The Future of Health Management – How Virtual Reality and 5G Networks Can Contribute to Sustainability in Healthcare

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Abstract
Developments in healthcare usually directly target innovations in intervention techniques and medical devices for diagnosis, analysis and treatment. On the other hand, digital development in administration, handling and accessing (sensitive) patient data or real-time availability of information also contribute to improvement of management. The CoVid situation highlighted emerging technologies that covers both, and blurs the border between, management (i.e., cost reduction) and actual treatment. The newly introduced 5G New Radio wireless technology and the expansion of virtual, augmented and mixed reality applications not only assist medical personnel during treatment, but can increase safety, availability and sustainability of services, and at the same time, can reduce costs. This paper briefly introduces benefits of these technologies focusing on state-of-the-art use cases.

Keywords
Health management, Virtual Reality, Telemedicine, 5G, IoD

1. Introduction.

Only two decades ago, the everyday routine of treating patients was to get an appointment, see the doctor(s), get patient documents and results in paper form, file a huge amount of personal health related data, repeat basic examinations and lab-diagnostics, have prescriptions for medicine that had to be filled at a pharmacy.

Nowadays, we book appointments online and consult the doctors via e-mail or messenger services. Digital copies of patient data and results can be accessed in the cloud or on digital storage devices, and e-prescriptions replace unnecessary spending of time in waiting rooms (Lapão, 2016).

Future perspectives include immersive 3D spaces with multimodal accessing methods, virtual presence, and real-time applications using high-speed wireless networks and mobile devices (Liu et al., 2020; Ahad et al., 2020; Thuemmler et al., 2018; Lapão, 2019). Although developments usually focus on the technology itself, the impact on management will be also important (Yan et al., 2021; Qiu, 2021), especially the handling of sensitive patient data and large files will be critical. Furthermore, improved time management of both personnel and patients, re-allocation, grouping and optimization of activities can contribute to cost and waiting time reduction (Gjellebæk et al., 2016; Gellerstedt, 2016; Blix et al., 2018; Germann-Johnsen et al., 2020).

Sustainability in Healthcare

The term *sustainability* became a buzz word of the 2010s. Global warming, climate change, the melting of the polar ice caps, or the ever-growing demand for cheap and clean energy moved the world biggest organizations towards new technologies

(Olawumi et al., 2018). People live longer, population grows, healthcare systems are overloaded. Digital technology contributes many ways to sustainability: less printed paper, shorter waiting lists, problem solving from a distance all play their part in the system (Alsharif et al., 2018; Lennox et al., 2018; Rich et al., 2018).

Besides cost perspectives, high self-rated health status increases trust in telemedicine services (Groom et al., 2021; Wu et al., 2021). Acceptance toward the telemedicine technology is mainly based on usefulness, individual approach, and the need for social support (Harst et al., 2019; Schwalb et al., 2019; Vizitiu, 2019). Social environment and theory-based individual aspects have to be considered in development of services as well as theoretical frameworks. Cultural context and age of the individuals also build barriers between technology and acceptance (Pang et al., 2022). A current scoping review compared functional features and theoretical approaches of 14 web portals designed for patients. Interestingly, non real-time correspondence was higher accepted than real-time interactions. Adequately designed and constructed web pages can be the entrance to telerehabilitation, and increased motivation of patients (Morimoto et al., 2022). All these suggest future works not only in the field of (practical) application development, but in the field of theoretical frameworks.

5G Wireless

5G New Radio (5G NR) is the latest generation of wireless technology (Vook et al., 2018). For the last 2-3 years roll-out of the technology has accelerated. This includes rapid installation of cell towers (base stations) by the network operators and marketing affordable 5G enabled mobile devices and services. Vendors and service providers promote their solutions, trying to convince users to switch to the new technology.

Figure 1.
3G to 5G – Comparison of speed, latency and bandwidth (Vella, 2019).

