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USE OF IMMERSIVE TECHNOLOGY FOR DIGITAL HEALTHCARE PRODUCTS DEVELOPMENT

Abstract

Active use of immersive technologies in medicine. The development of IT leads to the emergence of new digital products that are actively used in medicine. Further development leads to the transfer of some medical services to the metaverse – the concept of Metahospital is formed. This article provides a systematic review of research to determine the prevalence and current state of the use of immersive technologies for the development of digital health products. Studies from leading scientific databases were reviewed. The results show that research interest in the use of immersive technologies in medicine has increased significantly over the past ten years, peaking during the pandemic. Immersive technologies are the most common types of technologies used in medicine for training, practical training, telemedicine, and diagnostics. In addition, our own software product is described – a coronary artery stenting simulator using virtual reality technology. A description of the model and the results of a survey on the effectiveness of using immersive technologies among medical school students are provided.

Key words: Unity, eXtended reality, immersive technology.

Introduction

Safe teaching practices for medical students are important for both patients and students. This allows you to develop the necessary skills required when working with patients. Of course, depending on the profile of the physician, the set of skills may vary, but the most common ones are presented in Figure 1 (p. 20).

There are 9 general skills that are necessary for medical staff: communication, critical thinking, technical competence, meticulousness, teamwork, flexibility, empathy, ethical awareness, teamwork. Under perfect conditions all of these have to be developed equally however in real life only some of them are obtained during studying. The most general and common skill is communication. Medical workers need to communicate effectively with patients, their families, and other members of the healthcare team [1]. This includes active listening, empathy, and the ability to convey information clearly and compassionately. Nowadays is complicated to provide medical students with communication skills in a real environment due to many reasons including patient's reluctance to speak with students, privacy of personal information, improper studying program with no content on communication.

Another important skill is critical thinking [2]. Sharp critical thinking allows medical professionals to analyze information, make sound judgments, and solve problems effectively. This is vital for accurate diagnoses, treatment plans, and handling emergencies.

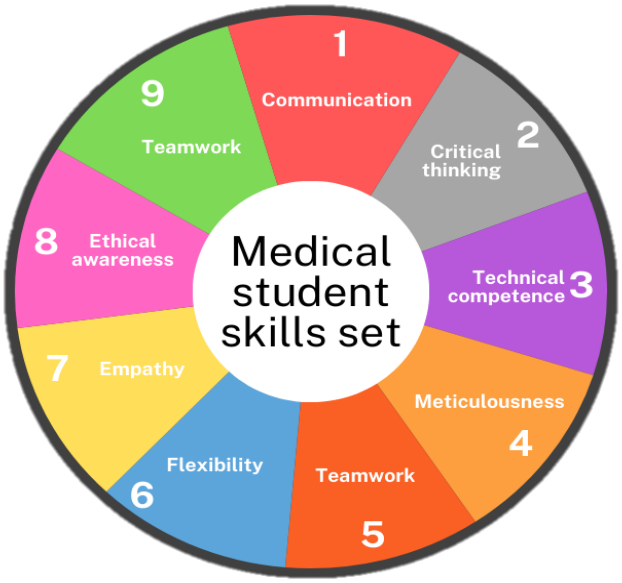


Figure 1 – Medical students' skills set

Also, each medical role requires specific technical expertise [3]. Doctors excel in diagnosis and treatment, while nurses expertly manage patient care, medication administration, and procedures.

Healthcare is a field where precision is paramount. Medical workers meticulously [4] pay attention to detail to ensure accuracy in recording information, administering medications, and following treatment protocols.

Working in team is crucial, as doctors usually work in collaboration with each other to make a diagnosis and treatment prescription as accurate as possible. Effective collaboration is key, requiring open communication, information sharing, and working together to achieve shared goals with saved individual responsibility [5].

The healthcare landscape is constantly evolving. Medical professionals need to be adaptable and flexible [6], adjusting to new protocols, technologies, and patient populations.

Ethical awareness is crucial [7]. Medical workers must uphold ethical principles and standards in interactions with patients and colleagues. This includes patient confidentiality, maintaining professional boundaries, and advocating for patient rights.

Illness and injury can be emotionally taxing. Medical workers demonstrate empathy and compassion, showing sensitivity to the physical and emotional needs of those they care for.

