REMOTE HEALTH MONITORING SYSTEM FOR PATIENTS

Anna Hovakimyan, Siranush Sargsyan, Tatev Hovakimjan, Vahagn Aleksanyan

Abstract: *In this paper, we introduce the Virtual Clinic, a hardware and software system that enables patients and doctors to communicate remotely. To utilize the system, patients must have a wearable medical device and a mobile phone, while doctors require access to a computer device. The Virtual Clinic allows for the quick exchange of vital data and messages between patients and doctors, and even employs machine learning techniques to diagnose diseases automatically.*

This system provides the opportunity to use telemedicine and telehealth concepts to remotely monitor a patient's health, offer personalized health services, manage drug treatments, handle chronic illnesses, provide psychological services, give second opinions, collaborate on treatments, and quickly respond to emergencies.

Our Virtual Clinic system, which utilizes IoT, network, and cloud technologies, is a versatile tool suitable for individuals, medical clinics and trainers alike.

Keywords: *wearable medical devices, IoT technology, remote patient monitoring, disease diagnosis, personalized treatment.*

ITHEA Keywords: *Information Systems.*

DOI: *https://doi.org/10.54521/ijita30-01-p06*

Introduction

In today's busy world, many people neglect their health because of a lack of time or motivation. As the demand for accessible and affordable healthcare services grows, there is a clear need for innovative systems that connect patients, doctors, coaches, and consultants. With the prevalence of modern technology in our daily lives, integrating such systems into the healthcare industry is easily achievable [Rodrigues, 2016].

Currently, there are multiple systems available that facilitate continuous communication between patients and doctors, as well as athletes and trainers. These systems enable easy exchange of data and details related to the patient's health or the athlete's current sports performance. By utilizing a range of equipment and technologies, these systems collect real-time information and promptly notify the relevant doctor or coach if needed [Rodrigues, 2016, Kadry, 2019].

Usually, these systems consist of both hardware and software components. The hardware component comes in the form of different devices and sensors that are capable of generating massive amounts of data. Advanced analytics and artificial intelligence techniques are employed to extract useful insights from that data. Through the use of data analysis algorithms and machine learning models, various patterns can be identified, predictions can be made, diseases can be diagnosed, and personalized health care plans or training tactics and schedules can be developed to aid decision-making [Noar, 2012, Müller, 2017, Duke, 2018].

A reliable system should have a strong, adaptable, and scalable structure that is not reliant on specific devices. It should function on various platforms, prioritize data security, privacy, and accessibility, and utilize contemporary information technologies [Tiwari, 2022, Idoudi, 2021].

In this paper, we introduce the Virtual Clinic system, designed to allow doctors to remotely monitor a patient's condition in real-time. Additionally, the system utilizes a pre-trained machine learning model to assist with disease diagnosis. The Virtual Clinic system is built on a foundation of IoMT, Bluetooth, WebSocket, and cloud technologies.

1. Internet of Medical Things

The Internet of Medical Things (IoMT) refers to the interconnected set of medical devices, healthcare systems, and applications [Hemanth, 2021]. IoMT is revolutionizing the healthcare sector by creating an ecosystem that allows by bringing together the capabilities of medical devices and sensors, data analysis methods, advanced information and communication technologies and the power of the Internet to monitor the health of patients and improve healthcare services. This results in improved overall healthcare outcomes, improved patient care, and simplified healthcare processes (Fig.1). IoMT-systems can also be used for disease diagnosis purposes.

