 281 mg/dl is considered extraordinarily high and is not appropriate at all. This ambiguity is expressed through FL by designating a specific membership level for each category. In the preceding example, we may argue that a blood alcohol level of 181 mg/dl falls into the “high” group 70% of the time but the “very high” category only 30% of the time [77].

13. Application of AI in Healthcare

13.1. Automated Retinal Screening

The diagnosis of diabetic retinopathy can now be performed automatically thanks

to deep learning algorithms [65]. Artificial intelligence-based retinal screening is a practical, reliable, and widely recognized technique for identifying and following up diabetic retinopathy. For automated retinal screening, high sensitivity and specificity of 92.3% and 93.7%, respectively, have been recorded. With 96% of the patients reporting being happy or extremely satisfied with this procedure, patient satisfaction with automated screening is also high [77]. In order to provide lesion-specific probability maps for hemorrhages, microaneurysms, exudates, neovascularization, and normal appearance in the retina, convolutional neural networks (CNN) have been trained on a few datasets [78].

13.2. Clinical Decision Support

Supervised machine learning-based clinical decision support systems have been created to forecast the short- and long-term HbA1c response following the start of insulin in patients with Type 2 diabetes mellitus. These instruments can aid in identifying clinical factors that can affect a patient's HbA1c response. According to reports, the generalized linear model with elastic net regularization can accurately predict the HbA1c response to insulin introduction using baseline HbA1c and estimated glomerular filtration rate. An intuitive method of tailoring interventions in medication adherence and forecasting the likelihood of hospitalization for diabetes has been developed using machine learning [79].

13.3. Genomics

Modern advances in diagnosing and treating disease problems include advanced molecular phenotyping, genomics, epigenetic changes, and the invention of digital biomarkers [80]. They can be used for diabetes, whose heterogeneous nature and protracted duration create enormous data sets. A database of microbial marker genes has been created using microbiome data that may be used to predict the likelihood that diabetes will develop and to direct therapy in individuals who already have the disease [81]. More than 400 signals have been found in genome-wide association studies that may indicate a genetic predisposition to diabetes [82]. Several genome-wide epigenomic annotations for pancreatic islets have been used to train CNN models to anticipate regulatory variations to enhance the signals associated with diabetes [83].

14. Impact of AI in the Future

In the not-too-distant future, AI will usher in a significant transition inside the surgical process. It is possible to do surgery with the assistance of robots, which will help to improve the medical staff. With the help of the digital data that are already accessible, education and training on new illnesses will also play an important role. The use of sophisticated surgical methods is made easier with the help of AI. It gives the patient peace of mind that they will receive superior care, which increases their confidence throughout the procedure. Patient symptoms are the first factor considered when diagnosing any disease. It does this using readily

available information to make projections of future illnesses. This technology will result in new developments that will improve human health and solve a variety of other problems that are now insurmountable. Because it automatically checks the sugar level, blood pressure, and blood test, the physician will have more time to focus on other patient needs. AI will prepare several significant dangers and their responses to improve patient health. In the not-too-distant future, this technology will appear to be an effective method for making appropriate decisions in a shorter time [4].

14.1. Challenges and Limitations of AI in Diabetes Management

Despite the promise of AI in diabetes management, several challenges and limitations need to be addressed [84]-[87].

Data Privacy Concerns: AI algorithms rely on large datasets of patient information, raising concerns about data privacy and security. Ensuring compliance with regulations like HIPAA and GDPR is crucial to maintaining patient trust and protecting sensitive data. Breaches can result in significant financial penalties and damage the reputation of healthcare providers and AI developers [84].

Table 2. AI in healthcare: key ethical considerations.

Key Ethical Considerations	Description
Bias and Discrimination	AI algorithms can inherit and amplify existing biases in healthcare data, potentially leading to discriminatory outcomes. Addressing this requires ensuring diverse and representative datasets and rigorous testing for bias.
Privacy and Confidentiality	AI systems often rely on vast amounts of patient data, raising concerns about privacy and security breaches. Robust data protection measures and strict adherence to privacy regulations are essential.
Autonomy and Informed Consent	The use of AI should not undermine patient autonomy. Patients should be fully informed about how AI is being used in their care and have the choice to opt out.
Beneficence and Non-Maleficence	AI should be used to improve patient outcomes and avoid harm. This requires careful consideration of potential risks and benefits and ongoing monitoring of AI systems.
Justice and Equity	AI should promote equitable access to healthcare and avoid exacerbating existing health disparities. This requires addressing potential biases in algorithms and ensuring that AI technologies are accessible to all populations.