		3G	4G	5G
	Deployment	2004-05	2006-10	2020
	Bandwidth	2mbps	200mbps	>1gbps
	Latency	100-500 milliseconds	20-30 milliseconds	<10 milliseconds
	Average Speed	144 kbps	25 mbps	200-400 mbps

Figure 1 shows the basic parameters of current wireless network generations for comparison. The main advantages of 5G can be exploited in healthcare applications, such as the increased top and average speed, and low latency (as low as 1 ms) (Latif et al., 2017; Li, 2019; Liu et al., 2020). Furthermore, the technique of network slicing would allow using dedicated frequency bands and speeds for reliable and safe communication on the same hardware equipment (Zhang, 2019; Li et al., 2017). Note that simultaneous to the implementation of 5G networks, 3G networks will be shut down and 5G will coexist with 4G/LTE networks.

However, public concerns arise. “Health issues” not only mean new possibilities for health care but also the concerns about real or imagined adverse effects of electromagnetic radiation (Chiaraviglio et al., 2021; Kostoff et al., 2020; Caudeville, 2020). Operational frequencies used by 5G are either below 6 GHz or around 30 GHz or higher. The so called “Sub 6” frequency bands are already used by 3G, 4G and WiFi networks; 5G will not provide dramatically better experience in contrast to 4G. On the other hand, the so called “mmWave” domain above 30 GHz will offer larger bandwidth, thus, higher speed and lower response times (suitable for healthcare applications). Both frequency regions of electromagnetic radiation belong to non-ionizing radiation, having thermal effects on living tissue, especially the eyes, skin, palms and fingertips can be affected (Moskowitz, 2017; Simkó et al., 2019). Ongoing research focuses on detecting short-term and long-term effects. Safety levels and regulations are constantly updated and new results adopted. These levels are usually many orders of magnitude higher than the measured radiation of selected equipment.

Virtual and Other Realities

Virtual Reality (VR) assumes full immersion of the user that blocks the physical world completely (Gigante, 1993). Augmented Reality (AR) uses real-world environments and objects are enhanced by computer-generated information, usually using various other sensory modalities (Rebbani et al., 2021). In Mixed Realities (MR), we combine elements and methods of both VR and AR where real and digital objects and entities interact.

All realities are based on audiovisual interaction and representation in a 3D space. Furthermore, many applications try to exploit the possibilities of other sensory modalities, such as movement (gesture control, arm and whole-body movements, head-tracking etc.) and haptics (tactile information, smaller movements of the finger), and try to integrate all modalities in a complete 3D system. In the case of VR, blocking the outside world completely by wearing some kind of a helmet can be risky, and also uncomfortable. Therefore, AR and MR solutions, such as smart glasses, embedded reality applications, and regular audiovisual playback devices (screens) are getting popular (Barteit et al., 2021). Current VR solutions have restricted applicability, but they are expected to be developed toward reducing size and weight, and increasing usability and comfort.

Internet of Digital Reality

The Internet of Things (IoT) was introduced many years ago, as the next level of (smart) connections using the Internet. Sensors, machines, and digital equipment are linked, and an enormous amount of data is transferred, enabling smart decisions by algorithms, artificial intelligence and human operators (Hassan, 2019; Shafique et al., 2020). Recently, human users coexist in this digital world with the “things”, including avatars, AIs, where the borders among them can blur (O’Connor, 2019). These digital cognitive entities are present in the same virtual universe where they interact. Furthermore, we are leaving the 2D internet to a 3D world, where besides vison and audio information, motion and haptics will be the new modalities. Recently, Facebook introduced “Metaverse”, a fully immersive 3D VR representation of the internet, especially for social media platforms (Lee et al., 2021). They even renamed the company “Meta”.

On the other hand, all this comes with an increased cognitive load for the human user, where expectations do not necessarily meet the outcomes, which can result in growing anxiety, addiction, deception and fraud by others, and various other safety issues. The IoT and the other Internet of "somethings" do not deal with these issues. The concept of the Internet of Digital Reality (IoD) was presented in order to handle and cover all aspects of the new Web3.0 possibilities, focusing on modalities, technological foundations, immersive 3D virtual scenarios and human factors (Baranyi et al., 2021; Wersényi et al., 2021).

2. Use Cases and Scenarios.

Health Management

Advances in technology and communication have a major impact on health systems. Virtual solutions have reached physical areas, making healthcare more modern, efficient, and cost efficient. Improvements include 3D printing, online pharmacies and special clinics where e-prescriptions are already used. The development of health informatics enables rapid medical reactions in the online space as well as the possibility of remote sensing. These developments accelerate and promote patient recovery (Lukas et al., 2020).

