Tec Empresarial
P-ISSN: 1659-2395; E-ISSN: 1659-3359

DIABETES MONITORING USING CONTROL SYSTEM IN METAVERSE ENVIRONMENT: A SCOPING REVIEW

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Abstract
There has been a surge in curiosity about the "metaverse" and conversations around what this platform can provide to other scientific disciplines are already starting to take shape. In this paper, we examine the most important possibilities and unanswered questions on how a metaverse, and control theory are working together to reduce the incidence of chronic diseases that such as diabetes. We can employ fundamental ideas of control theory to understand the real risk posed by immersive technologies, or we can apply these ideas to effectively use immersive technologies in the healthcare sector.

Keywords: Diabetes, Blood Glucose Level, Metaverse, Control System, Controller, Chronic diseases.

1 Introduction

Chronic diseases (CD) are conditions requiring ongoing medical care or restricting everyday activities. If a condition has persisted for at least a year, it is considered chronic. The main causes of death and disability in the United States are CD-like heart disease, cancer, and diabetes. On November 14, the globe celebrates "Globe Diabetes Day". Its goals are to raise public awareness of diabetes and to improve the lives of more than a billion people worldwide who have the condition. Diabetes, commonly known as diabetes mellitus, is a chronic illness brought on by the body's diminished capacity to make enough insulin or to use it efficiently. The pancreas secretes insulin, a hormone that enables food's sugar to reach the body's cells, where it could be kept or used as fuel. It might be difficult for people with insulin-dependent diabetes to keep their blood glucose levels (BGL) in check. To make the task simpler, hybrid closed-loop systems and automated insulin delivery systems have been created. By tracking BGL and automatically adjusting insulin delivery, continuous glucose monitors (CGMs) and insulin pumps can communicate with each other in a full circle to assist control BGL [1].

Patients suffering from non-communicable diseases are still struggling due to the following reasons: 1. severe scarcity of general practitioners, 2. small hospitals are not taken seriously, 3. specialists work overloaded, 4. the general public lacks medical knowledge, and 5. huge public hospitals are understaffed [2]. The conventional medical setting and methods of health care delivery are under pressure due to several causes.

The fusion of immersive technologies, digital twins (DT), BC, IoT, and AI in the context of the metaverse opens up new possibilities for the healthcare (HC) sector. Two decades ago, the idea of Metaverse was introduced. However, it was just starting to take off in 2021, and some saw it as the internet's replacement or even its pinnacle. The phrase "metaverse" combines the prefix "meta," which denotes something "virtual and transcendent," and the prefix "universe," which refers to the entire planet [3]. In a virtual setting, the metaverse replicates reality. The metaverse is now thought of as a digitally based ternary civilization. Digital identities are used by participants, and the three parts of the community combine people, machinery, and materials. In his novella true names, "Professor Verner Vinge" an American mathematician imaginatively envisioned a virtual environment that could be accessed and interacted with via a brain-computer interface (BCI). This is where the ideological idea originated. Its idea was formally put forth in the science fiction book "Snow Crash" in the year 1992 by American author "Neal Stephenson" [4]. It introduces a present era of internet users that intermingle and discern a virtual world like a reality using avatars [5]. Imagine virtual worlds where avatars are used, such as "Roblox" and "Fortnite" [6]. Every sphere of existence now has less opportunities thanks to the metaverse.

The medical domain also has a promising future in the metaverse [7]. By offering HC services virtually and through an immersive experience made possible by its implausible features, the HC industry significantly benefited from the potential of Metaverse [8]. The necessity for virtual and non-physical interaction treatment gained significant appeal after the COVID-19 epidemic. Additionally, it has in some manner altered the trajectory of life. Patients are now treated digitally by nurses using avatars [9]. The on-body sensors are used to collect patient information, symptoms, and other essential parameters in digital format. Patients are questioned by avatars including "Sensely and NHS (National Health Service)" to learn everything there is to know about them and their medical history [10]. New advancements in HC could result from the metaverse theory. The natural and the virtual world are merging as intelligent terminals become more commonplace, 5G, BC, and other infrastructures get better and virtual-reality (VR), augmented-reality (AR), mixed-reality (MR), and other virtualization skills get more advanced [11].

As efficiently as a brain implant, metaverse technologies could restrict our cognitive freedoms. To think logically about the potential risks of interactive systems, this paper wants to introduce an engineering notion. The phrase "feedback control" refers to the idea, which originates from the technical field of "control theory". The formal approach used to modify a system's behaviors is simply known by the label "control theory" by engineers and scientists. Whatever interacts with the outside world can be that system. In an uncontrolled metaverse, the controller can progressively change how the human perceives their environment also their experiences to exert a specific impact, changing what they see and hear to encourage them to pursue a certain objective. Additionally, the controller's ability to continuously monitor the user in real-time allows it to gradually modify its impact strategies, enhancing the impact of persuasion over time.

