Role of Artificial Intelligence of Things (AIoT) in Covid-19 Pandemic: A Brief Survey

Venkatesh K. Pappakrishnan[1], R. Mythili[2], V. Kavitha[2] and N. Parthiban[2]
[1]*Palo Alto Networks, CA, U.S.A.*
[2]*Department of Computer Science and Engineering,*
SRM Institute of Science and Technology, Kattankulathur, Tamilnadu, India

Keywords: AIoT, Healthcare 4.0, COVID-19, IoT, AI, Smart Healthcare.

Abstract: Digital twins, Internet of Things (IoT) and Artificial Intelligence (AI), plays a proactive role in numerous ways during a pandemic such as COVID-19 by allowing us to make informed decisions using real-time data. According to World Health Organization (WHO), COVID-19 is an infectious disease caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) that predominantly spreads through body fluids, leading to a mild-to-severe respiratory illness. Considering the global health crisis due to COVID-19 and novelty of the SARS-CoV-2 virus due diligence is required in vaccine preparation and human trials. At the early stages of the pandemic, due to lack of complete knowledge on the virus, there are two main objectives: (1) treat patients as effectively as possible and (2) control the spread of the disease. IoT devices in healthcare empower the healthcare industry in identifying potential carriers of COVID-19 and quarantine. Even though IoT plays a major role in healthcare 4.0, decision making capabilities are limited due to the type of the algorithms and decision making paradigms used. Using AI, we will be able to identify critical medical conditions earlier and take necessary steps. Artificial Intelligence of Things (AIoT) implementation has the potential to greatly reduce the mortality rate allowing us in early identification of high-risk patients, monitoring the spread of the disease, methods to limit the spread, predict mortality risk by analyzing patient's health history, remote or in-home treatments to reduce hospital occupancy, and other techniques to significantly control the spread and treat the patients effectively.

1 INTRODUCTION

Artificial Intelligence (AI) has gained a lot of traction recently and has been widely adopted and revolutionizing various fields including healthcare, retail, banking, financial services, marketing, travel, real estate, logistics, and food technology (Hall and Pesenti, 2017). Internet of Things (IoT) is a group of interconnected devices that are programmed to act individually or collectively with the knowledge gained through all the interconnected devices (Initiative et al., 2015). IoT devices typically contain sensors to collect useful data, processor and memory units, internet capability, and part of a network of millions of similar devices (Atzori et al., 2010). The collected data are either processed locally using edge computing which can efficiently handle a small amount of data within a limited bandwidth which provides us enhanced security mechanisms (local), low-latency, and faster responsiveness or using fog computing. The fog computing is a decentralized architecture where the computing is performed at the fog node which is located within the LAN providing the same advantages as edge computing in terms of data security and latency. The intelligence still remains close to the source of the data. However, when heavy data processing and computation is required due to the volume and velocity of the data, then cloud computing is the best alternative which comes at the cost of high latency, high cost, and possible data security issues (Armbrust et al., 2010). Recently, more focus is given to edge computing especially for IoT applications due to high responsiveness, improved performance, and better data security compared to fog and cloud computing architectures (Hassan et al., 2018). AIoT (Artificial Intelligence of Things) is the combination of AI's computational power and IoT's collective interoperability that pushes the limits on the intelligence of smart devices by empowering them to perform highly challenging tasks which are

Pappakrishnan, V., Mythili, R., Kavitha, V. and Parthiban, N.
Role of Artificial Intelligence of Things (AIoT) in Covid-19 Pandemic: A Brief Survey.
DOI: 10.5220/0010461502290236
In *Proceedings of the 6th International Conference on Internet of Things, Big Data and Security (IoTBDS 2021)*, pages 229-236
ISBN: 978-989-758-504-3

technically impossible with current IoT architectures (Ghosh et al., 2018; Poniszewska-Maranda and Kaczmarek, 2015; González García et al., 2019). AIoT has been widely adopted in different sectors such as retail, healthcare, automobile, home appliances, etc (Ghosh et al., 2018).