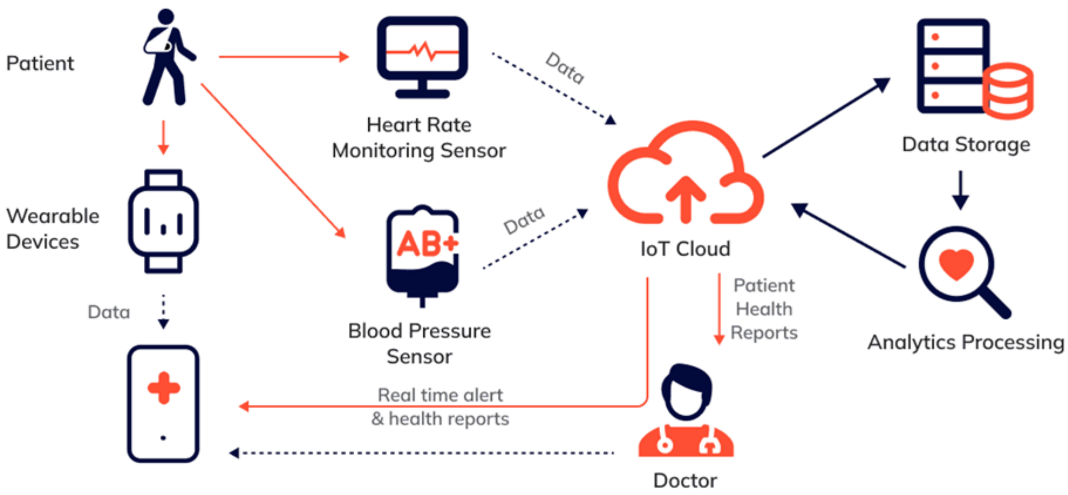

Figure 1. Internet of Medical Things

The main components of IoMT are:

1. **Medical devices and sensors.** IoMT relies on a wide range of medical devices and sensors that collect real-time data from patients. These devices include wearables (smart watches, fitness trackers), implantable devices (pacemakers, insulin pumps), remote control devices, and other specialized medical devices. These devices record and transmit the wearer's vital physiological data, behavioral and health-related information [Cardona, 2021].

2. **Connection.** IoMT uses various connectivity technologies to enable seamless communication between medical devices, healthcare

systems and healthcare providers.These include wireless technologies such as Wi-Fi, Bluetooth, Zigbee, cellular networks (3G, 4G and 5G), and emerging technologies such as Low Power Wide Area Networks (LPWAN) and satellite communication [Bray, 2001, Mishra, 2018].

3. **Data analysis and artificial intelligence.** IoMT generates massive amounts of data and uses advanced analytics techniques and artificial intelligence to derive actionable insights from this data [Yao, 2018]. Data analytics algorithms and machine learning models help identify patterns, make predictions, diagnose diseases, develop personalized health care plans, make decisions [Duke, 2018].

4. **Cloud technologies.** Medical data collected from various IoMT-system devices can be securely stored, managed and analyzed in the cloud, enabling healthcare professionals to easily access real-time data, collaborate with each other and provide timely care [Bahga, 2014].

5. **Security and privacy.** As the IoMT involves personal data on patients and critical healthcare systems, security and privacy are paramount. Robust security measures, encryption, authentication, access control and regulatory compliance are essential to maintain patient privacy, ensure data integrity and protect against unauthorized access and cyber threats [Sanders, 2013].

Some of the main applications of IoMT are:

1. **Remote patient monitoring.** IoMT allows healthcare providers to remotely monitor patients' health in real-time, tracking vital signs and disease progression. This allows for early detection of

anomalies, timely interventions, reduced visits to medical facilities, and reduced healthcare costs.

2. **Telemedicine and eHealth.** IoMT enables virtual consultations, remote diagnostics and telemedicine services, allowing patients to connect with healthcare professionals from anywhere. Video conferencing, real-time data sharing and remote diagnostics increase access to healthcare services, especially in remote areas [Khandpur, 2017].

3. **Personalized healthcare.** With IoMT, healthcare can be tailored to the needs of different patients. Continuous monitoring, data analysis and artificial intelligence algorithms generate personalized insights, provide advice on preventive measures, medication reminders, healthy lifestyle recommendations to improve overall health [Bhatia, 2021].

4. **Management of chronic diseases.** IoMT offers many opportunities for patients with chronic diseases, including self-monitoring and remote management. Wearable devices and mobile apps facilitate the monitoring and management of chronic diseases such as diabetes, hypertension, respiratory and other diseases, leading to better patient health control and reduced hospitalizations [Torres-Sanchez, 2022].

5. **Optimization of the health care system.** IoMT helps to optimize healthcare systems by streamlining functions, automating workflow operations and improving operational efficiency. Real-time data sharing, predictive analytics, and smart management improve resource allocation, patient flow, and operational decision-making, leading to cost-saving improvements in quality of care.