Formatting for the remaining paper is as follows: Section 2 describes the linked investigation of the metaverse in medicine; Section 3defines the Metaverse components; Section 4 presents the chronic illness treatment in the Metaverse environment; Control theory in the Metaverse for CD management is in Section 5; and a conclusion is given in Section 6.

2 Related work

A digital CD management platform based on wearable, the Internet of Things (IoT), block-chain (BC), and artificial-intelligence (AI) can take full advantage to remind patients to take their medications on time, process the monitoring data they've collected in real-time, and alert them to any unusual data, enabling remote monitoring of the therapeutic process. As indicated in Table 1, numerous researchers have suggested digital treatments utilizing different technologies for people with these CD conditions.

Technology related to the metaverse is becoming more and more well-known and is regarded as the next stage in the development of the internet. Every area, including HC, entertainment, business, and education, may benefit from it. A virtual world with an immersive experience is provided by this fantastic technology, which also integrates other technologies. There are many connected research papers on metaverse technology, which is the subject of current research on this new developing technology. The metaverse has received a lot of attention and popularity recently. The metaverse, which allows people to more fully connect the real and virtual worlds, is currently taking over the planet. The metaverse is still developing and in its infancy. All industries, including HC [22, 23], education [24], the travel and tourism sector [25], agriculture [26], social networking, entertainment, and gaming [27, 28], will have new opportunities made possible by it. Facebook, a massive social media corporation, altered its title to “Meta” to better reflect the possibilities of the metaverse [29]. This increased the significance of the metaverse.

Ioannis Skalidis et al. [30] proposed a metaverse-based paradigm for cardiovascular (CV) treatment. Cardio Verse was the name of it. It has the ability to adapt and change how CV disease is handled. Other uses include enhancing the effectiveness and accuracy of CV therapies, illness detection, and prevention, among others. BC technology and AI have been integrated into CV therapy, according to Chayakrit Krittanawong MD et al., [31]. They went into more depth about the potential applications and future possibilities of these innovations in the field of CV disease.

They also assessed the difficulties and looked at fresh approaches to effectively treat and prevent CV disease. The metaverse has also been utilized for instruction and training. Thoracic surgery was performed by Huilyung Koo et al., [32] in the modern operational chamber of the Bun-dang hospice of Seoul National University. There were more than 200 surgeons present for this surgery, which was webcast. While doing an immersive head-mounted display, the thoracic surgeons got online training. The participants could take part in the conversation and watch the surgeries in the virtual setting. A further application of metaverse technology is the treatment of cancer, one of the world's most serious diseases. Johns Hopkins used AR to successfully remove the patient's spine-based malignant tumor [33].

The metaverse application for treating and managing obesity and CD was studied by Jane Thomason [34]. Avatars and wearable technology can be used to provide patients with consultation, a preliminary diagnosis, and individualized care, socially prescribed medications, and education for patients. People can become more aware of their well-being and a balanced state of health thanks to the metaverse's gamification capabilities. A thorough study of VR-based therapy for Parkinson's disease patients was conducted by Desiderio Cano Porras et al. [35]. They conducted a thorough investigation and analyzed 97 research articles for their study. They found that it was among the best Parkinson's disease therapy options in the VR based rehabilitation technique. VR assisted therapy is important for treating a variety of health illnesses, according to Zhen Liu et al. [36]. VR-based technologies provide facilities remotely, overcoming the drawbacks of in-person traditional therapies. VR-based therapies were shown to be the most practical form of treatment for patients during COVID-19. The emergence of the metaverse and its effects on fitness

Table 1 Comparative Analysis of CD Treatment in the Age of Advanced Technology

SN	Author	Year	Description of study	Study topology	Technology	Main Objective
1.	Tiago M. Fernandez-Carames [12]	2019	Monitoring diabetes	Implementation	BC, IoT	Design and implementation of a system that enables remote patient monitoring and alerts patients to potentially harmful circumstances.
2.	Md. Abdur Rahman [13]	2019	keeping cancer patients'	Design	IoT, BC	Create a plan to enhance cancer sufferers' quality of life.

			quality of life intact			
3.	Jaehak Yu [14]	2020	Stroke prediction	Implementation	AI	Created a stroke estimate system that can identify strokes using real-time bio-signals.
4.	Chia-Tung Wu [15]	2021	Identification of an acute worsening of Chronic Obstructive Pulmonary Disease (COPD)	Review	AI, IoT	Create a prediction system employing patient symptoms and environmental factors, for the quick identification of acute worsening of COPD in the following week.
5.	Theo Jourdan [16]	2021	Gait monitoring using wearable sensors: Validation in patients.	Review	AI, IoT	Over a lengthy time, the system should be able to monitor the gait freely, and precision must be prioritized.
6.	Tien-En Tan [17]	2021	Retinal image analysis for myopia	Implementation	AI, BC	To create and evaluate retinal image analysis for detecting myopic macular degeneration and extreme myopia.

