Digital Technologies for New Healthcare Applications Under the COVID-19 Pandemic

Dr. Christine P. Tan, *PhD CEng FIET*

China FIoT Open Lab; Fujian Normal University

1. Abstract

The COVID-19 pandemic has disrupted the daily lives of people worldwide on an unprecedented scale, resulting in the emergence of new norms, such as people staying at home for longer periods of time, the ubiquitous pandemic prevention and control measures happening on individual, community and national levels, as well as the increased need for personal healthcare at home. These scenarios have brought about new challenges and issues, which digital technologies such as Internet of Things (IoT), artificial intelligence (AI), big data, and 5G can help to address. This paper will discuss some examples of these digital healthcare solutions and their innovative applications under the COVID-19 pandemic.

2. Background

In the past decade, advances in digital technologies and their increasing widespread use, have led to a more "connected" world. The basic connectivity infrastructure to support Internet access, mobile telecommunications, location based services *etc.*, have been extensively setup in place, enabling even the rural and remote areas to become connected. Information is shared at a faster speed across countries, forming the impression that the world is shrinking to a "digital village".

In this backdrop of digital globalisation, when the COVID-19 broke out in early 2020, the world had information at their fingertips through a highly interconnected ecosystem [1]. The World Health Organisation and governments around the world were able to release daily reports, updates on the pandemic, as well as coordinate sharing of scientific data on the COVID-19 virus [2], more quickly compared to the previous SARS epidemic. For example, epidemiological statistics were reported daily, down to details such as the number of confirmed cases, deaths, recovered cases, severely ill, and even the geographical locations of these cases. Ad-hoc local grassroots scientific communities translated official reports and news, even setting up a dedicated COVID-19 information website [3]. Big data analysis played an important role in identifying trends and detecting COVID-19 outbreak clusters early [4]. COVID-19 genome sequencing data were shared in the scientific and medical communities to speed up vaccine development [5,6]. AI algorithms were used to optimise the image analysis of Computed Tomography (CT) scans of patients' lungs aiding COVID-19 diagnosis [7]. Indeed, how the digital world handled the pandemic is quite different today.

However, the world was still inadequately prepared for the protracted COVID-19 crisis and its corresponding social and economic impact. New social norms have emerged, such as the lockdowns due to outbreak clusters in local communities, prolonged periods of study or work from home and the major reduction in outdoor activities. Many social and technical issues arose from these common scenarios, such as the massive monitoring of individuals' movement and epidemiological progression, and conducting outdoor activities at home. In response, digital technologies such as Internet of Things (IoT), artificial intelligence (AI), big data, and 5G, were integrated for innovative healthcare applications, to better meet the challenges posed by the evolving pandemic.

3. Digital Technologies Enable New Healthcare Applications

By definition, digital technologies are electronic tools, systems, devices and resources that generate, store or process data. During the pandemic, digital technologies played an important role in maintaining the social connectivity between people, enabling school and work to continue online, facilitating pandemic surveillance and control, and disseminating public health information and news updates. This paper will highlight several innovative examples of deploying digital technologies for healthcare under the COVID-19 situation, and also discuss some of the new social issues caused by the adoption of these technologies.

3.1. Contact Tracing for COVID-19

Efforts in pandemic monitoring and control have taken on digital measures in several countries like China, Singapore and Australia. In China, an individual's movement was tracked via a combination of health apps, QR codes, colour codes, and telecommunications operators' network reports [8]. Within a health app, one could scan QR codes clocking in to locations visited, especially for high-density places such as tourist spots, supermarkets, hospitals *etc*. Furthermore, based on the geographical locations where the mobile phone had been used, telecommunications operators would report on where the individual had visited, and the health app would then display a corresponding colour code – green for "no risk", yellow for "potential risk", and red for "high risk" areas. Individuals who had completed COVID-19 vaccinations had a gold-coloured border around their health codes. While these methods were broadly effective, some social problems arose including the elderly's learning challenges to use the apps [8], the heavy dependence on the self-awareness and diligence of individuals scanning the QR codes, as well as personal privacy issues.

In a similar manner, the Government Technology Agency in Singapore had implemented a TraceTogether app augmented by wearable IoT tokens, to facilitate contact tracing of persons who might have been close contacts of confirmed COVID-19 cases. The physical token was waterproof, had a battery life of 6 months, did not have buttons, and relied on Bluetooth to autonomously communicate with other nearby users. The token did not require any user know-how or intervention and its simple design was a gospel for vulnerable individuals (children, elderly, cognitively impaired persons) who might not possess a mobile phone. Furthermore, the token did not have GPS functionality; it could only identify the people within vicinity of the user, but not the user's actual location, which was said to afford more individual privacy.

Singapore's TraceTogether system had a relatively high 92% adoption rate in the population by May 2021 [10], while other COVID-19 tracing systems tested in Australia (COVIDSafe app) and United States (via Apple-Google) had lower adoption rates in the populations [9,11]. Overall, these national contact tracing tools were helpful tools to track and halt the progression of outbreak clusters, however the public also raised concerns about data ownership, trust and control [9].

To address the data protection issues, countries had measures in place that allowed data release upon consent by users, or only in emergency situations that warranted access to individuals' data by the local authorities. Nevertheless, these solutions could be optimised with more community consultations, and alternative solutions with stronger privacy protection (*e.g.* through the use of blockchain technology) could be also explored and tested, so as to improve the pandemic readiness of these digital contact tracing systems.