Industrial revolution 4.0 (I4.0) is the integration of technologies from different sectors such as IoT, AI, Big Data, 5G, etc (Lampropoulos et al., 2019). There are four major components in I4.0: Cyber Physical System (CPS), IoT, resource availability, and cognitive computing. Information and Communication Technology (ICT) is the integration of information through telecommunication and the components in the ICT are computing, communications, and entertainment that helps in exchange of information through digital electronic media. Health-CPS is designated for patient-centric healthcare applications and services which is based on cloud computing and big data analytics (Zhang et al., 2015). Healthcare 4.0 is an integral component of Industry 4.0 where different domains of the industries are integrated through personalization and virtualization. It revolves around the idea of how a centralised health care system such as hospitals, provide a decentralized patient-friendly health care services using innovative research fields of computer science such as IoT, AI, big data, robotics and so on (Javaid and Haleem, 2019; Javaid and Haleem, 2018; Ekstrand et al., 2018).

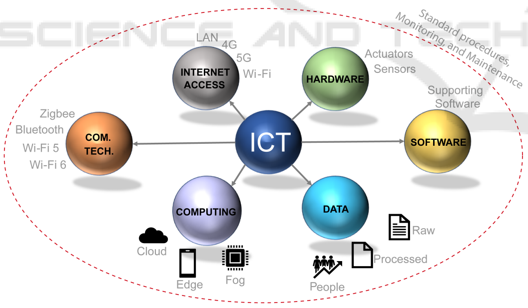

Figure 1: Components of Healthcare 4.0 (H4.0).

Figure 1 shows different components in H4.0 which are borrowed from I4.0 with applications tailored to the healthcare industry. As everyone is connected through digital technologies, ICT helps in improving healthcare for individuals and larger communities (Thilakarathne et al., 2020). ICT monitors and controls every component in the system including hardware such as sensors and actuators. All the components should follow a predetermined procedure and require constant monitoring and periodic maintenance.

In H4.0, patients' data are continuously collected using various sensors and stored in a cloud infrastructure for data analysis and predictive modeling. In IoT based health care systems, sensors connected to micro-controllers (eg. arduino) and integrated chips (eg. raspberry pi) monitor health statistics and vital parameters such as body temperature, pulse rate, respiratory rate, blood glucose level, and ECG (Kumar et al., 2017). For effective communication, wireless technologies currently used in IoT are: (1) wide area cellular technologies such as GSM, LTE and 5G, (2) short range technologies such as ZigBee, Z-wave, WiFi and Bluetooth, and (3) low power technologies such as LoRa and Sigfox are used (Qadir et al., 2018).

This paper is organised as follows: In section 2 we discuss the pandemic evolution and the challenges faced. In section 3 we present existing work related to AI and IoT in the field of healthcare. In section 4 we discuss the technologies currently available for diagnosis and monitoring of patients. In section 5 we discuss the process flow of telemedicine using AIoT, remote health monitoring, and telematics. This is followed by applications and benefits of AIoT during pandemics. In section 6 we briefly discuss the security challenges of personal health data and finally in section 7 we summarize all the important findings.

2 PANDEMIC OVERVIEW AND CHALLENGES

Infectious diseases are classified into endemic, epidemic, and pandemic based on geographic spread and scale of the people infected. A pandemic is usually triggered by a zoonotic transmission of pathogens from animals to humans (Belay et al., 2017). This is due to the fact that human's immune system are not evolved to fight pathogens from other species, especially the ones that are from uncommon environmental conditions known to humans.

The following are the common challenges faced during a pandemic (Madhav et al., 2017):

- Lack of preparedness after the initial outbreak as the developing countries have limited financial and technical resources.
- Shortage in essential medical necessities such as gloves, masks, syringes, etc. Unavailability of antiviral agents and vaccines.
- Insufficient number of healthcare workers and lack of training in specialized areas for effective control of the infection in the early stages.
- Economic downfall including short-term fiscal shocks and longer-term negative impact to the economic growth.

- Slowdown in social and economic growth due to pandemic mitigation plans from every country.
- High morbidity and mortality rates due to poor public health resources and population density (Oshitani et al., 2008).

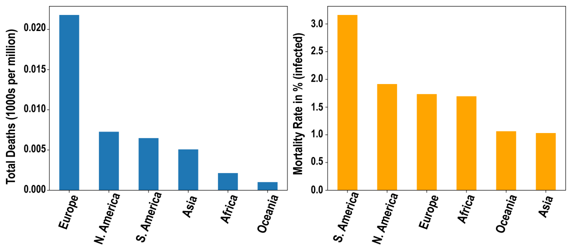

Figure 2: (a) Total deaths and (b) mortality in percentage across different continents (data source: https://ourworldindata.org/coronavirus-data).

Mortality rate and total deaths of the COVID patients are continuously tracked and periodically published for the public by various organizations and universities including WHO and John Hopkins University. Europe has been critically affected in terms of total deaths followed by N. America and other continents (Figure 2 (a)) and in terms of mortality rate, which considers only infected patients, S. America has been severely affected with over 3% mortality rate (Figure 2 (b)).