7.	Konstantina-Maria Giannakopoulou [18]	2022	Diagnosis, surveillance, and treatment of Parkinson's disease	Review	AI, IoT, BC	To make projections or estimates about several elements of Parkinson's disease.
8.	Purushottam Kaushik [19]	2022	Indian cancer treatment	Article	AI, IoT, BC	The delivery of HC in India will change as a result of AI, BC, and IoT.
9.	Sibo Prasad Patro [20]	2022	Monitoring senior people's heart rates	Analysis	AI, IoT	Analyzed how machine learning (ML) may help forecast outcomes and assist in decision-making for health monitoring systems.
10.	TagnePoupi Theodore Armand [21]	2023	cardiology patient monitoring	Implementation	IoT	To create and build a low-cost wireless CV patient monitoring system.

was presented by Ali Garavand et al. in their article [37]. They gathered information by conducting online searches in well-known scientific databases like the Web of Science, PubMed, etc. They found that different facets of HC, including medicine, medical procedures, medical imaging, etc., are seeing exponential growth in the metaverse as indicated in Table 2.

3. The Metaverse's Components

The metaverse's potential in the life sciences and HC environment is fascinating. These are some fundamental elements of the metaverse:

3.1 Guidance, learning, and expertise development

The immersive features of the metaverse—3D graphics, 360-degree movies, haptics—enable efficient, real-time, simultaneous training and up-skilling of a larger number of medical staff members at any time and any place. Gamification and no-risk simulations are effective tools that employ the user's senses of sight, hearing, and touch to simulate real-world situations. Medical education is expensive and is based on the cost and availability of cadavers, equipment, and medical personnel. Pharmaceutical businesses can provide visualization for the performance of the drug and even recreate the experiences created by different situations. Enterprise can train HC personnel on different sorts of therapies and equipment. For instance, several prestigious medical schools use a virtual operating room with a table, tools, and a dummy patient to train surgeons.

3.2 Clinical trial modification

Decentralized clinical trials can be transformed by the metaverse by removing physical and geographic barriers, moving clinical trials from venues to patients' homes, enhancing healthy behavior, drug adherence, remote monitoring, and similar things.

Table 2 Comparative Analysis of the Metaverse's Healthcare Sector

SN	Author	Year	Description of study	Study topology	Technology	Main Objective
1.	David Holloway [38]	2012	Opportunity for simulation in the provision of HC	Case study	VR	Exemplify the usage of the virtual world as a tool for well-being research, highlighting the connection between virtual and real-world health behaviors.
2.	Yi Xie [39]	2021	Smart CD management in the Metaverse.	Framework study	AI, BC, and Wearable Technology	Establish a patient-centered technical foundation focused on wearables, BC, and AI and also

						examine these technologies' potential applications for managing chronic illnesses.
3.	Huilyung Koo[32]	2021	The Metavers''s lung cancer operation training	Medical training study	Extendedreality (ER), VR, AR	Surgical training for lung cancer via the Metaverse
4.	Jeong Ok Yang [40]	2021	Metaverse-based anti-aging fitness	Fitness Analysis	VR, DT,AR,MR	provide a technique for utilizing the metaverse for exercise rehabilitation
5.	Jens R. Chapman [41]	2022	Application of the metaverse to spinal treatment.	Case study	Robotics,VR,ML, and, AI	Enhancing fusion quality, developing novel tissue regeneration alternatives, and improving spinal decompression, alignment, or fixation procedures, in both education and research.
6.	Ioannis Skalidis [30]	2022	Training, preventing, and diagnosing CV disease	A clumsy state analysis of the future	AR/VR and AI	Treatment of CV disorders with the aid of metaverse
7.	Gaurang Bansal [42]	2022	Clinical care, physical and mental	Thorough investigation	IoT, AI, ML, BC, AR/VR, 6G, networking, DT.	Aid in developing a long-lasting, viable, and

			health in the metaverse of HC			future-proof remedy for HC systems
8.	Myeon-Gyun Cho [43]	2022	A smart aging solution that can be customized by the user that uses AI and Metaverse technology	Study based	IoT,AI,AR/VR	Offers a smart aging system that may be customized by the user in a rapidly changing social environment.
9.	Brenda K. Wiederhold [44]	2022	Anti-aging through entertainment in the Metaverse	Online game framework	AR	Virtual coaching as a form of anti-aging therapy
10.	David Benrimoh [45]	2022	Metaverse mental health	Future analysis	tele networking, VR, and social media.	Offers a Metaverse environment for mental health treatment
11.	Y Zeng [46]	2022	Mmetaverse cancer care	Future analysis	AI,AR,VR,MR, cloud computing, BC	Offers a Metaverse environment for cancer care
12.	Jane Thomason [34]	2022	Chronic Sickness and token economies in the Metaverse	Future health analysis in the Metaverse	AI, big data,IOT, ER, BC	Describes potential future uses of the metaverse for improving and possibly transforming CD care and prevention.
13.	Sikandar Ali [47]	2023	Treatment for aging through	Metaverse framework	Grad Cam and Lime,decentralized BC technology	offers an HC system based