Multiple tasks and responsibilities often come with limited time. Effective time management allows medical professionals to prioritize tasks, stay organized, and deliver care efficiently. In common all of these skills are necessary for a medical professional.

Literature review

The Metahospital concept in the Metaverse represents an innovative view of medicine and healthcare based on the use of advanced digital technologies in treatment, patient communication and education. Metahospital integrates various digital technologies such as artificial intelligence, augmented reality, virtual reality, mixed reality, cloud computing, blockchain and 5G/6G wireless networks. The main aspects of such a metahospital include:

- Application of advanced technologies such as nanomedicine, quantum medicine, molecular reconstruction of cells and others.

- Telemedicine, providing immediate provision of services using immersive reality technologies and artificial intelligence.
- Digital doctors and artificial intelligence providing instant consultations and diagnostics.
- Use of artificial organs and tissues to solve the problem of organ deficiency.
- Genetic optimization to prevent hereditary diseases and improve physiology.
- Consideration of ethical issues related to confidentiality and potential negative consequences.

For example, research by Zeng and colleagues [8] considers various scenarios for the use of the metaverse in medicine, from surgical treatment to cancer rehabilitation. Cerasa et al [9] propose the use of the metaverse in the treatment of mental illness. The Gruson Group explores the possibilities of laboratory medicine in the Metaverse.

Successful integration of the metaverse and metamedicine laboratories requires additional training and education from scientific societies, educational institutions, and laboratory medicine professionals. Additionally, continued research and large-scale testing are necessary to fully understand the potential of these innovative approaches in medicine.

Despite the development of different versions of metaverses many young surgeons still often learn by observing the operations of more experienced colleagues or participating in them as observers and trainees. However, some countries and institutions are introducing digital simulations to provide additional practice opportunities for students.

The paper presented by Li [10] examines the promising application of virtual reality simulation in medicine. The approach described in the paper is based on creating an environment based on patient data, which facilitates real-life operations. The system interacts directly with clinical data and recreates a model of the heart, providing haptic feedback for realistic training.

Another interesting example presented by Mishvelov [11] also uses patient data to create mixed reality layers that facilitate surgical procedures. This application allows surgeons to work with MRI images of the patient's organs in real time, which significantly increases the efficiency of surgical interventions.

The prototype application developed by researchers [12] combines the reconstruction of organ models with the operation of surgical instruments, providing quick access to necessary information and increasing the efficiency of preoperative planning.

Additionally, a paper by Regrebusbly [13] presents a simulation system for training in dual interventional cardiac catheterization, allowing students and junior surgeons to master complex procedures without risk to patients.

Many medical schools create their own simulators and use a wide range of platforms and applications such as Epocrates, Medscape, Touch Surgery, Orcanhealth and others [14–17]. These tools not only support training, but also provide healthcare professionals with access to relevant information and tools to improve the quality of care.

Conjunction of two ideas provides interaction of many people [18] within one digital space and improve the learning outcomes as this experience feels real and tangible.

Some of the works [19] demonstrate necessity of improved mechanisms for accessibility, infrastructure limitations, and maintaining student engagement. As them tend to make these virtual simulations a promising tool for the education.

Authors suggest more careful observation and integration of virtual reality and other modern tools as despite a great potential in telemedicine, but it is still crucial to avoid depersonalization and loss of connection with a real world [20].

Also, in case of medical education it is substantial to adopt technology and approach in a proper manner, including specific learning objectives and student needs [21].

In this work we propose the existing concept of metahospital at International information technology university, Almaty, Kazakhstan.