Algorithm Bias: AI algorithms can perpetuate existing biases in healthcare, leading to disparities in access to care and treatment outcomes. Developing and training AI models on diverse datasets is essential to mitigate bias and ensure equitable care. For example, an AI model trained on data primarily from one ethnic

group may not generalize well to other populations, potentially leading to misdiagnosis or inappropriate treatment recommendations.

Need for Large, Diverse Datasets: Training effective AI models requires large, diverse datasets that accurately reflect the heterogeneity of diabetes populations. The lack of such datasets can limit the generalizability and accuracy of AI algorithms. This is particularly important for diabetes, which affects diverse populations with varying risk factors, comorbidities, and responses to treatment.

Patient Overreliance on AI: Patients may become overly reliant on AI-driven recommendations, potentially neglecting their judgment and the importance of healthcare provider oversight. Emphasizing the role of AI as a tool to support, rather than replace, healthcare providers is crucial. Open communication between patients and healthcare providers must ensure that AI-driven recommendations are interpreted and implemented appropriately.

Regulatory and Ethical Considerations: The use of AI in healthcare raises ethical considerations, such as accountability, transparency, and informed consent. Establishing clear regulatory frameworks and ethical guidelines is necessary to ensure responsible AI development and implementation. This includes addressing concerns about the potential for AI to exacerbate health inequities and ensuring that AI technologies are used in a way that benefits all patients. See **Table 2** for more ethical considerations.

14.2. Emerging Trends and Future Directions

The future of AI in diabetes management holds immense potential. Emerging trends include integrating CGM data with other health data sources, enabling a more holistic view of the patient's health. AI can be used for personalized medication and lifestyle recommendations, tailoring treatment plans to individual needs and preferences. Developing AI-powered virtual assistants for education and support can empower patients to self-manage their diabetes effectively [88].

Furthermore, AI can improve health equity and access to care for underserved populations with diabetes. AI-powered telehealth platforms can bridge geographical barriers and provide remote access to care, while AI algorithms can help identify individuals at high risk of developing complications, enabling early interventions [89].

However, realizing the full potential of AI in diabetes management requires addressing challenges such as data privacy concerns, algorithm bias, and the need for large, diverse datasets to train AI models effectively. Patient overreliance on AI-driven recommendations and the importance of maintaining healthcare provider oversight are also important considerations. Additionally, establishing regulatory frameworks and ethical guidelines for using AI in healthcare is crucial to ensure responsible and equitable implementation [90].

15. Conclusion

With the help of artificial intelligence, we can reimagine approaches to diabetes

care and prevention. AI aids in creating prediction models that gauge the likelihood of developing diabetes and its associated consequences. This will contribute to adding a component of individualized care in treating diabetes. Using digital platforms, clinicians can offer timely and focused interventions for patients who are now empowered to control their health. These developments reduce time and expense because data can be obtained remotely, and normal clinic visits are being replaced by virtual management. Treatment of Diabetes has undergone a sea shift thanks to artificial intelligence, which will only advance. Additionally, the expanded expertise brought about by ongoing AI use will aid in standardizing the functionality and usefulness of diabetic treatment.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

AI	Artificial Intelligence
FL	Fuzzy Logic
DM	Diabetes Mellitus
CGMS	Continuous Glucose Monitoring Systems
R&D	Research and Development
HER	Electronic Health Records
IDF	International Diabetes Federation
GDM	Gestational Diabetes Mellitus
MI	Myocardial Infarction
CVD	Cardiovascular Diseases
DR	Diabetic Retinopathy
FDA	Food and Drug Administration
Scikit-learn	Scientific Computing Tools for Python
IRIS	Intelligent Retinal Imaging System
fMRI	Functional Magnetic Resonance Imaging
FCM	Fuzzy C-Means
PDCA	Plan-Do-Check-Action
DN	Diabetic Nephropathy
EMR	Electronic Medical Records
SVM	Support Vector Machine
CVD	Cardiovascular Diseases
ECG	Electrocardiogram
CNN	Convolutional Neural Network
ANN	Artificial Neural Networks
MLP	Multi-Layer Perceptron
PNN	Probabilistic Neural Networks
VRF	Vascular Risk Factors
CUVs	Carotid Ultrasound Variables
PDN	Peripheral Diabetic Neuropathy
NLP	Natural Language Processing
PWDs	People With Diabetes
EHRs	Electronic Health Records
ES	Expert System
KA	Knowledge Acquisition
RBR	Rule-Based Reasoning
CBR	Case-Based Reasoning
ML	Machine Learning
SVM	Support Vector Machine
KNN	K-Nearest Neighbors
GAN	Generative Adversarial Network
GaNDLF	Deep Learning Framework

Scikit-Learn also known as SKLEARN is a popular open source machine learning library in Python. It provides a wide range of machine learning algorithms for tasks such as classification, regression, clustering, and dimensionality reduction, as well as tools for data pre-processing and model selection.