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Artificial Intelligence (AI) powered emergent technologies for COVID-19 screening

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1.1 INTRODUCTION

As the world struggles to get back to normalcy after the outbreak of the deadly virus, COVID-19, new emergent technology has helped the diagnosing the patients of the virus faster than it did a year ago.

AI-based screening using computerized tomography or CT Scans are an alternative emergent technology to using an RT-PCR test to assess a patient's possibility of carrying the virus. CT scans before took a lot of time to produce an image of the subject. And as it is known that carrying the COVID-19 strain also presents pneumonia-like symptoms, the application of AI with CT scan can help with faster evaluation of the scans to distinguish between COVID and other medical issues. (Harmon et al., 2020)

Keywords: artificial intelligence, CT scans, computerized tomography, x-rays, technology assessment, technology speciation, public policy, ethical concerns

1.2 TECHNOLOGY SPECIATION

1.2.1 HISTORY OF AI

The origination of AI dates back to the creation of the 'first mathematical and computer model' of biological neurons by Walter Pitts and Warren McCulloch in 1943. Isaac Asimov had also published his three laws of robotics.

Near World War 2, Alan Turing explored the intelligence of computers and how they work with John Von Neumann. Both are credited with being the introducers of the technology behind AI. These events pushed computer scientists into questioning the boundary between the human and machine.

The word AI was first used at a Dartmouth College conference in 1957 by a computer scientist, John McCarthy. Marvin Minsky, a cognitive scientist was very excited about the possibility of artificial intelligence. (Lewis, 2014) Unfortunately, between the years of 1970s and mid-'90s, there was a shortage of government funding for AI research. The interest in the field had decreased and cooled down as the high expectations of AI were not being met. These two time periods were known as the 'AI Winter'. (Ray, 2018) The 'AI Boom' of the late 1990s and early 2000s was triggered by IBM's Deep Blue computer defeating the world chess champion. After a series of high-profile cases involving artificial intelligence, interest in AI resurfaced in the late 2000s.

Early inventions included the use of the chatbot, ELIZA to solve hard complex problems as well as MYCIN in 1972 which helped doctors diagnose blood diseases and prescribe drugs. They developed two AI systems that analysed human knowledge and provided an output of the best expertise. This was one of the baselines of the implementation of AI in the medical field.

Donald Hebb, a pioneer in the field of neurons, described a rule known as the Hebbian learning which worked upon how neurons work and the first demonstration of the neural network was able to be stimulated but were not successful. This concept was then further developed in the next few years. Convolutional neural networks (CNN) are a subset of this which is used as a machine learning model in image understanding. This concept is further applied in medical image understanding in the form of various forms of technology such as MRI, CT, PET or ultrasound scanning. (Sarvamangala and Kulkarni, 2021)

1.2.2 HISTORY OF CT SCAN

Alessandro Vallebona created the first tomography which could see a single slice of the body, but not carry out soft tissue imaging. X-ray imaging was further developed into a tomogram, a new form of it in 1971 at the hands of a radiologist, James Ambrose and an engineer, Godfrey Hounsfield. The latter is credited as single-handedly developing X-ray technology, through this he caused the development of the computed tomography medical imagining technique or more commonly known as the CT Scan. Hounsfield initially wanted to remake a box in 3D using a set of slices which then caused a progression in the field of EMI research and funding as well as the setup of the first-ever commercially feasible CT Scan in Atkinson's Morley Hospital the same year.

However, this concept of imaging was adopted by Hounsfield from two other scientists. Johann Radon's 'Radon Transform' in 1917 and Stefan Kaczmarz's 'Algebraic Reconstruction Technique'in 1937 which was then used for one of the best technological creations in medicine. (Catalina Imaging, 2019)

1.2.3 APPLICATION OF AI IN CT SCANS

Technology speciation means that the technology will do the same thing in one domain as it may do in another domain, however, the way it is applied will be different and vary in nature. For example, the CT Scan and X-Ray, both have different structures, however come from the same technology and are applied similarly in diagnosing COVID-19 patients through the application of AI.

The merging of AI with CT Scans is a type of technological speciation and it is a type of emergent technology. Emergent technologies are those that are already existing or are a new introduction to a domain. As the world grappled with the worldwide pandemic of COVID-19, there was a need to allow for the diagnosing of patients in a faster and more efficient manner. This is where the application of AI using a deep learning model known as the 'COVID-19' neural network was developed to aid in distinguishing between the COVID-19 virus and a normal case of pneumonia based on the results of the CT Scan.(Arora, Banerjee and Narasu, 2020) Numerous researchers used different types of neural networks to detect COVID-19 from chest CT Scans such as Singh et al. (2020) who developed a deep learning model with the use of multi-objective differential evolution and CNN.