3.2. Remote Healthcare at Home

Healthcare at home with professional remote assistance is becoming increasingly popular, especially in view of COVID-19 where people are more inclined to stay home. A new paradigm, Social Internet of Things (SIoT) was introduced to include the additional level of social connection between people and edge devices (things) [12], which played an important role in remote healthcare at home. Advances in telecommunication such as 5G, allowed for faster and smoother video streaming connections with physicians, more bandwidth for data transfers and lower latency for continuous patient monitoring at home. There are now more healthcare devices at home due to breakthroughs in portable medical devices and wearable biomedical sensors. Through these IoT healthcare devices and social interaction with healthcare professionals via remote connections, patients at home could conduct basic medical tests themselves, feedback the test results to their local healthcare clinics or hospitals, and even perform some simple treatments for chronic conditions.

Some examples of home-based healthcare tests [13] include continuous glucose monitoring, electrocardiograms (ECG) monitoring, urine tests, and even COVID-19 preliminary screen tests. Companies such as Medtronic, Abbott, BodyTel have developed "under the skin" implants or patches pricked into the abdomen, which could communicate wirelessly with mobile phone apps to continuously monitor glucose level in patients. Wearable ECG necklaces were developed by Belgian research institute Imec to monitor daily cardiac activities based on a combination of low-power microcontrollers, radio and sensors. Spanish company Nuubo [14] developed a medical wearable vest for cardiac arrhythmia monitoring, diagnostics and rehabilitation solutions with remote reporting for evaluation by cardiologists. Chinese company Dongze Medical [15] developed a home-based automated peritoneal dialysis system for chronic kidney disease patients, which also featured a real-time urea sensor, built-in AI algorithms to detect anomalies during dialysis, and 5G wireless connection for remote feedback to healthcare professionals. Home-based rapid antigen COVID-19 tests have emerged to prevent the pandemic from flaring up into larger outbreaks, gaining popularity in countries like United States, United Kingdom and Singapore [16]. However, US company Ellume conducted recent product recalls due to a high false positive rate [17]. While these tests need to be improved for accuracy and sensitivity, it could be argued that these tests could serve as a quick pre-screen before the final confirmation via the gold standard PCR test, thereby reducing the testing burden by local PCR test centres.

Healthcare at home with remote professional assistance is increasingly becoming a viable option for vulnerable individuals who have difficulties leaving home, or for individuals with chronic conditions during COVID-19 lockdowns. Digital technologies need to be more user-friendly towards patients who might not have the technical know-how to manage the IoT medical devices, and remote assistance by professionals to help troubleshoot technical issues and/or medically observe patients, are important steps towards effective implementation. Business models for providing chronic health treatments will also likely need to innovate and keep up with patients' new needs [18], for example it might not be feasible to go to dialysis centres during lockdowns. Additionally, more robust data protection and informed consent management workflows are critical for helping patients to trust their healthcare providers and third-party service providers, as well as hold all parties with access to patients' data accountable.

3.3. Smart Wearables for Home Fitness

Wearables like smart glasses, smart watches or wristbands [19], activity trackers [20], intelligent patches [21], are gaining popularity for personal health fitness monitoring, optimising athletic performances, and recently by schools for tracking students' sports lessons. These IoT wearables contain miniature sensors inside to detect and count the users' physical and physiological statistics. Microelectromechanical systems (MEMS) like accelerometers and gyroscopes monitor mechanical steps, speed and acceleration, angular movements, which are then correlated to the users' activity levels during sports exercise. Near-infrared sensors monitor users' blood oxygenation levels in oximeters. Infrared sensors or radar based sensors detect users' heart rates. Bio-microfluidic sensors absorb bodily fluids for measuring biomarkers levels such as lactate. Often, these wearables are also equipped with low-power short-range wireless communication protocols such as Bluetooth, NFC, to facilitate data transfers with a mobile phone fitness app. Although personal fitness devices are already prevalent, the accuracy of the fitness data collected remains a challenge, since the sensors' data collection can be affected by vigorous body movements during exercise. Depending on the end user application, the accuracy and hence technical complexity and cost of the wearables needed, were different for home use versus performance training.

Sport lessons at home for school children was an interesting application brought on by the COVID-19 situation. When schools were locked down, there was a worrying trend that children at home were becoming more sedentary and gaining weight. In China, several schools were testing the use of smart wristbands developed by Tai Ji Xing company [22] for children at home to perform regiments of exercise prescribed by the school. AI algorithms were extensively used to optimise the wearables. For example, the learning algorithms inside the smart wristband ensured that the device was individually customised for each user. A child's baseline levels for heart rate was recorded and the wearable could detect potential cheating in the event the users gave the wearable to someone else to work out on their behalf. AI and big data analysis were also deployed on the data collected from the wristband's multiple sensors, making the resulting wristband "intelligent" enough to differentiate the users' sports activity, *e.g.* whether the user was skipping ropes or running. However, for "personal fitness at home" scenarios that were not mandatory, it would be helpful to consider additional factors such as the users' psychology, behaviours and quality of experience, so as to ensure the continued use and the efficacy of fitness outcomes [20,23]. Additionally, it would be vital to consider the users' pre-existing health conditions to ensure that the wearable would not interfere for example with implanted cardiac devices [24].

4. Conclusions

Advances in digital technologies have enabled smart healthcare devices to permeate the daily lives of people worldwide. Under the pandemic, the integration of digital technologies such as IoT, AI and big data, have created innovations in healthcare applications, ranging from COVID-19 contact tracing, remote healthcare and school sports lessons at home, helping to alleviate some of the inconveniences brought about by COVID-19. However, there remains much room for improvement in these new digital healthcare solutions, especially in areas such as data privacy, reducing the learning curves of using these technologies, as well as considerations of new social interaction modes and economic models in smart healthcare today. It would also be helpful and interesting to reach out to users in the form of community consultations and gather their feedback for improvements.

5. References

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