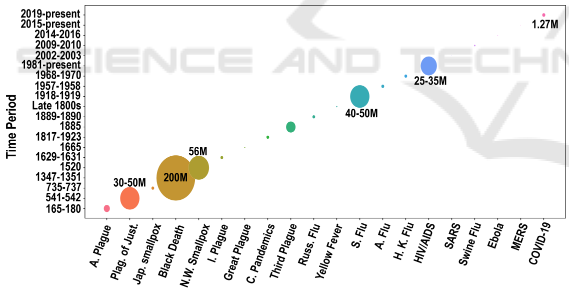

Figure 3: Impact of pandemics (death count) during different time periods (data sources: https://www.worldometers.info/coronavirus/, https://en.wikipedia.org/wiki/List_of_epidemics).

Figure 3 depicts the death count during each pandemic that are known to us. One of the recent pandemics that has been making a significant impact is HIV/AIDS with over 35M deaths and this is mainly due to the nature of the virus itself and lack of technological advancements to predict and control the spread during that period. The COVID-19 has already claimed over 1.27M lives across the world as of Nov 2020 (Organization et al., 2020) and continues to climb. Recent technological advancements allows us to accelerate the research and development of the vaccine for SARS-CoV-2 compared to the technologies we had during HIV/AIDS outbreak. According to the WHO, there are currently more than 60 COVID-19 vaccine candidates in clinical development and over 170 in pre-clinical development.

For COVID-19 two types of vaccines are developed by three major pharmaceutical companies: Pfizer-BioNTech COVID-19 Vaccine (pfizer, BioNTech) (Tanne, 2020), Moderna COVID-19 Vaccine (Morderna) (Cohen, 2020), and Serum Institute of India (Covishield ChAdOx1_nCoV19). The vaccines show promising results based on initial human trials and released to public. However, the side effects and the effectiveness of the vaccine still needs further study. Although, various hospitals are pioneering in smart healthcare and forge ahead for better and advanced treatments, there still prevails various challenges in this sector (Zhu, 2019; Gastaldi and Corso, 2012).

3 RELATED WORK

Pardeshi et al., explains the process remote monitoring of patients remotely, data storage techniques, data processing, and data transmission methods along with the hardware and the software required for the successful monitoring of the patients (Pardeshi et al., 2017). Remote monitoring system is used for keeping track of non-critical patients from their home without the need for hospital occupancy. Islam et al., discusses the advances imposed in the IoT industry and various industrial implementations of healthcare solutions along with a detailed explanation of a collaborative security model to address the security issues (Islam et al., 2015). Rodrigues et al., discusses products, services, and features of IoHT technology (Rodrigues et al., 2018). Smart clothing based health care system has been introduced as Wearable 2.0 to support bedridden patients with accurate monitoring of health statistics (Chen et al., 2017). To improve the energy efficiency of the IoT devices, ARM micro controllers are used for collecting real-time data. Pang et al., discusses the advancement in automation, biomedical industry, and health analytics and identifies the research gap and industrial demands to set direction on future research (Pang et al., 2018). Assisted living for the elderly people can be achieved using AIoT; *Genni* an intelligent IoT application designed as a personal assistant using wearable technology for monitoring vital signs such as heart rate, blood pressure, sleep hours, etc., and integrate them in a distributed data management framework for demonstrating data interoperability and data accessibility (Serrano et al., 2018). In spite of strong security measures to protect patients medical e-records, security breaches may still occur due to various unique techniques followed by the hackers. The security challenges include privacy and confidentiality of the patients data. According to Ermakova et al., due to the privacy concerns, patients are still skeptical and less likely to prefer cloud environments for storing their medical records (Ermakova et al., 2013; Kuo et al., 2014). AIoT is currently used for cardiac disease detection and analysis of electrocardiogram (ECG) signals. Convolution Neural Network (CNNs) are used for arrhythmia classification (Lin et al., 2019).