6. **Emergency response and disaster management.** The IoMT plays a crucial role in emergency response and disaster management situations.

7. **Drug treatment management and monitoring.** IoMT helps manage and maintain medication dispensing by providing smart medication dispensing devices, medication reminders and real-time medication tracking [Rodrigues, 2016, Kadry, 2019].

8. **Health research and population health management.** IoMT allows for the extensive gathering of data from various sources, which can aid in health research and managing the health of populations. Information that has been stripped of personal identifiers, obtained from an array of devices and sources, can be utilized to pinpoint public health patterns, monitor the spread of illnesses, and establish interventions supported by factual evidence [Castiglione, 2021].

2. Wearable Medical Devices

Wearable devices refer to electronic gadgets that can be worn on the body, including smart watches, fitness trackers, health monitors, and more. [Dey, 2019]. Devices equipped with multiple sensors and other technologies can be extensively utilized in healthcare. They can collect and process data on the wearer's physical activity and other vital signs, providing valuable insights into the patient's current health.

Wearable smart watches are widely popular due to their numerous health-related features and multiple sensors (Fig. 2). Several smart watches provide additional functionalities like alerts to stretch and walk around if you have been inactive for a while. Moreover, they also offer guided breathing exercises to help ease stress [Dey, 2019]. Certain smart watches have a fall detection feature. This function can alert pre-registered individuals, like family members, caregivers, and doctors, in addition to contacting emergency services if the wearer falls. The feature also provides the exact location of the person who fell [Cardona, 2021]. This feature can be extremely beneficial for individuals who are elderly or have specific health issues.

There are various types of monitors available that can monitor and track different aspects of a person's health, such as heart rate, blood glucose levels, blood oxygen saturation, and electrocardiography. Additionally, certain monitors also have the capability to adjust the insulin dosage given to patients [Tong, 2018].

Figure 2. Smart watch

Specialized wearable devices called health monitors track one or more attributes (Fig.3).

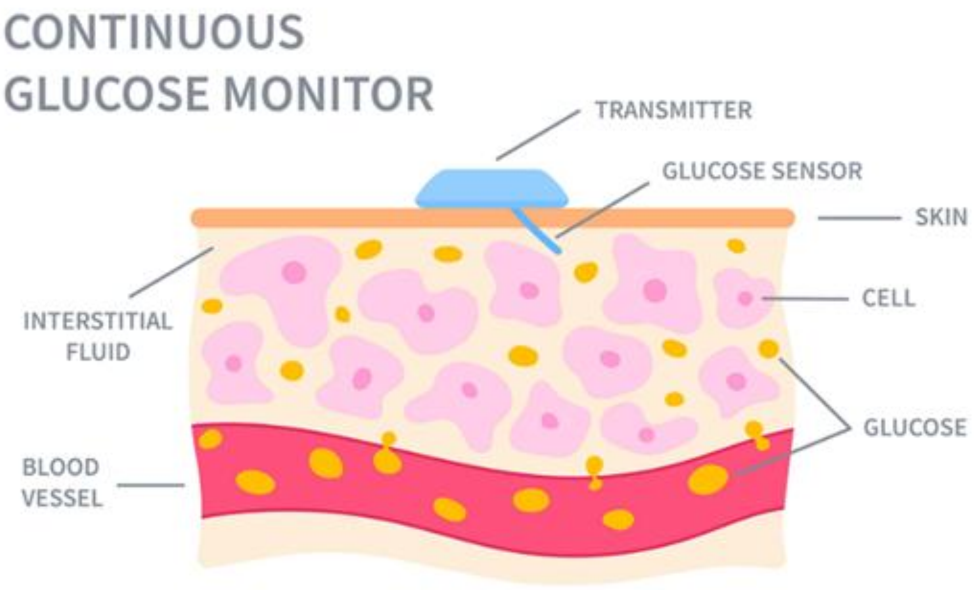

*Figure 3. Blood glucose moni*tor

3. The Architecture of the Virtual Clinic System

The design of the Virtual Clinic system is crucial in ensuring smooth communication and effective sharing of data among wearable devices, patient and physician applications, and other system components.