			Telemedicine in the Metaverse			on the metaverse
14.	I Moon [48]	2023	Metaverse physical therapy	Investigation of physical therapy using Metaverse	Avatar AR, VR	Children with cerebral palsy benefit from metaverse physical treatment in terms of their overall motor skills, CV health, and COVID-19 risk.

Success depends on protecting patient privacy and safety. Non-fungible tokens (NFT) have the potential to tokenize medical records, prescriptions, and medical bills, however, more innovations will inevitably appear.

3.3 Integrated Therapies

Immersive therapeutics refers to medical interventions offered via AR, VR, and MR to treat, manage, and prevent a medical problem. The metaverse enables applications such as cognitive therapy, counselling, mental examinations, rehabilitation, and—with the aid of touch sensors—even physical therapy.

3.4 Surgery using augmented reality

Teaching doctors how to use surgical instruments from 2D static images is difficult. There are intricate surgical techniques with numerous learning sequences that may result in mistakes. Using technology to replicate each patient's specific pathology in 3D, the metaverse offers an immersive environment where surgeons can learn or plan a challenging procedure and practice and prepare the surgery with more precision and consistency. For instance, a major MedTech company collaborated with Microsoft to optimize the floor design and produce 3D pictures of operating rooms using the latter's HoloLens.

3.5 Visualizer for radiology

Currently, 2D screens are used to visualize medical pictures during radiology diagnosis. It may be more valuable to analyze diseases and plan surgeries if improved medical imaging visualization is made available. Medical experiences can be made more engaging and realistic thanks to the metaverse's immersive and visualization capabilities. For effective training of its medical robot, a top manufacturer of medical devices uses VR. The company also offers AR imaging software that uses ML algorithms to give surgeons access to crucial picture data for surgery planning and as a teaching aid.

3.6 Telemedicine using virtual reality

Hospitals' capacity to provide patient care is threatened by a shortage of lab technologists, nursing assistants, and technicians. Through the use of ER tools, the metaverse provides a potential telehealth option. By utilizing wearable technology and AR headsets, HC professionals can deliver remote services (diagnosis, treatment, monitoring, and care). In addition, because VR is so intense, it's a fantastic way to divert patients' attention from their stress.

3.7 Simulation using immersive digital twins

DTs in HC can produce useful models that allow simulations and insights. It can be made available as a web-based HC service that gathers information from patient records and real-time data from a wearable to correlate data from patients, physicians, hospitals, and drug and device makers. The utilization of the DT to enhance the functioning of medical devices and HC organizations will be made possible by the immersive and 3D visualization capabilities of the metaverse.

4. The Metaverse's Approach for Managing Chronic Illness

Conditions known as CDs limit daily activity or necessitate continual medical attention. States that a disorder is considered chronic if it has persisted for at least a year and that causes include excessive alcohol intake, poor diet, cigarette use, exposure to secondhand smoke, and poor nutrition. Major CDs include but are not limited to, diabetes, cancer, Alzheimer's, Parkinson's, arthritis, COPD, heart-related disorders, stroke, and obesity. The method of transferring the aforementioned technology is called the medical metaverse, and Sun et al. have proposed four essential steps for its development. A road for integrating medical treatments into the metaverse is represented by the four stages stated below:

4.1 Building using holograms

This stage requires the construction of a stationary geo-metric prototype for the virtual atmosphere. The health professionals, tool, and virtual hospitals are all included in this. The various objects that emerge in the environment are grouped into three categories: prospects, occasions, and persons. In a medical situation, the room containing the instruments is referred to as the scene, the patients, as well as the entire medical personnel, make up the people, and the dynamic data that is produced as a result of interactions between the scene and the people, constitutes the event.

4.2 Holographic modeling

It is necessary to incorporate and emulate the corporeal biosphere's surroundings in the virtual one. To continually improve the corporeal operation, all available technologies need to be merged and applied. With connections to existing data systems and medical information, the immersive process is projected to be at its optimum. Real-time recording of motion and multi-sensor gadgets help with the procedure by providing data from the avatar of patients and clinicians.

4.3 Fusion between the virtual with the real

Giving the virtual environment the best chance to appear authentic is the aim. Immersive encounter are anticipated as MR lowers the barriers separating the health virtual world and the real world. The continuous advancement of digital technologies is what motivates the search for the most immersive experience. Anywhere the patient or doctor may be, XR gadgets are used to enter VR and enable interactions. Real-time access to patient data and information would require its virtual world transfer.