4 DIAGNOSIS AND MONITORING OF COVID-19 PATIENTS

According to the WHO, the most common symptoms of COVID-19 are fever, dry cough and tiredness and the less common symptoms are aches and pains, sore throat, diarrhoea, conjunctivitis, headache, etc. Severe symptoms include difficulty in breathing, chest pain, loss of speech or movement (Chamola et al., 2020). For effective identification, the diagnosis needs to be scaled up to test millions of potential patients with symptoms which is critical during a pandemic. For scaling up, the challenges include availability of the medical kits, trained health care workers, and health care facility. IoT would tackle the challenge by integrating the medical devices with the in-built sensors, algorithms and mobile health applications. AI, virtual healthcare management, and telemedicine reduces the manual interventions in considerable way thereby protect the front line workers. The image sensing such as CT scans and X-ray detect and classifies the abnormalities observed. This intelligent classification will enhance the automation process, less intervention of the physician with the patients. The performance of analytics helps in monitoring the spread of COVID-19. The complexity in handling the applications has been reduced and the technology is easy to adapt. Although there are several challenges, AI and IoT would help us optimize logistics of medical kits and required equipment to reduce shortage during critical times, improve the accuracy of the diagnosis, efficient and effective data collection required for gain better understanding of the disease and in developing accurate algorithms or models. There are sensors that help us in pure data collection and others that allow us to continuously monitor the patients for taking necessary actions. Here we have listed sensors and devices in the table 1 that are known to be quite helpful so far in the early detection of COVID-19 symptoms and monitoring of affected patients. The contact tracing applications developed by various countries are COVIDSafe (Australia), Stopp Corona (Austria), e-Tabib (Azerbaijan), Corona Tracer BD (Bangladesh), CoronApp (Colombia), Smittestop (Denmark), StopCovid (France), Corona-Warn-App (Germany), Aarogya Setu app (India), and HaMagen (Israel).

5 AIoT FOR COVID-19

AIoT holds a tremendous potential in addressing the limitations of IoT in H4.0. A typical process of AIoT system involves three main components: telemedicine, remote data gathering, and algorithm. The telemedicine segment includes both the sensors for recording data or monitoring health of patients and the actuators to act physically based on the signal either from health care practitioner (semi-automated system) or the algorithm directly (fully-automated system). The collected data is pre-processed and stored in distributed storage system and the data can be processed in batch mode or streaming mode for model building and prediction. During every batch or cycle, the data collected is used for predicting the next behavior. The algorithm could be re-trained periodically like every 3-6 months using last *n* days of data or the entire data set.

5.1 Contact Tracing and Tracking

Contact tracking is the process of monitoring a person who has been exposed to the disease in-order to alert his contacts to curtail the transmission of the disease (Thayyil et al., 2020). The contact tracing and tracking API have been developed by Google and Apple and they provide a GUI platform for building tracing apps using which a user can participate in digital contact-tracing. For instance, if two people meet for five minutes or more, an identifier is exchanged between their phones via Bluetooth. Later, if one of them is tested positive for COVID–19, an alert notification is send to the other person's phone who has come in contact with him. Privacy is preserved as user's location and other details are not shared. Tracing and tracking of patients and their health statistics is discussed in detail in (Nazirun et al., 2017).

Table 1: Types of Sensors.

SENSOR	MEASURES / MONITORS	COMPANY
Temperature	Body temperature	Analog devices, Mitsumi, Melexis
Pressure	Blood pressure	Sensata Technologies, IFM Efector, Keller America
Airflow	Breathing rate	HydraCheck, RCM Industries, Inc., ERDCO Engineering Corporation
Oxygen	Oxygen level	Honeywell, Unimed, Cubic
Electrocardiogram	Heart rate	NeuroSky, Eko Devices, Inc. , Cognionics
Accelerometers	Movement of body	First Sensor Inc., Baumer Group, Colibrys SA
Biosensors	Level of cholesterol	InnovoGENE Biosciences, Biodot, Aryballe

5.2 Telehealth, Remote Health Monitoring, and Telematics

With ever increasing number of COVID-19 patients across the globe, automation of healthcare workers' duties will be of great deeds (Alwashmi, 2020). This would reduce medical expenditures and in-facility congestion. Remote Patient Monitoring (RPM), also called home-care telehealth, allows patients to perform a routine check up, send real-time data to the medical practitioner, and receive medicines through home delivery (Avitall et al., 2001). RPM technology with the introduction of biosensors makes health care accessible to remote areas requiring timely action. The WHO describes the synergy of telehealth and telemedicine as telematics, a term for information technology based health care activities. Telemedicine