The system architecture is composed of different layers, namely the user layer, server layer, and data layer. Each layer has its own set of responsibilities for performing various functions and interactions.

1. **User layer**

- **Wearable device software application.** These devices gather data about a patient's health and transmit it to user applications through technologies such as Bluetooth, networking and IoT.

- **Patient software application.** This app can be installed on a patient's smartphone or other device to give them an easy-to-use interface for monitoring their health, viewing data collected by the wearable device, staying in touch with their treating physician, booking appointments, and accessing healthcare resources. In case of an emergency, the program will immediately inform the doctor.
- **Doctor software application.** When installed on a doctor's device, this software enables them to monitor patient data, communicate with patients, conduct virtual consultations, prescribe medication, and perform other related tasks. Additionally, the program receives emergency notifications whenever the need arises.

2. **Server layer**

- **Application’s Server.** The Virtual Clinic system's main logic and functions are implemented by the application server. It manages user authentication, data processing, creates and oversees meeting schedules, performs data synchronization, and facilitates user-to-user communication.
- **Application Programming Interface Gateway (API Gateway).** The API gateway serves as a point of entry for applications to connect with the server layer.
- **Business logic.** This layer defines and implements rules and algorithms that regulate the behavior of the Virtual Clinic system. This layer processes and analyzes patient data to trigger automated actions based on predefined rules.

3. **Data layer**

- **Database.** Patient data, physician profiles, and other pertinent information are stored in the database.
- **Data analysis.** Patient data can yield insightful information when analyzed with data analytics tools and algorithms. This can lead to personalized healthcare recommendations, early detection of health issues, and informed decision making based on data.

- **Integration services.** These services allow for effortless integration with external systems such as laboratory and pharmacy systems.

4. The Implementation of the Virtual Clinic System

The Virtual Clinic system has various features that are worth mentioning. It comprises of four different programs that work independently on their respective devices and perform specific functions.

1. **Server application (SA)**. The program running on the server is coded using the Python programming language. Presently, it serves as a central hub for communication, facilitating the transfer of messages between various devices. Our system's server is hosted on a virtual machine utilizing cloud technologies, ensuring uninterrupted access and operation. We utilize the Web Socket technology for server-side messaging, enabling our constantly running server to promptly accept and process requests whenever needed [Chopra, 2015].
2. **Wearable device application (WDA)**. WDA is installed on an Android smartphone and mimics the process of gathering and sharing health-related information from any wearable device worn by the user. WDA is programmed using the Java language, specifically for Android operating systems [Phillips, 2017]. The purpose of this application is to mimic the functions of a wearable gadget that gauges a user's vital statistics and transmits the data to a linked smartphone through Bluetooth [Morrow, 2002]. To run the simulation, we need to input the "measured" data using the numeric keypad as there are no access protocols available for the data collected by the wearable device [Islam, 2022]. This system can detect when the wearable device falls and send a message to the connected device accordingly.
3. **Patient smartphone application (PSA)**. PSA is also implemented in the Java programming language for devices running the Android operating system [Phillips, 2017]. PSA is designed to connect to a wearable device via Bluetooth connection, receive information from

it, and send the received information to the server via WebSocket connection. The program also has the ability to establish a dialogue with the doctor by sending messages via WebSocket technology [Chopra, 2015, Morrow, 2002].

4. **Doctor web application (DWA)**. DWA is written using JavaScript programming and HTML, CSS markup languages. The application can be accessed from any device with internet access. The app serves as a doctor's interface to monitor and communicate with patients [Meloni, 2018].The program, using WebSocket technology, implements the possibility of receiving data about the patient's health condition from the server during the specified period. The program also has the ability to establish a dialogue with the patient [Chopra, 2015].

5. The Operation of the Virtual Clinic System

The operation of the system, in which the doctor and the patient participate, is carried out in the following scenario.

Patient's functions

The patient runs the apps on the wearable device and the patient's smartphone (Fig. 4, 5).