4.4 Virtual and real world connections

For the simulation process, we'll create medical tools and procedures using technologies like AI, IoT, BCI, and others. It's expected that the implementation process will change as technology advances to make medical treatments easier.

In the meta-medicine period, new thoughts and techniques will finally be born as a result of alterations in health handling on the two spheres, which will steadily increase the connections. Supplementing and enhancing medical procedures in the real world will be made easier with help from the meta-medical community. We shall have access to the information space through which we can view and influence the physical world.

The main differences between meta-medicine and traditional medicine will be these three features.

All-encompassing interaction: With the actual and virtual worlds becoming connected, patients and medical professionals can use a variety of hardware to access and edit the digital world in real-time.

Actual and virtual worlds are combined: Over financial, communal, and identity methods, meta-medicine will seamlessly combine the actual world and the virtual world thus the patients and medical professionals can understand the similar better-off, more instinctive perception in the three-dimensional real and virtual worlds.

Decentralization: BC technology may be used for the distribution, exchange, usage, liquidness, and verification of virtual personalities in digital health capitals and also for the smart management of digital privileges.

5. Chronic Disease Management using Control Theory in the Metaverse

5.1 Fundamental Principle of the Control System

The formal technique for altering a system's behavior is simply known by the moniker "control theory". Any device that communicates with the outside world can be that system. A diabetic patient or a human being is a system in this paper. Imagine an inexpensive nightlight with a sensor. The nightlight turns on when the outside world grows dark. The nightlight turns off whenever it starts to get light outside again. That is a system of control. A fasting BGL of 99 mg/dL or less is regarded as normal; a value of 100 mg/dL to 125 mg/dL indicates prediabetes and a result of 126 mg/dL or higher indicates diabetes, accordance to the CDC (Centers for Disease Control and Prevention). BGL, commonly known as blood sugar, is continuously monitored by CGM both throughout the day and at night. Humans should be in a range of desired BGL, unlike a nightlight that has only two states (On or off).

According to the patient's age, the doctor set a target (desired BGL). When operating properly, CGM helps diabetes patients stay within the prescribed range. Feedback control is that three important boxes, labeled System, Sensor, and Controller, are shown in Figure 1. In the case of diabetes mellitus, the blood sample of the patient would serve as the system, the gluco-meter the sensor, and the DOCTOR as the controller. The desired BGL, which is chosen as the objective by the doctor according to the patient's medical history, is an input signal known as the reference. The variance among the goal (desired BGL/reference) and the measured BGL is called the measured error. Based on the measured error, the doctor needs to take the desired action. If the BGL is too low, generally doctors suggest feeding the person a fast-acting source of sugar. If it's too high, doctor suggests taking insulin to help control their BGLs. That's a classic control system that is represented in Figure 2.

The primary duty of the controller (doctor) is to minimize the difference between the patient's measured BGL and desired BGL. Such patients require cognitive medical professionals who can interpret the rich sensor "continuous glucose monitoring (CGM)" data and shape behaviors in a variety of ways. Medical devices known as CGMs are used to continuously track and monitor a person's BGLs. Persons with diabetes, those who are at risk of getting the illness, and those who want to monitor their BGLs for other reasons can all benefit from using these devices. A tiny sensor is used in a CGM device, which is often placed on the upper arm or stomach. The interstitial fluid, or fluid surrounding the cells just below the skin, is the medium in which the sensor measures glucose levels. The sensor wirelessly transmits this data to a receiver that shows the BGLs in real-time, such as a smart phone or specialized gadget. In addition, some CGM systems contain alarms or alerts that can be programmed to alert the user if their BGLs are too high or too low.AI algorithms in the metaverse are being used more and more in the HC industry nowadays. Based on the patient's disease course evolution, AI can generate real-time disease information and quickly return feedback in the form of algorithms regarding diagnostic and therapeutic information.

5.2 The Control System Concept in the Metaverse

As we know, human beings do not have time for themselves due to busy lifestyles, metaverse can analyze every manifestation that will lead to CDs. The metaverse aims to change how we as humans engage with the online environment. Digital content will evolve into immersive, spatially displayed experiences in the metaverse.