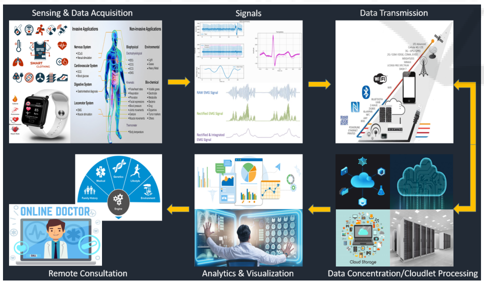

Figure 4: Remote Health monitoring.

involves distance learning component wherein consultation of the case management can also be performed between the physicians at different geolocations. The prescription and drug management is also enhanced by tracking and delivering drugs to the concerned client and to analyze the side effects of the same, if any (Organization et al., 2019). In telemedicine although the doctors can check the external features for diagnosis, however there are still challenges that exist including checking of the heart beat, blood pressure, etc. In this scenario, wearables play a vital role to monitor heart rate and blood pressure and abnormalities could be diagnosed in earlier stages. The factors influencing the telemedicine deployment are the installation space, network availability, proper management of sensors and wearables, and proper adherence to the health care polices and digital infrastructure. The incident rate for COVID-19 is increasing exponentially; in such a scenario reverse quarantine would be the best possible monitoring system in near future (Raveendran and Jayadevan, 2020). Figure 4 shows remote health monitoring system that collects the medical health data using the sensors and actuators from one place and transmit it to the cloud infrastructure and can be used for decision making and analytics to the physicians or healthcare providers for medical assessment or medicine recommendations. Here is a list of telemedicine apps developed by companies worldwide: Mfine (Novocura Tech), eSanjeevaniOPD (C-DAC, India), Practo (Practo), DocClocker (Fast Pathway), and CMED Health (CMED).

5.3 AI and IoT Applications in Pandemic and beyond

- **Early Warning System:** BlueDot, an AI based company detected and notified to its users an outbreak of pneumonia cases (Wuhan, China) as digital smoke signal even before it was officially declared by WHO. The AI VFusion platform by Vivace Health Solutions is reliable in identifying Acute Respiratory Distress Syndrome (ARDS).
- **Tracking the Spread of Virus:** AI-based Healthmaps integrate data sources from Google and other social media platforms. The data are then sent to epidemiologist for the detection of early sign of a possible outbreak. Healthmaps in the Boston Children's Hospital first recognizes the kind of pneumonia attacking a group of people.
- **Contact Tracing:** Geo-location data are used to identify people coming in close contact with each other and notify them directing to isolate them-

selves if one of them is infected.

- **Prediction of Virus Protein Structure:** DeepMind, a company developed a method to predict the virus protein structures using AlphaFold AI system (Alimadadi et al., 2020). They have released AlphaFold, a deep learning library that use neural networks for predicting how the proteins that make organisms crinkle or curve on the basis of their genome. This predicts the receptor shape in the cells of the living being. By learning its shape drug development becomes easier.
- **Early Detection and Diagnosis:** AI and digital-imaging are used together with the COVID-19 detection neural network (COVNet) algorithm to detect positive cases using the chest computed Tomography (CT) images (Li and Xia, 2020). XGBoost machine learning based model to predict survival rates of the COVID-19 affected patients using blood samples data.
- **Robots:** Robots are deployed to respond to immediate needs in hospitals such as delivery of food, medications and equipment, to cleanse and sterilise tools, and to aid medical practitioners. Asimov Robotics, a robotic service provider company based in India, assist patients with their needs to minimize the risk of health-care workers. UVD Robots, emit powerful UV light that can disinfect surfaces (Chamola et al., 2020).
- **Drones:** Drones are deployed for crowd surveillance and to avoid gathering of people in large groups. In India, drones are used to monitor body temperature using an array of infrared (IR) sensors and supply commodities, medical kits, food supplies, and collect samples from people for COVID-19 diagnosis (Anggraeni et al., ; Mohammed et al., 2020).

5.4 Advantages of AIoT during a Pandemic

AI allows us to minimize the workforce required to achieve a task which is critical during a pandemic. Chatbots, a NLP based AI application, is vital in spreading general awareness to the public. Violation of rules in areas with restricted movements can be monitored efficiently using unarmed aerial vehicles (UAV), real-time monitoring using closed circuit television (CCTV) reduces the incident rate of COVID-19. Medical fraternities are moving towards e-learning to abridge the gap in medical workforce (Jecker et al., 2020; Tang et al., 2020). ML algorithms, a subset of AI system helps in the following ways to handle such pandemics:

- **Screening of Individuals:** Using CNNs people with illness, sweating, and discoloration can be detected using thermal scanning face cameras. Wearable rings are used at the University of California to track health statistics of people.
- **Chatbots for Diagnostic:** Chatbots can be programmed to feed patients with a questionnaire about their symptoms as a part of self triage, hence reducing the risk of infection to other health-care workers.
- **Risk Prediction:** Health risk of a patient can be determined using various factors such as age, general hygiene, and social interactions.
- **Bio Medical Knowledge Graphs:** Using NLP, entities of drugs and proteins are connected together as structured graphs. Similarly, customised BenevolentAI knowledge graph is used to find the connection between COVID-19 and Baricitinib (Richardson et al., 2020).