Telemedicine and medical surveillance are realities that can be realized with developments in technology and the installation of 5G networks. The development of online systems will facilitate the examination of chronic patients, the organization and detection of screenings, and the establishment of early diagnosis. Screenings reduce the pressure on healthcare systems, thus, increasing the number of screenings contributes to early detection and prevention (Margolin et al., 2021). In regions with difficult infrastructures, it can be the solution to the problem of poor patient care.

Rehabilitation

The brain responds to all information coming through the sense of vision, even if it is just a movie or we are just dreaming. The incoming stimuli run through a reflex circuit, triggering movement if necessary.

Experience of movement in a virtual space triggers the elements of movement in a healthy nervous system as if we were actually present. Different spaces can trigger different movements, and these can evolve with repetitions (Agostini et al., 2015). Practicing and repeating movements in an environment that would be difficult to induce can be realized virtually. The possibilities of a virtual space can add more to motion development than ordinary spaces, because more stimuli can be elicited in a unit of time (Tchero et al., 2018). These spaces can be changed and updated up to every minute, and there can be extra tools for moving that makes the movement of the body even more intense.

The VR options so far have come a long way in getting the body moving. The repository of motion therapy has never gained as much as now, using VR technologies. Providing visual and auditory stimuli together with body movements that can be tracked allow the patient to be instructed and controlled with the same device. There is opportunity for improvement of coordination, balance, body symmetry, reflexes, and muscle strengthening in every direction. With the help of technological and digital

developments, even home rehabilitation can be realized using properly set devices resulting in safe treatment at home.

Problems

Health care systems vary from country to country, and hospitals are not uniformly distributed spatially. Larger countries with sparsely inhabited areas, archipelagos, and mountain ranges also face larger problems. Integrating technological tools and educating both the public and the personnel takes a long time. The elderly learn how to handle devices, computers or mobile equipment slower. Faulty or inadequate internet coverage is also a serious problem in the communication of modern devices. Reliable internet connection and proper education is a prerequisite for a well-managed and structured healthcare system.

Telemedicine

Telemedicine is a healthcare service in which the person receiving treatment does not meet the healthcare personnel. The connection is established through some remote data transmission system. Telemedicine is a diagnostic or therapeutic remote monitoring procedure supported by an information and communication tool, in which the presence of healthcare professionals is replaced via an online electronic connection (Figure 2). With the establishment of stable networks, the implementation of so called telemedicine and control studies becomes feasible. Developments will enable

- remote consultation, where remote doctors and professionals will be involved in the diagnosis and treatment process through communication tools;
- remote manipulation, where the person performing the test or intervention remotely controls (performs) an examination (e.g., endoscopy) or intervention (e.g., remote manipulation with a robot or remote control device in addition to video control) relying on remote sensors;
- remote diagnostics, when the performer of the examination on which the diagnosis is based and the person who established the diagnosis are separated in space, but are in an interactive relationship;
- remote monitoring or telemonitoring, when the presence of medical personnel is replaced by relays (detectors), and signal transmitters monitoring the patient (Chaet et al., 2017).

Telemedicine also plays an important role in disseminating knowledge. With the development of healthcare applications, patients can now turn to specialists. A virtual healthcare system can assist doctors to consult colleagues worldwide in an easy and inexpensive way. In addition to existing devices such as smart watches, and wearables, there are dedicated tools that, for example, measure UV radiation and provide personalized skin protection advice. T-shirt-mounted sensors can monitor a person's stress level by examining heartbeat and skin status. With technological advances, we can reduce waiting lists and provide a better, more manageable patient path (Waller et al., 2018; Lee et al., 2018).

Next, two application areas, namely telesurgery and telerehabilitation, will be highlighted.

Figure 2.

Telemedicine Services: Inpatient Teleconsultation, Telepathology and Second Opinion Consults (UCLA Health, 2021).

Telesurgery and Teleassistance

Virtual assistance during surgery and other interventions needs a reliable network, a secured connection and good quality transmission of audio and video. Although the speed offered by a 4G network may be sufficient, reliability is not maintained. 5G mobile networks co-operated with high-speed wired connections can fulfill these requirements.