Main provisions

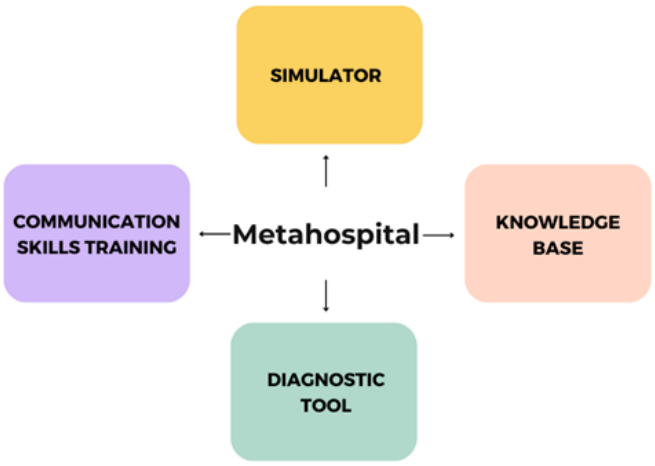


Figure 2 – Metahospital's structure

At IITU the Metahospital concept was created to unify several projects into one general idea. The previous experience of authors in virtual laboratory works development and rapid acceleration of the virtual reality and the sphere as whole nowadays has forced many researchers and creators to the definition of new ideas and meanings under metaverse scope. The proposed idea of metahospital consists of 4 parts as shown in figure 2. Each of them provides user with ability to progress certain skill. The concept has simulator module that is dedicated to the surgery simulations, knowledge base where user can study certain concepts or anatomic issues, then goes module for the communication skills training. It makes it possible to talk with virtual avatars that behave as different patients' type. And the last option is diagnostic tool for the cognitive decrease tracking and early diagnosis of the Alzheimer's disease using specially developed, and VR adopted tests.

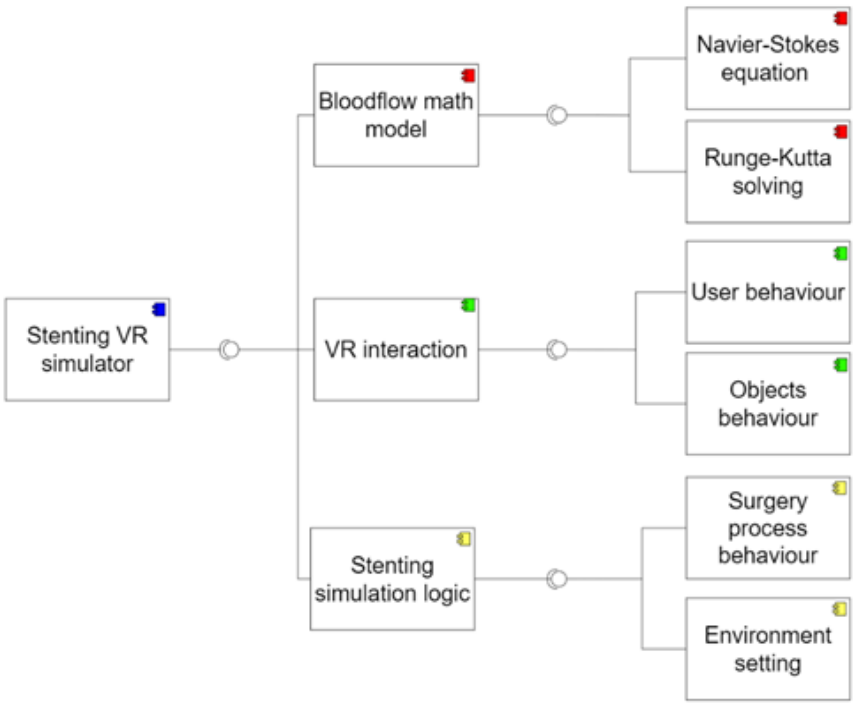
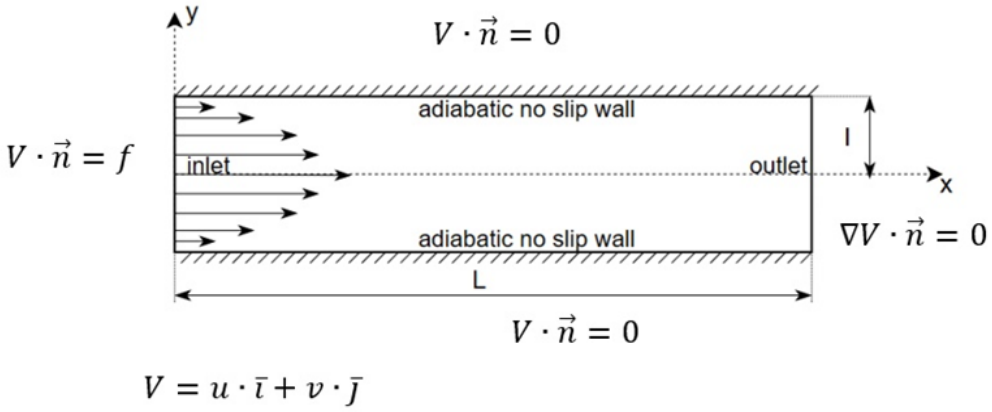