6 SECURITY CHALLENGES OF DATA

Health records are continuously monitored and recorded using telemonitoring facilities, there exists a potential security threat (Singh et al., 2020). Tampering of data, unauthorized access of personal information of the patients, sensitive and confidential information breach, Distributed Denial of Service (DDoS) are possible as the records are most likely placed in a centralized server. A poorly configured central server in terms of network security, all the sensitive content could be compromised and data would be leaked. To limit the security threats, it is important to highest privileges to only few individuals who are qualified to handle. By limiting the number people with broad privileges we could greater reduce the chances of being hacked (Tarouco et al., 2012). According to Anastasios Arampatzis, most of the healthcare threats are done using hidden HTTPS and Domain Name Server (DNS) tunnels, ransomware, and BOTNET. Necessary privacy policies need to be adhered to protect against unauthorized access to health records. Telehealth sector must be provided with enhanced authentication, authorization and accountability (Williams and McCauley, 2016). Data integration and consistency is an another major challenge. A proper environment has to be provided in-order to integrate large sets of data and to make them readily available for accessing and analyzing at any given point of time. According to TrapX report, some hospitals are prone to medical device hijacking which is also called medjacking. A different scenario includes radiology image storage system connected to the main server gets compromised and the sensitive contents are leaked. In another scenario attackers could use a vulnerability in drug pumps to control the hospital's network.

7 SUMMARY

Healthcare 4.0 integrated with AI would greater help in lowering the mortality rate during a pandemic such as COVID-19. We specifically discussed the role of IoT with various sensors to monitor health remotely and how AI would further improve the capabilities in terms of accurate detection of the disease, tracing and tracking of infected/potential patients, etc., allowing us to proactively handle the situation. The need for digital intervention in healthcare and supporting structures has also been discussed along with the security challenges in protecting patients medical records. Finally, we have proposed ideas and listed relevant works on AIoT in healthcare and how it could be used to improve the current healthcare system even beyond 4.0.

REFERENCES

Alimadadi, A., Aryal, S., Manandhar, I., Munroe, P. B., Joe, B., and Cheng, X. (2020). Artificial intelligence and machine learning to fight covid-19.

Alwashmi, M. F. (2020). The use of digital health in the detection and management of covid-19. *International Journal of Environmental Research and Public Health*, 17(8):2906.

Anggraeni, S., Maulidina, A., Dewi, M. W., Rahmadianti, S., Rizky, Y. P. C., Arinalhaq, Z. F., Usdiyana, D., Nandiyanto, A. B. D., and Al-Obaidi, A. S. M. The deployment of drones in sending drugs and patient blood samples covid-19. *Indonesian Journal of Science and Technology*, 5(2):18–25.

Armbrust, M., Fox, A., Griffith, R., Joseph, A., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., and Zaharia, M. (2010). A view of cloud computing. *Commun. ACM*, 53:50–58.

Atzori, L., Iera, A., and Morabito, G. (2010). The internet of things: A survey. *Computer networks*, 54(15):2787–2805.

Avitall, B., Peterson, B., Kletch, J., Griswold, E. B., and Moran, P. (2001). Remote health monitoring system. US Patent 6,171,237.

Belay, E. D., Kile, J. C., Hall, A. J., Barton-Behravesh, C., Parsons, M. B., Salyer, S., and Walke, H. (2017). Zoonotic disease programs for enhancing global health security. *Emerging infectious diseases*, 23(Suppl 1):S65.

Chamola, V., Hassija, V., Gupta, V., and Guizani, M. (2020). A comprehensive review of the covid-19 pandemic and the role of iot, drones, ai, blockchain, and 5g in managing its impact. *IEEE Access*, 8:90225–90265.

Chen, M., Ma, Y., Li, Y., Wu, D., Zhang, Y., and Youn, C.-H. (2017). Wearable 2.0: Enabling human-cloud integration in next generation healthcare systems. *IEEE Communications Magazine*, 55(1):54–61.