Then, with the "Connect to Smartphone" operation, a Bluetooth connection is established between the given device and the patient's smartphone (Fig. 6) and the list of available wearable devices is displayed on the patient's smartphone (Fig. 7).

When selecting the wearable device ("Vahagn's Mi 9T Pro"), a connection confirmation request is sent from the patient's smartphone to the wearable device (Fig. 8, 9).

Figure 4 . Wearable device app main window

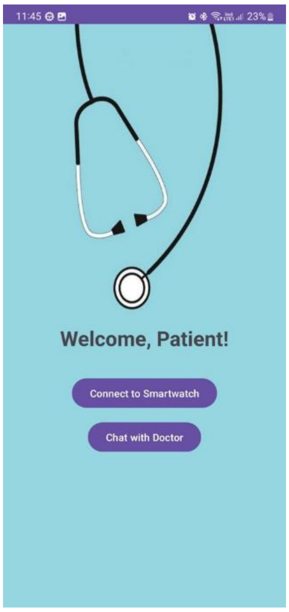

Figure 5 . Patient smartphone app main window

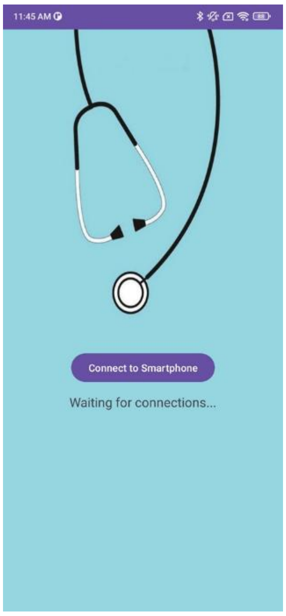

Figure 6 . Setting Bluetooth connection

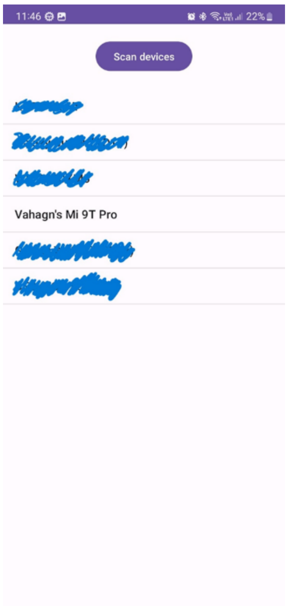

Figure 7 List of devices available to the patient's smartphone via Bluetooth

Figure 8 The wearable is ready to send information

Figure 9.The smartphone is ready to get information

Now the two devices are connected via Bluetooth connection and ready to exchange information (Fig. 10, 11).

Figure 10 . Several numbers are sent from the wearable device to the patient's smartphone

Figure 11. The smartphone has received numbers sent from the wearable

A FALL message is sent to the smartphone if the wearable device is dropped or violently shaken (Fig. 12, 13).

Figure 12. The wearable device has sent a "FALL" message

Figure 13. The smartphone has received the "FALL" message

Doctor's functions

The doctor runs the doctor web application (Fig. 14).