Figure 3 – Angioplasty and stenting simulator component diagram

The simulator contains 3 main components: blood flow model, VR interaction and the stenting simulator logic itself as shown in figure 3. The blood flow model for this case describes the motion of the blood at different velocities of fluid based on the geometry of specific artery. In math terms viscous flows are described using Navier-Stokes equations. The project observes specific case a constantly flowing, compressible fluid with some internal friction (viscous). It's accepted that the flow moves along x-axis, and during the motion meets some separation points using Runge-Kutta approach. The math model domain is described in figure 4. The blood flows from the inlet boundary through the artery and exits from the outlet. Artery's diameter at the inlet is around 6.3 mm, with the length equal to 10 mm.

Figure 4 – Math model domain for the blood flow



The domain of the model is set after the definition of governing equations (1)-(3).

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial P}{\partial x} + v\left(\frac{\partial^2 x}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) \quad (1)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial P}{\partial y} + v\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) \quad (2)$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial v} = 0 \quad (3)$$

Where and -velocity by X and Y axis, -density, P – pressure and v-viscosity.

The VR interaction within the simulator is defined using Meta tools for Unity engine the more details on them are given in Methods and Tools section. However, the more specific communication of the user and environment is defined using scripts that were written by authors.

The stenting simulation is crucial module of the project. Basically, it has two areas for the definition. The first is the procedure of the stenting including the algorithms for the tissues, patient's bahaviour, interaction between tools and the user as well as the environment which includes secondary objects as UI elements, audio sources etc.

Materials & methods

By now there is simulation of the stenting procedure and mathematic blood flow model. The implementation of the project in VR is done based on Unity game engine, using XR Meta packages that provide basic interaction within the VR scene. The choice is based on the availability of Meta

Quest 2 HMD at the university, while the picking of Unity is based on its cross-platform deployment feature and wide support among different VR devices producers. For the logic implementation C# programming language is used. The mathematical model was solved using Python.

Results and discussion

For now, the project goes through the stage of merging of all the elements of the metahospital concept. In the figure 5 there is a view on a user's scene where a person can conduct the operation. The scene consists of the user's avatar, the operation room and required tool set. Along with this equipment user's view is provided with screens of the patient's monitor and the coronarography screen where the user can see where his tools are situated in the patient's coronary system.

a) General scene view b) User's view of the scene

Figure 5 – The scene view of the simulator

The scene is also provided with an instruction guide in the bottom of the user's view to make the order of procedures to complete the surgery.

To study the demand for similar applications author's conducted survey among medical students at medical school at Shoqan university. The school is provided with different physical simulators that allow to obtain practical skills however along with that they do use VR for emergency block and some other specifications. Also, they have special communication application with different characters having specific anamnesis and diagnosis that should be defined by the student by the end of the interaction.

The survey has shown that even the people that are familiar with technology and have access to equipment and devices do not use it in a full range. However as shown in Figure 6 students evaluate use of VR in surgical studying (62.5%) as useful and find it most profitable for surgery practicing.

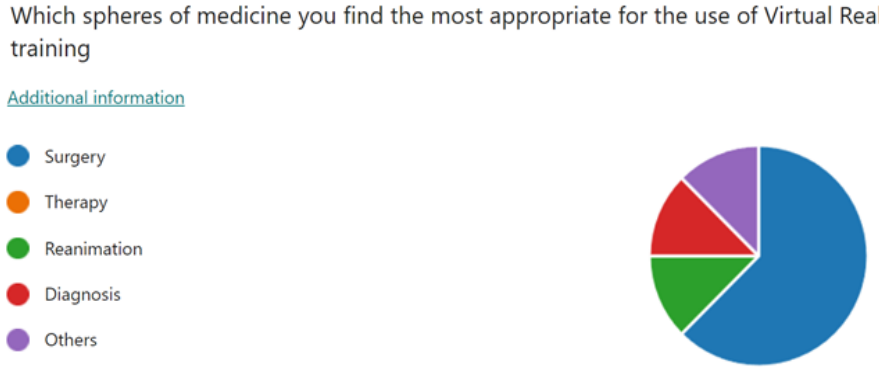


Figure 6 – Answer of the students on question "Which spheres of medicine you find the most appropriate for the use of Virtual Reality in studying and training?"