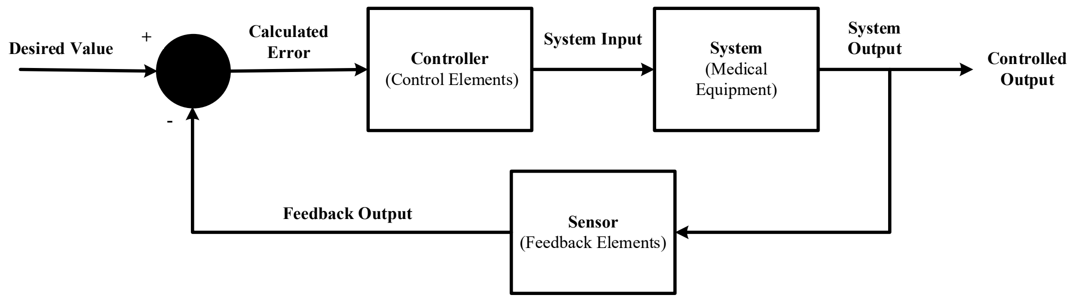

Fig. 1 Schematic for a Basic Control System

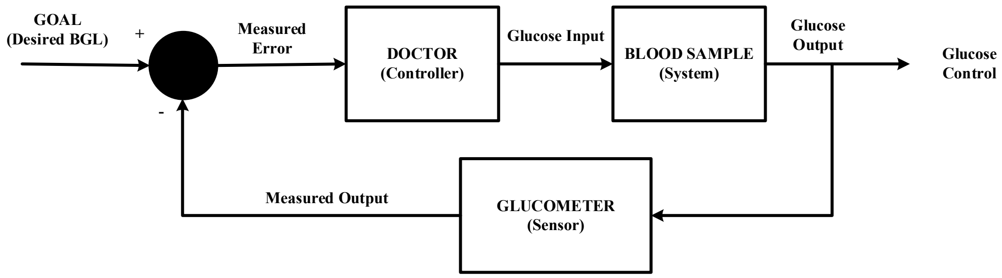

Fig. 2 Control System Diagram for Controlled Diabetes

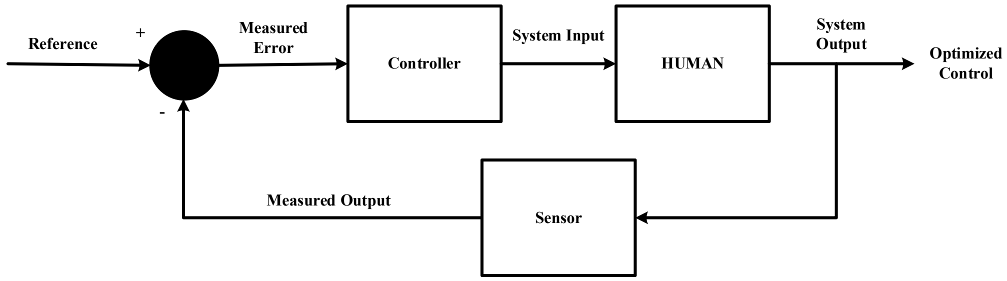

Fig. 3 Control System Diagram with “Human” in the loop

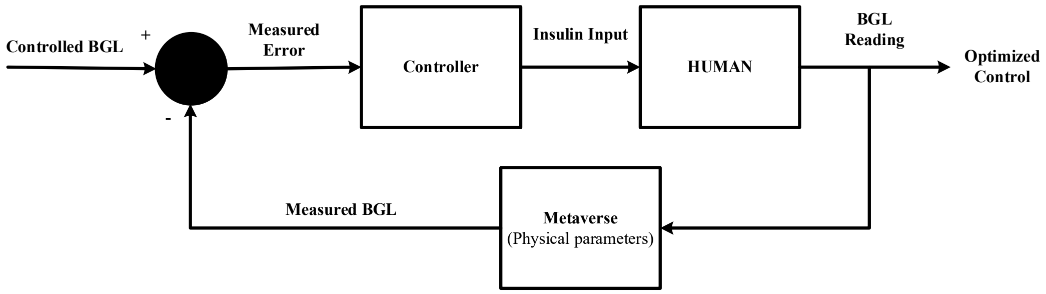

Fig. 4 Metaverse Environments Control System Diagram

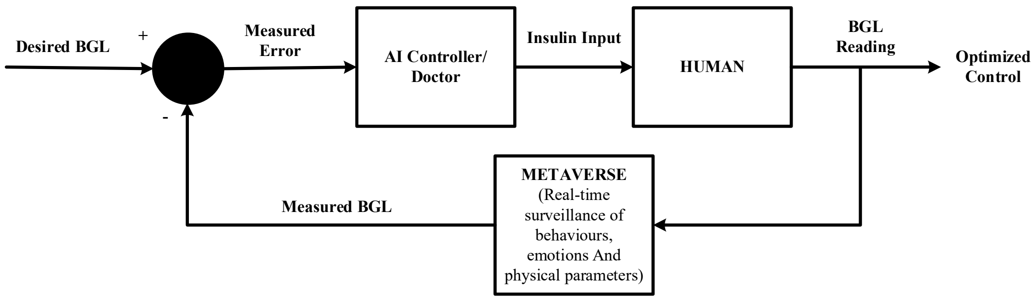

Fig. 5 Diagram of a control system showing a doctor's schedule

The metaverse can significantly advance humankind through technology. In the end, it will give us information in the manner in which our senses were designed to receive it as authentic first-person experiences rather than as flat texts seen through tiny windows. I firmly believe that humanity will greatly gain from this. Immersive media does have the potential to be effective in both positive and harmful ways. Positively, it has the potential to help people all over the world gain new perspectives and knowledge, while negatively; it has the potential to release the best potent means of persuading and management ever devised by humans.