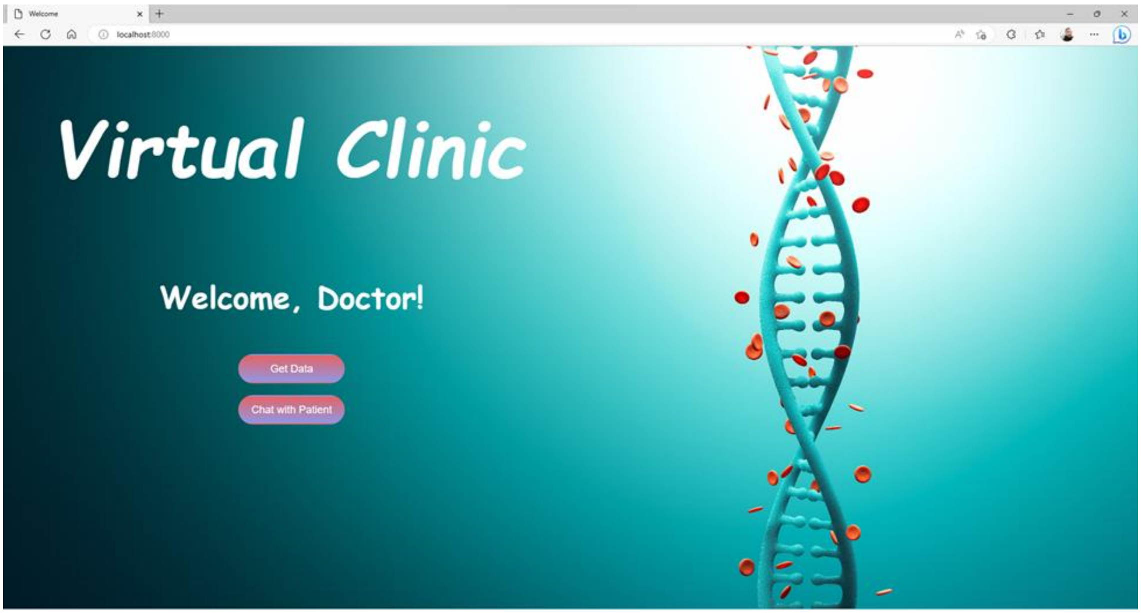

Figure 14 . Doctor's app main window

With the "Get Data" action, the doctor gets access to the data selection page (Fig. 15). By selecting a reporting period and making a request to the server, it receives certain aggregations of data for the specified time period: the minimum, maximum and average data values (Fig. 15).

Figure 15. Aggregations of data recorded during the specified time period

"Chat with Patient" action takes you to the dialog page (Fig. 16).

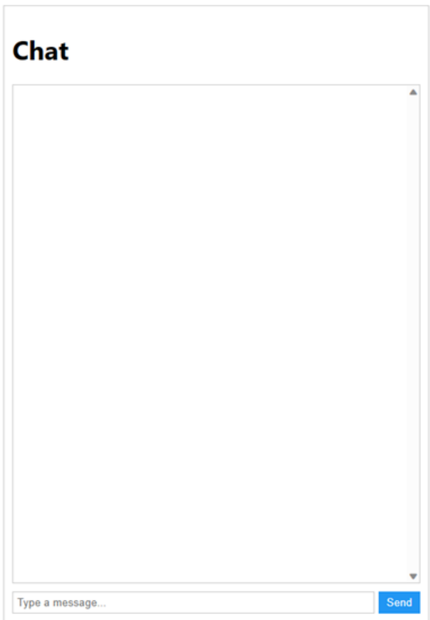

Figure 16.The dialog page in the doctor web application

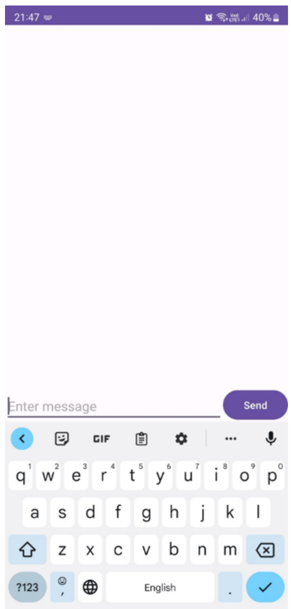

Figure 17. The dialog page in the patient's smartphone application

The patient can start a dialogue with the doctor from his window (Fig. 5) with the "Chat with Doctor" action (Fig. 17). The dialogue between the patient and the doctor is supported on the basis of WebSocket connection (Fig. 18, 19).