Cohen, J. (2020). Vaccine designers take first shots at covid-19.

Ekstrand, C., Jamal, A., Nguyen, R., Kudryk, A., Mann, J., and Mendez, I. (2018). Immersive and interactive virtual reality to improve learning and retention of neuroanatomy in medical students: a randomized controlled study. *CMAJ open*, 6(1):E103.

Ermakova, T., Fabian, B., and Zarnekow, R. (2013). Security and privacy system requirements for adopting cloud computing in healthcare data sharing scenarios.

Gastaldi, L. and Corso, M. (2012). Smart healthcare digitalization: Using ict to effectively balance exploration and exploitation within hospitals. *International Journal of Engineering Business Management*, 4(Godište 2012):4–9.

Ghosh, A., Chakraborty, D., and Law, A. (2018). Artificial intelligence in internet of things. *CAAI Transactions on Intelligence Technology*, 3(4):208–218.

González García, C., Núñez Valdéz, E. R., García Díaz, V., Pelayo García-Bustelo, B. C., and Cueva Lovelle, J. M. (2019). A review of artificial intelligence in the internet of things. *International Journal of Interactive Multimedia and Artificial Intelligence*.

Hall, W. and Pesenti, J. (2017). Growing the artificial intelligence industry in the uk. *Department for Digital, Culture, Media & Sport and Department for Business, Energy & Industrial Strategy. Part of the Industrial Strategy UK and the Commonwealth*.

Hassan, N., Gillani, S., Ahmed, E., Yaqoob, I., and Imran, M. (2018). The role of edge computing in internet of things. *IEEE communications magazine*, 56(11):110–115.

Initiative, I. I. et al. (2015). Towards a definition of the internet of things (iot)(revision-1).

Islam, S. R., Kwak, D., Kabir, M. H., Hossain, M., and Kwak, K.-S. (2015). The internet of things for health care: a comprehensive survey. *IEEE access*, 3:678–708.

Javaid, M. and Haleem, A. (2018). Additive manufacturing applications in medical cases: A literature based review. *Alexandria Journal of Medicine*, 54(4):411–422.

Javaid, M. and Haleem, A. (2019). Industry 4.0 applications in medical field: a brief review. *Current Medicine Research and Practice*, 9(3):102–109.

Jecker, N. S., Wightman, A. G., and Diekema, D. S. (2020). Prioritizing frontline workers during the covid-19 pandemic. *The American Journal of Bioethics*, pages 1–5.

Kumar, S. P., Samson, V. R. R., Sai, U. B., Rao, P. M., and Eswar, K. K. (2017). Smart health monitoring system of patient through iot. In *2017 international conference on I-SMAC (IoT in social, mobile, analytics and cloud)(I-SMAC)*, pages 551–556. IEEE.

Kuo, K.-M., Ma, C.-C., and Alexander, J. W. (2014). How do patients respond to violation of their information privacy? *Health Information Management Journal*, 43(2):23–33.

Lampropoulos, G., Siakas, K., and Anastasiadis, T. (2019). Internet of things in the context of industry 4.0: An overview. *International Journal of Entrepreneurial Knowledge*, 7(1):4–19.

Li, Y. and Xia, L. (2020). Coronavirus disease 2019 (covid-19): role of chest ct in diagnosis and management. *American Journal of Roentgenology*, 214(6):1280–1286.

Lin, Y.-J., Chuang, C.-W., Yen, C.-Y., Huang, S.-H., Huang, P.-W., Chen, J.-Y., and Lee, S.-Y. (2019). Artificial intelligence of things wearable system for cardiac disease detection. In *2019 IEEE International Conference on Artificial Intelligence Circuits and Systems (AICAS)*, pages 67–70. IEEE.

Madhav, N., Oppenheim, B., Gallivan, M., Mulembakani, P., Rubin, E., and Wolfe, N. (2017). Pandemics: risks, impacts, and mitigation.

Mohammed, M., Hazairin, N. A., Al-Zubaidi, S., AK, S., Mustapha, S., and Yusuf, E. (2020). Toward a novel design for coronavirus detection and diagnosis system using iot based drone technology. *International Journal of Psychosocial Rehabilitation*, 24(7):2287–2295.

Nazirun, N. N. N., Shakhih, M. F. M., Ren, P. C., Zaini, M. A. A., Nordin, N., Empaling, S., Amran, D. I., and Supriyanto, E. (2017). User acceptance analysis of hospital asset management system. In *2017 International Conference on Robotics, Automation and Sciences (ICORAS)*, pages 1–5. IEEE.