To comprehend the true risk posed by immersive skills, we can apply the fundamental ideas of control theory, or we can employ these ideas to positively utilize immersive technologies. Recalling Figure 1, we can see that, whether it's a straightforward nightlight or a complex robot, only a few components are required for a system to be efficiently controlled. The two greatest crucial components are a SENSOR to identify the equipment's current performances and a CONTROLLER to have some control over those performances. The one additional component required are the feedback rounds, which continuously monitor performances and transmit impacts to direct the system toward desired goals. While "the system" is a person or patient in a communicating setting like the metaverse, the controller will establish a real-time feedback loop. This loop continuously observes the patient's behavior and feelings, then applies influence to nudge them in the direction of the cure.

5.3 Human-being in the Metaverse Environment

Figure 3 may look a little disconcerting, but when a person dons a headset and enters the metaverse, they are submerging themselves in a setting that can act upon them more than they act upon it. Humans are the most likely target because they live in a built environment that can be seen and affected by them in real-time. In Figure 3, the controlling system is HUMAN. The immersive images, sounds, and touch sensations that are sent into a human's eyes, ears, hands, and body are referred to as system input. This is a deluge of information—possibly the broadest and most personal the average person has ever encountered. This indicates that the system's (i.e., the human being's) capacity for impact is both broad and specific. The System Output, which consists of human real-time activities, reactions, and interactions, is on the other side of the human user. Everything a person does that might be monitored by sensors is included in this. This might seem benign, but tracking in the metaverse is much more widespread than most people realize.

Come now to the SENSOR box in Figure 3. Sensors will monitor every action people do in the metaverse in real-time, including their delicate head, hand, and body movements. This includes the way a person looks, how long their gaze lingers, the slight movement of their eyes, the dilating of their pupils, the changes in their posture and gait, and even their vital signs, such as their heartbeat, respiration rate, BGL, and blood pressure, are probably tracked in the metaverse. The patient can receive real-time input from the DT as it continuously tracks the patient's vital indicators, including blood pressure, heart rate, and glucose levels. For instance, the most modern headset used by META can precisely track facial emotions and eye movements in people [49]. The capability extends beyond only detecting the facial expressions that other people pick up on and also includes subconscious facial expressions that are too quick or subtle for human observers to pick up on. Known as "micro-expressions," these occurrences can reveal feelings that people weren't intending to communicate or weren't even aware they were conveying [50].

In other cases, the system will know the user better than the user knows them because humans may not even be conscious of feeling the feelings. It's also critical to understand that AI technology can be employed to infer data that is not immediately detected by sensors. In a recent publication, researchers from META demonstrated that AI technology could precisely anticipate the position, posture, and motion of the rest of your body when processing "sparse data" from only a few sensors on your head and hands [51]. As demonstrated by other researchers, a variety of medical disorders, including depression and dementia, can be inferred from bodily motions like gait [52, 53].

Metaverse technology already exists to track basic physical data as well as infer human emotions in real time from facial expressions, verbal inflections, gestures, and body position. Some devices use sensors in human earphones and blood flow patterns on the face to identify emotions and monitor vital signs [54]. This implies that the sensor in Figure 3 will be able to track practically everything people do and say when they immerse themselves in the metaverse and properly forecast how people will feel during each action, reaction, and interaction. As shown in Figure 4, equip the SENSOR box with metaverse gear that can precisely track a human's actions and feelings in real time. In other words, while the human is receiving immersive experiences (System Input) that fill their senses with material, a variety of sensors can track almost everything they do and can infer how they are feeling while doing it. Once more, subtle expressions can be recognized through micro-expressions, facial blood flow patterns, and vital signs in addition to conscious emotions.

Additionally, the aforementioned behavioral and emotional information might be saved over time via metaverse platforms, building a database that depicts how people are likely to respond to a variety of stimuli in daily life. This vast amount of data might be converted into predictive behavioral and emotional models by AI algorithms, allowing platforms to precisely forecast how users will respond to target stimuli (i.e. System Input) from a controller. Additionally, as the metaverse combines AR with VR, user surveillance and profiling may take place throughout our daily lives, from the minute we wake up to the moment we fall asleep [55].