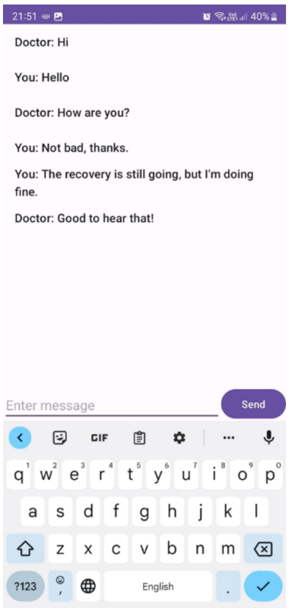

Figure 18. The dialogue on the patient's smartphone app

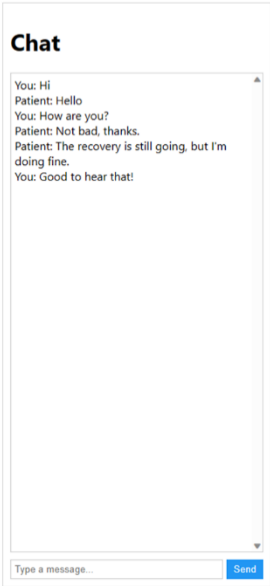

Figure. 19. The dialogue on the doctor's app

A disease diagnosis subsystem developed on the basis of machine learning is implemented in the Virtual Clinic system [Hovakimyan, 2023].

Conclusion

The Virtual Clinic System comprises several components and layers that function harmoniously to offer diverse health services. With a robust, flexible, and scalable architecture, the system can effectively track patients' health status, thus enhancing healthcare providers' and doctors' efficiency.

The use of the Virtual Clinic system in telemedicine is diverse and extensive. It allows for remote monitoring of patient health, management of chronic diseases, provision of follow-up care, mental health services, health education and resources, second opinions, collaborative care, and much more.

Further work

The research and development discussed in this work is still ongoing and will continue to progress in various directions.

To ensure wide accessibility and compatibility, patient and physician apps should be developed for different platforms such as iOS, Android, Mac, and web. This will allow patients and doctors to access the system at any time and from any place using their preferred devices: smartphones, tablets, or computers.

The Virtual Clinic system must ensure the safety and confidentiality of patient data. Measures such as encryption, secure authentication, role-based access control, and compliance with data protection regulations must be implemented.

Ensuring that the architecture meets performance requirements is crucial. This is due to the possibility of the system's performance being affected by workload and data volume increases. In order to ensure the best performance, it's important to incorporate resilience mechanisms like load balancing and data caching.

It is desirable that the Virtual Clinic system be as universal as possible. The specific use cases and functions of the system may vary depending on the requirements of the healthcare organization and the needs of the patients. The system can be adapted to different healthcare sectors. With proper design and robust functionality, the Virtual Clinic system can be used in a variety of healthcare environments.

Bibliography

[Rodrigues, 2016] Joel J. P. C. Rodrigues, Sandra Sendra Compte, et al. e-Health Systems: Theory and Technical Applications. ISTE Press – Elsevier, 2016.

[Kadry, 2019] Seifedine Kadry and Abdelkhalak El Hami. E-Systems for the 21st Century: Concept, Developments, and Applications. Volume 1: E-Commerce, E-Decision, E-Government, E-Health, and Social Networks. Apple Academic Press, 2019.

[Noar, 2012] Seth M. Noar and Nancy Grant Harrington. eHealth Applications: Promising Strategies for Behavior Change (Routledge Communication Series). .2012 ,Routledge

[Müller, 2017] Andreas C. Müller and Sarah Guido. Introduction to Machine Learning with Python: A Guide for Data Scientists. O'Reilly, 2017.

[Duke, 2018] Annie Duke. Thinking in Bets: Making Smarter Decisions When You Don't Have All the Facts. Portfolio, 2018.

[Tiwari, 2022] Sanju Tiwari, Fernando Ortiz Rodriguez, et al. Semantic Models in IoT and eHealth Applications (Intelligent Data-Centric Systems). Academic Press, 2022.

[Idoudi, 2021] Hanen Idoudi and Thierry Val. Smart Systems for E-Health: WBAN Technologies, Security and Applications (Advanced Information and Knowledge Processing). 1st ed., Springer, 2021.

[Hemanth, 2021] D. Jude Hemanth, J. Anitha, George A. Tsihrintzis. Internet of Medical Things: Remote Healthcare Systems and Applications (Internet of Things). 1st ed,. Springer, 2021.

[Bray, 2001] Jennifer Bray, Charles Sturman. Bluetooth: Connect Without Cables. Prentice Hall,2001

[Mishra, 2018] Ajay R. Mishra. Fundamentals of Network Planning and Optimisation 2G/3G/4G: Evolution to 5G 2nd Edition. Wisley, 2018.