Though the use and development of VR application for medical studying provide students with "presence sense" it is also important to consider changing in an educational program. 50% of asked students answered that educational program should include special time slotted for the use of the simulator.

Conclusion

The use of immersive technologies in the development of digital healthcare products has the potential to significantly improve the quality of care and increase patient satisfaction.

Immersive technologies such as virtual reality complement traditional treatment methods by allowing clinicians and patients to interact with data and information in a more visual and understandable way. These innovations not only improve training for medical personnel, but also help patients better understand their conditions and treatments, which can lead to more effective health management and reduced risk of complications.

However, to successfully integrate immersive technologies into digital health products, it is necessary to continue research, develop standards, educational programs and regulation, and ensure that these innovations are accessible and safe for all users. Overall, the promise of immersive technology in digital health products promises significant advances in medicine and improved quality of life for patients.

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САНДЫҚ ДЕНСАУЛЫҚ ӨНІМДЕРІН ӘЗІРЛЕУ ҮШІН ИММЕРСИВТІ ТЕХНОЛОГИЯЛАРДЫ ПАЙДАЛАНУ

Аңдатпа

Медицинада иммерсивті технологияларды белсенді қолдану. АТ дамуы медицинада белсенді қолданылатын жаңа цифрлық өнімдердің пайда болуына әкеледі. Әрі қарай даму нәтижесінде кейбір медициналық қызметтерді метаәлемге көшіріліп, метаемхана тұжырымдамасы қалыптасады. Бұл мақала денсаулыққа арналған цифрлық өнімдерді әзірлеу үшін иммерсивті технологияларды қолданудың таралуы мен ағымдағы жағдайын анықтау үшін зерттеулерге жүйелі шолу жасайды. Жетекші ғылыми деректер қорынан алынған зерттеулер сараланды. Нәтижелер соңғы он жылда медицинада иммерсивті технологияларды қолдануға ғылыми қызығушылықтың айтарлықтай артып, пандемия кезінде шарықтау шегіне жеткенін көрсетеді. Иммерсивті технологиялар медицинада оқыту, практикалық сабақтар, телемедицина және диагностика үшін қолданылатын технологиялардың ең көп тараған түрлері. Сонымен қатар мақалада біздің жеке бағдарламалық өніміміз сипатталған – виртуалды шындық технологиясын пайдаланатын коронарлық артерияны стенттеу симуляторы. Модельдің сипаттамасы және медициналық университет студенттері арасында иммерсивті технологияларды қолданудың тиімділігі туралы сауалнама нәтижелері ұсынылған.

Түйін сөздер: Unity, eXtended reality, иммерсивті технологиялар.

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ИСПОЛЬЗОВАНИЕ ИММЕРСИВНЫХ ТЕХНОЛОГИЙ ДЛЯ РАЗРАБОТКИ ЦИФРОВЫХ ПРОДУКТОВ ЗДРАВООХРАНЕНИЯ

Аннотация

Активное использование иммерсивных технологий в медицине. Развитие ИТ приводит к появлению новых цифровых продуктов, которые активно используются в медицине. Дальнейшее развитие приводит к переносу некоторых медицинских услуг в метавселенную – формируется понятие метабольницы. В данной статье приведен систематический обзор исследований, который позволяет определить распространенность и современное состояние использования иммерсивных технологий для разработки цифровых медицинских продуктов. Были изучены исследования из ведущих научных баз данных. Результаты показывают, что исследовательский интерес к использованию иммерсивных технологий в медицине значительно возрос за последние десять лет, достигнув пика в период пандемии. Иммерсивные технологии являются наиболее распространенными видами технологий, используемыми в медицине для обучения, получения практических навыков, телемедицины и диагностики. Кроме того, описан собственный программный продукт – тренажер стентирования коронарных артерий с использованием технологии виртуальной реальности. Приведено описание модели, результаты проведенного опроса по эффективности использования иммерсивных технологий среди учащихся медицинского института.

Ключевые слова: Unity, eXtended reality, иммерсивные технологии.