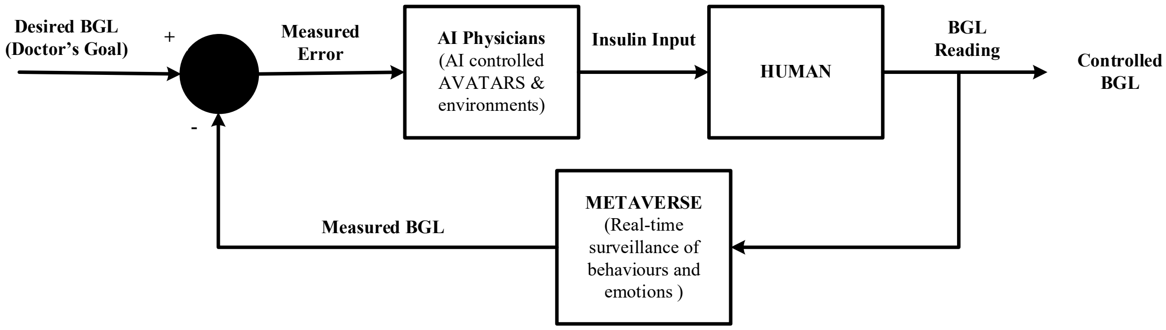

Fig. 6 Diabetes monitoring in the metaverse environment

5.4 Controller Role in the Metaverse

Therefore, in an uncontrolled metaverse, platforms may accumulate and analyze a large amount of user data over time and develop AI models that precisely forecast how to elicit the necessary behavioral or emotional responses from the intended audience. This might potentially make the metaverse the most dangerous tool of persuasion ever made and move us one great step closer to mind control. Now, we must take into account the controller, the last box in the system, to understand the hazards.

The controller might be software running on CPUs with advanced AI capabilities. The difference between a Reference Goal (a desired behavior) and a Measured Output (a detected behavior) is known as a Measured Error, which is sent to the controller. To return to the subject of diabetes control, the objective could be a desired BGL according to the doctor's prescription as shown in Figure 5.

The ability of the metaverse to build quick feedback loops where a user's actions and emotions are continuously sent into a controller that optimizes its influence in real-time for persuasion is what makes it special. A controller's primary goal is to "reduce the error" between a system's expected behavior and the behavior that is seen in the system. According to the aforementioned diagrams, it accomplishes this by providing System Input. This arrow in the metaverse denotes the capability of the controller to change the user's current augmented or virtual surroundings. To direct the patient toward the desired BGL (i.e. agenda), the controller can change the environment the patient is in, changing what they hear, see, and feel. The controller will be able to modify in real-time, optimizing the persuasive influence much like a thermostat does for a home's temperature since it can precisely track how the user responds to its alterations of the outside world. The controller will first create the virtual doctor to have the greatest influence as shown in Figure 6. This means that based on the user's medical history, AI algorithms will choose the doctor's age, gender, ethnicity, dress, speaking, and other characteristics to be the most persuasive to the target diabetic patient. The doctor will then start talking to each other under AI control when the target patient is around.

The controller/ DOCTOR keeps track of the user/PATIENT in real-time as the dialogue starts, analyzing small facial expressions, body language, eye movements, pupil dilation, and BGL to determine when the patient starts paying attention as indicated in Figure 7. Simple methods for doing this include observing a patient's slight physiological shift about remarks made by the virtual doctor.

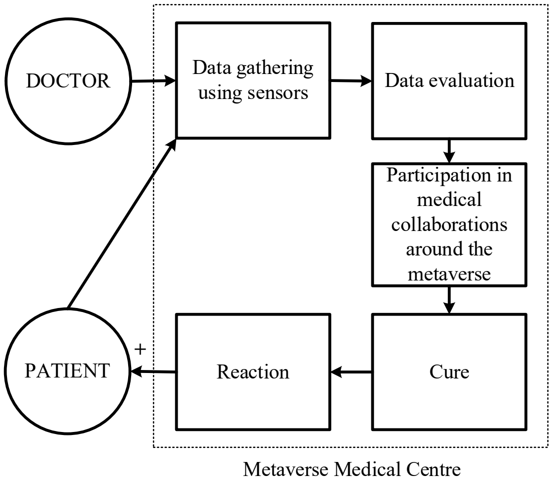

Fig. 7 The metaverse's system for keeping track of patients

6. Conclusion

The metaverse may be used to build feedback-control systems that track people's actions and emotions in real-time and use AI agents to alter their environment (such as BGL, physical parameters, behavioral and emotional parameters) to influence them in the most persuasive ways. This implies that highly effective metaverse systems could track billions of humans and have an impact on any one of them by changing their environment in a targeted and adaptive manner.

Declarations

Conflict of interest: The authors declare no conflict of interest. The funding agency had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Data Availability: Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Funding: None of the funds receive No fund or grant received from any source for this research.

Authors contributions: All authors collectively contributed to the conception of the study. All authors have read and approved the final version of the manuscript.

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