[Yao, 2018] Mariya Yao, Adelyn Zhou, Marlene Jia. Applied Artificial Intelligence: A Handbook for Business Leaders. TOPBOTS, 2018.

[Bahga, 2014] Arshdeep Bahga, Vijay Madisetti. Cloud Computing: A Hands-On Approach. Vijay Madisetti, 2014.

[Sanders, 2013] Chris Sanders, Jason Smith. Applied Network Security Monitoring. Syngress, 2013.

[Khandpur, 2017] R.S. Khandpur. Telemedicine : Technology and Applications: (mhealth, telehealth and ehealth) 1st edition, PHI Learning, 2017.

[Bhatia, 2021] Surbhi Bhatia, Ashutosh Kumar Dubey, et al. Intelligent Healthcare: Applications of AI in eHealth (EAI/Springer Innovations in Communication and Computing). Springer, 2021.

[Torres-Sanchez, 2022] Irene Torres-Sanchez and Marie Carmen Valenza. eHealth in Chronic Diseases. International Journal of Environmental Research and Public Health, MPDI. 2022.

[Castiglione, 2021] Castiglione, M. Umer, S. Sadiq, M. S. Obaidat, P.Vijayakumar. The Role of Internet of Things to Control the Outbreak of COVID-19 Pandemic. doi: 10.1109/JIOT.2021.3070306, 2021.

[Dey, 2019] Nilanjan Dey, Amira S. Ashour, Simon James Fong, Chintan Bhatt. Wearable and Implantable Medical Devices, Elsevier, 2019.

[Cardona, 2021] Manuel Cardona, Vijender Kumar Solanki, Cecilia E. García Cena. Internet of Medical Things. Paradigm of Wearable Devices. Routledge, 2021.

[Tong, 2018] Raymond Tong. Wearable Technology in Medicine and Health Care.Elsevier, 2018.

[Chopra, 2015] Varun Chopra. WebSocket Essentials – Building Apps with HTML5 WebSockets. Packt Publishing, 2015.

[Phillips, 2017] Bill Phillips, Chris Stewart, Kristin Marsicano. Android Programming: The Big Nerd Ranch Guide. 3rd Edition. Big Nerd Ranch Guides, 2017.

[Morrow, 2002] Robert Morrow. Bluetooth: Operation and Use. 1st Edition. McGraw-Hill Professional, 2002.

[Islam, 2022] Milon Islam, Sheikh Nooruddin, Fakhri Karray. Internet of Things Device Capabilities, Architectures, Protocols, and Smart Applications in Healthcare Domain: A Review. 2022.

[Meloni, 2018] Julie Meloni, Jennifer Kyrnin. HTML, CSS, and JavaScript All in One. .2018 ,Sams Publishing

[Hovakimyan, 2023] T.Hovakimyan, A.Hovakimyan, A.Badalyan. Osteoporosis prediction system based on methods of Artificial Intelligence. Proceedings of 6th International Medical Congress of Armenia. July 6-8, 2023, Yerevan, Armenia.

Authors' Information

Anna Hovakimyan *– Yerevan State University; Associate Professor. 1, Alek Manukyan St. Yerevan, 0025, Armenia; e-mail:ahovakimyan@ysu.am*

Major Fields of Scientific Research: Artificial Intelligence, Data structures and Algorithms, QA and Software Testing

Siranush Sargsyan *– Yerevan State University; Associate Professor. 1, Alek Manukyan St. Yerevan, 0025, Armenia; e-mail:siranushs@ysu.am*

Major Fields of Scientific Research: Artificial Intelligence, Pattern Recognition, Quantum Computing

Tatev Hovakimyan *– AltMed Medical Center; endocrinologist. 3/15, Hakob Hakobyan St., Yerevan, 0033, Armenia; e-mail: tovakimyan87@mail.ru*

Major Fields of Scientific Research: diabetes, osteoporosis, obesity

Vahagn Aleksanyan *– Yerevan State University; Graduate student; 1, Alek Manukyan St. Yerevan, 0025, Armenia; e-mail:vahagn.aleksanyan@gmail.com*

Major Fields of Scientific Research: Data Science, Web-programming, mobile programming