Other countries such as China where the virus first originated from also developed AI-based diagnostic software that can both detect lung cancer and lung-related problems as a result of the coronavirus, this has been applied to over 30 Chinese hospitals where it was used to screen over 30,000 possible cases. (Simonite, 2020)

Application of AI with CT Scans and X rays shows to prove a faster and more efficient way to screen all the covid or suspected covid cases, this can help in reducing the spread by immediately quarantining the patients and possibly reducing the fatalities as a result of the virus. Additionally, advances in both imaging as well as computing have caused the implementation of AI in monitoring and defining diseases.

1.3 EVALUATION

1.3.1 INTELLECTUAL PROPERTY

Firstly, we need to understand the fact that the application needs to have its intellectual property protected. Intellectual property is classified as unquantifiable assets that are in control by the company or a person which contribute to both national and state economies. These include patents, trademarks and copyrights which allows customers to purchase secure and trusted goods. The more the innovative idea, the more possibility it being commercially viable. Some of the AI-based solutions can be protected by keeping them as trade secrets which essentially is done by filing patents. The importance of these IP's is to allow start-ups or small businesses to keep their competitive edge while partnering with bigger companies as well as protecting something originated by them. (Mao and Yap, 2020)

An example of a company protecting their IP is Baidu who have a massive AI portfolio dating back to 2014. This has helped them apply AI-based technologies in medicine to help with battling COVID-19. One of the fields they have used their patents are within the CT Imaging field, with their open-source deep learning platform, PaddlePaddle, they have further confirmed a partnership with LinkingMed to create an open-source AI Model for pneumonia CT image analyses, this has greatly provided benefits to hospitals within the region of China, moreover, it is further supporting clinical research to bring about more advancement across medicine. (Liang, 2020)

During COVID-19, top companies such as Microsoft and IBM allowed free use of their intellectual property (IP) to aid in fighting against the pandemic. This allowed multiple companies to be able to use these IPs to carry out the innovation and development of vaccines, diagnostic tools, software. (Bisarya, 2020) However, on the other side, political affairs fell into the world of intellectual property where certain companies do not want other countries such as Russia to know how to produce vaccines hence do not want to waive off their IP. Additionally, countries that are already ahead in producing vaccines such as the US and UK are resisting waiving off the IPs. (Sachs, 2021) In this deadly time, this is completely immoral and unwarranted and can be the cause of the deaths of millions of innocent civilians just because of political imbalance. Countries such as India, South Africa and Malaysia are in dire need of patented-based technologies to fight covid-19 in their countries and if the IPs are not available to be of use for them then it will make the situation worse.

1.3.2 FINANCIAL OPTIONS

A business can fund itself in a multitude of ways such as personal investment from the owner or other manners such as investments from other companies. In the medical field, the investment for AI in healthcare had reached about $1.3 billion by 2017 across 103 deals. It is predicted that due to the urgent need for AI in healthcare, this number is sure to grow through the years to come. Overall, its seen that when AI is implemented in areas of medical imagining and diagnosis, they receive the most attention from possible investors and therefore more funding. According to CB Insights (2019), 29% of start-ups raised approximately $1.5 billion in funds.

AIDOC, an artificial intelligence company was able to raise about $66 million in funding for keeping on with their development of decision software to help carry out functions such as the examining of CT Scans, detection of abnormalities and instructing the radiologists on the next

step. (Betuel, 2021) Other ways technology such as AI-based CT Scans can be funded is through government funding, this example can be seen by the NIH and National Cancer Institute who funded the study of developing an algorithm, UCF to distinguish influenza from COVID-19 with 84% accuracy in diagnosing positive cases. (McGrail, 2020)

Most of the funding of AI projects is from the government side as they push for innovations, such as during the start of AI Winter, when the government had first drawn funds. Currently, most companies usually will only invest if they can see that they will be benefitted financially. Hence, as in the pandemic, businesses will not be getting the most benefit, companies will invest, but not have a massive interest in it and therefore, in the case of AI-based CT Scan, most of the funding can be attained through the government as they are looking to protect their citizens and get their country back on its feet instead of looking at the financial aspect.