Figure 3.

Telesurgery using high-speed network connections for real-time assistance (Vella, 2019).

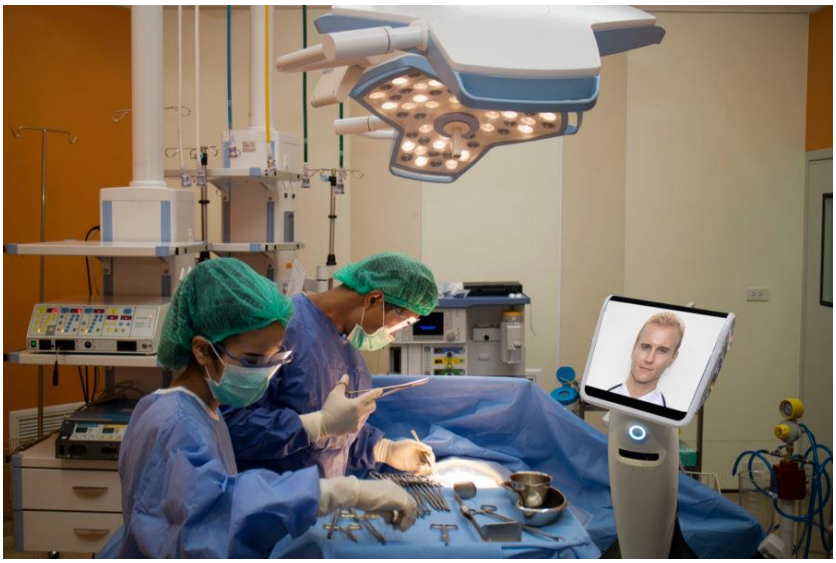

Figure 3 shows a good example of what Telesurgery can offer. In case of assistance, neither ultra-low latency nor extreme reliability are necessarily required. In this observer mode, duplex communication is established for audio, video (including still pictures) and maybe for data (vital signs, patient data). Real Telesurgery means active contribution, i.e., execution of the intervention by means of a teleoperated robot or laser (Gupta et al., 2019; Choi et al., 2018). In this case, latency should be so low that it will be experienced as real-time. Another question is feedback, where not only video but haptic information is delivered via the network (it also "feels like" being there through sensing, e.g., the softness of the tissue). Increased network reliability must be maintained; loss of network connection is not acceptable. From the management perspectives, there is mainly a classic network management (service provider side) task and at the beginning, increased amount of work with the patient. It is expected to bring long-term benefits, if this solution becomes routine. However, the procedure raises also questions, whether it is reasonable, as a surgical team has to be present in the operating room in case of an emergency.

Telerehabilitation

After injuries and surgery, rehabilitation can be time-consuming. Therapeutic gymnastics, special exercises and rehab can be partly done at home, where commands and supervision can be made from a distance (Sarsak, 2020; Leochico et al., 2020). Using VR/AR can be more entertaining and new possibilities and methods can be offered. With the help of haptics and a low-latency feedback channel, even correcting movements is feasible (Figure 4). There is lots of space for management solutions in order to decrease costs using this technique.

Figure 4.
Telerehabilitation or Virtual Rehabilitation (PMR Press Release, 2020).

Telerehabilitation can be used for hospital-quality treatment of a patient without delivery. The advanced technological background ensures the quality of care. Patients can perform their rehabilitation treatments under continuous monitoring. It is effective not only in the treatment of acute, but also in the treatment of chronic, diseases. It has

been used in many neurological and orthopedic cases with promising results (Gandolfi et al., 2017; Laver et al., 2020).

3. Conclusion.

Emerging technologies using high-speed, low-latency and ultra-reliable network connections will change the future of healthcare systems, both in patient treatment (examination, surgery, rehabilitation) as well as in management (data handling, organization etc.). The use of gigabit connections both wired (fiber optics) and wireless (5G and beyond) will serve as the technological background. Furthermore, application development, new use-cases and services will contribute to sustainability in various forms. Among these, Virtual Reality and connecting technologies open the way for different telemedicine services. Finally, human factors, cognitive aspects and even legal and business issues should be and will be covered along with the technical developments under the umbrella of the Internet of Digital Reality (IoD).

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