Organization, W. H. et al. (2019). Who guideline: recommendations on digital interventions for health system strengthening: web supplement 2: summary of findings and grade tables. Technical report, World Health Organization.

Organization, W. H. et al. (2020). Covid-19 weekly epidemiological update, 24 november 2020.

Oshitani, H., Kamigaki, T., and Suzuki, A. (2008). Major issues and challenges of influenza pandemic preparedness in developing countries. *Emerging infectious diseases*, 14(6):875.

Pang, Z., Yang, G., Khedri, R., and Zhang, Y.-T. (2018). Introduction to the special section: convergence of automation technology, biomedical engineering, and health informatics toward the healthcare 4.0. *IEEE Reviews in Biomedical Engineering*, 11:249–259.

Pardeshi, V., Sagar, S., Murmurwar, S., and Hage, P. (2017). Health monitoring systems using iot and raspberry pi—a review. In *2017 international conference on innovative mechanisms for industry applications (ICIMIA)*, pages 134–137. IEEE.

Poniszewska-Maranda, A. and Kaczmarek, D. (2015). Selected methods of artificial intelligence for internet of things conception. In *2015 Federated Conference on Computer Science and Information Systems (FedCSIS)*, pages 1343–1348. IEEE.

Qadir, Q. M., Rashid, T. A., Al-Salihi, N. K., Ismael, B., Kist, A. A., and Zhang, Z. (2018). Low power wide area networks: a survey of enabling technologies, applications and interoperability needs. *IEEE Access*, 6:77454–77473.

Raveendran, A. and Jayadevan, R. (2020). Reverse quarantine and covid-19. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, 14(5):1323–1325.

Richardson, P., Griffin, I., Tucker, C., Smith, D., Oechsle, O., Phelan, A., and Stebbing, J. (2020). Baricitinib as potential treatment for 2019-ncov acute respiratory disease. *Lancet (London, England)*, 395(10223):e30.

Rodrigues, J. J., Segundo, D. B. D. R., Junqueira, H. A., Sabino, M. H., Prince, R. M., Al-Muhtadi, J., and De Albuquerque, V. H. C. (2018). Enabling technologies for the internet of health things. *Ieee Access*, 6:13129–13141.

Serrano, M., Dang, H. N., and Nguyen, H. M. Q. (2018). Recent advances on artificial intelligence and internet of things convergence for human-centric applications: internet of things science. In *Proceedings of the 8th International Conference on the Internet of Things*, pages 1–5.

Singh, R. P., Javaid, M., Haleem, A., and Suman, R. (2020). Internet of things (iot) applications to fight against covid-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*.

Tang, Y.-W., Schmitz, J. E., Persing, D. H., and Stratton, C. W. (2020). Laboratory diagnosis of covid-19: current issues and challenges. *Journal of clinical microbiology*, 58(6).

Tanne, J. H. (2020). Covid-19: Fda panel votes to approve pfizer biontech vaccine.

Tarouco, L. M. R., Bertholdo, L. M., Granville, L. Z., Arbiza, L. M. R., Carbone, F., Marotta, M., and De Santanna, J. J. C. (2012). Internet of things in healthcare: Interoperatibility and security issues. In *2012 IEEE international conference on communications (ICC)*, pages 6121–6125. IEEE.

Thayyil, J., Kuniyil, V., and Cherumanalil, J. M. (2020). Covid-19: digital contact tracing technologies and ethical challenges. *International Journal of Community Medicine and Public Health*, 7(7):2854.

Thilakarathne, N. N., Kagita, M. K., Gadekallu, T. R., and Maddikunta, P. K. R. (2020). The adoption of ict powered healthcare technologies towards managing global pandemics. *arXiv preprint arXiv:2009.05716*.

Williams, P. A. and McCauley, V. (2016). Always connected: The security challenges of the healthcare internet of things. In *2016 IEEE 3rd World Forum on Internet of Things (WF-IoT)*, pages 30–35. IEEE.

Zhang, Y., Qiu, M., Tsai, C.-W., Hassan, M. M., and Alamri, A. (2015). Health-cps: Healthcare cyber-physical system assisted by cloud and big data. *IEEE Systems Journal*, 11(1):88–95.

Zhu, X. (2019). Case vi: Children's hospital of shanghai: A pioneer in smart healthcare. In *Emerging Champions in the Digital Economy*, pages 195–210. Springer.