2.1 TECHNOLOGY ASSESSMENT PROCESS

2.1.1 SCOPING

AI-based CT-Scans were used in place of chest x-rays due to better accuracy in establishing the covid-19 patients by showing different types of patterns and features than when x-rays were used. (Alhasan and Hasaneen, 2021) CT-Scans have been used to detect different disorders and internal injuries, tumours, blood clots, heart diseases and cancer. This allows a radiologist to diagnose the problem area. As the cases of COVID-19 rise daily, AI-based technology needs to come into the picture such as the implementation of a CNN to detect COVID-19 (Mbunge et al., 2020). Here data is collected and used to help in diagnosing hundreds of patients with the help of machine learning algorithms which can then be used for future COVID cases as AI's uses old information to help predict new data. CT Scans can also be used to detect COVID-19 symptoms such as the presence of pneumonia through lung imaging analysis. (Buschman, 2020) These technologies will greatly help reduce the burden on the frontline staff due to diagnosing patients at an extremely fast rate as well possibly help prevent burnout to occur in the medical field which may cause improper care (Lim, 2020).

Moreover, these datasets are utilized to find out the classification of the virus and can use it to identify patients. A researcher suggested a system of merging the demographic data along with medical information to swiftly identify patients of coronavirus. (Vafea et al., 2020)

Scoping further looks at the target users where in this case are the radiologists, doctors and medical staff who want to diagnose patients. Moreover, these scans are also helpful in

diagnosing patients who are in the early stages of the virus and who may not show symptoms when tested with other mediums such as a PCR test. This can ensure faster isolation and limiting the spread of the virus which in turn saves thousands of people from succumbing to the disease. The threat which medical professionals may face is cyber-security risks. If there are no proper security protocols in place, medical patients all over the world are at risk of having their private information leaked.

2.1.2 SEARCHING

Searching is where the IT sources that need to be monitored must be looked at. This can include the way the data is being collected, the manner it is collected and the way it is stored; AI application in various technological aspects including CT Scans, Tracking and more have been crucial in tackling COVID-19. As the policy section will be talked about in the next section, we need to mention that having a grasp of certain policies which affect the public and must be in favour of their safety must pass government regulations. Following this, we can refer to certain procedures that should be followed and how they should be arranged. One of the most important things in using AI-based technology is the way the information is used. It must be done ethically with the patient's consent or have their consent to use their data without their personal information. One such example is a study carried out by Chaganti et al. (2020) where they wanted to introduce a technique that instinctively segments and quantifies abnormal CT patterns frequently appearing in COVID-19, specifically “ground-glass opacities and consolidations”. For this, they required datasets and had to approve them from the ethics committee with waived consent. Moreover, searching involves how the emergent technology will be commercially viable. If AI-based CT Scans are to implement in the hospitals for faster COVID-19 screening then it might be a better route to implement it through a “Safety and Health Management System”. These systems allow to test the system and make sure it meets the policies set by the hospitals. Furthermore, it also allows for setting the whole planning process of how this will be done. The commercial viability can also be proved through the various studies that have been carried out to show the benefit of having this technology for COVID-19 screening. (HSA, 2018)

2.1.3 EVALUATING

This phase consists of ensuring that all the searching and scoping of the emergent technology has been done thoroughly and that there is proof to back up the efficiency of future implementation of the technology. AI-based CT Scans have shown better accuracy than

traditional methods and provide a faster way to diagnose patients. The need for it in diagnosis has been touched upon as well as how it is simply a combination of software with a technology. A brief analysis can be done on the possible technology, organizational and marketing risks that may happen during the process of implementing this technology.

2.1.3.1 TECHNOLOGY, MARKETING AND ORGANIZATIONAL RISKS

All three types of risk relate to each other and are responsible for how they can affect the implementation of technology.

In terms of technology risk, this technology is much safer as compared to other methods of diagnosis. They provide a better scan and simultaneously see a reduction in radiation exposure. As this is something that must be used to screen many possible covid patients, the amount of radiation taken in by both the medical staff and patients must be as minimum as possible. (Soomro et al., 2021) For technical feasibility and supply of materials, at most every hospital is sufficiently equipped with CT Scans as it is a staple in every hospital to diagnose certain issues. The implementation of AI software into hospitals must be carried out smoothly and efficiently to ensure there is a minimal risk of security issues and data loss. This is one of the most important things in the safety and health management system. (HSA,2018)

The main marketing risk can be the ability to use certain algorithms without breaking intellectual property rights. Many companies are against the use of free IP hence there could be a possible struggle with trying to use the best available resources unless there is free IP. In poor countries, it is harder to implement this technology as the government cannot afford the cost of importing equipment as well as the cost of training. (Mbunge et al., 2020)

Organizational risks are minimal, however, as this is the software-based application of technology, then there will possibly be retraining costs if the hospital wants the whole process to be carried out internally. Moreover, this type of technology may not cause the loss of jobs of the medical staff, however, one of the things hospitals will possibly be at risk of is having to depend on an external organization when these technologies are initially placed in the hospitals. At the moment, AI-based CT Scans are not available in every hospital, so this technology is still relatively new to certain countries, hence there must be doctors who are already capable. In the future, these considerations can be used in future training for the medical staff.

2.1.4 COMMITTING

It has been confirmed that AI-based CT Scans are as accurate as medical professionals with years of experience. This finding can be employed in other countries and hospitals worldwide to help out the victims of the virus. (Kent, 2020) although there is some hesitancy with the implementation of this technology, it has shown incredible results in fast diagnosis. Moreover, it has been stated that over 30% of the costs come from simple tasks, by applying AI in other areas of the medical sector such as administrative tasks can greatly reduce the workload on health professionals. AI does have its limitations and that is normal with every type of technology that is implemented, AI is software that learns and grows through a continuous process of feeding it data. In the healthcare world, there is a tremendous amount of information that is coming through various channels. AI is shown to be credible in carrying out predictions by taking patients information and other related data. This can further improve other areas of patient care that currently may struggle due to the lack of these important AI-based technologies. (Phaneuf, 2021)

2.2 PUBLIC POLICY

Due to the surge of the pandemic, governments must employ the use of AI in health care to fight against COVID to protect its citizens. At current times, there are not any particular public policies set in place for COVID-19 screening (Mbunge et al., 2020), however, there have been certain things put in place to start the motion towards implementing them. In basic terms, AI greatly relies on the data fed to it and the way the data is handled must be secure, especially in the medical field. Every country in the world has found ways to implement certain measures to handle COVID-19.

OECD, the organization of economic co-operation and development develop and suggest policies to encourage a better lifestyle for the people; they released policy responses on how the use of AI can help in combatting COVID-19. They said that policymakers must also promote communication of medical, molecular, and scientific sets of data and prototypes on collaborative platforms to help AI researchers construct effective methods for the health sector, and they should focus on ensuring that researchers have access to reliable computational resources. (OECD, 2020)

This could be seen in practice by the university of oxford as they developed various AI-based COVID-19 technology which they then uploaded to their GitHub for open access for the public.

This was a very good move as scientists in other countries could have access to these codes and technical specifications and apply it in their technology to provide benefit to their own countries.

In European countries, they have laws and strict rules which have been a sort of barrier to implementing AI in the health sector such as having data protection acts and cyber-security concerns. Moreover, most country's policymakers will always focus on making their policies surrounding security, reliability and transparency of information to ensure that trust can be established in them.

However, as stated since there have not been any set policies in place, most countries worldwide have gone ahead in having certain policies to avoid transmission of the virus with these policies coming under wearing of masks, PPE's, contact tracing, compliance with infection protocol, screening when necessary and more.

Such as the case in South Korea where their mass testing with the application of AI in disease diagnosis where it was able to help them regain some control of the spread of the pandemic in the country where they mass tested over 230,000 people in early March 2020. (Watson et al., 2020) We can see that this specific action was then implemented worldwide with mass testing carried out in every other country to detect as many covid cases as possible and quarantine them to reduce the spread in the safer parts of the country.

In Taiwan, a type of compliance with infection protocol is where they had ordered infected cases to keep their GPS open while they are at home so in case they leave confinement, they will be able to be tracked. This was further developed into an application and assured users that their data will be protected which is the main thing as talked about before when developing public policies.

Malaysia implemented a public policy regarding the distribution of the vaccine starting with the elderly population and immunocompromised people. The same was also noted in other countries, including Saudi Arabia, which started with vaccinating the population above the age of 60. They used an AI-enabled application known as SEHATY and TAWAKALNA allowed citizens to book their appointments for specific vaccines on their chosen dates. (Hassounah, Raheel and Alhefzi, 2020) However, in mid-May, they announced that they want to ensure every citizen in the country gets vaccinated hence stopped providing second doses and moved

towards providing the first dose to every citizen. This was their way to move towards protecting their citizens and ensuring everyone's health comes first.

The University Of Washington in the United States published a paper discussing how they enacted policies and guidelines, in general, to deal with COVID-19. It showed that they only screened patients based on the urgency of whether it was needed or not as well as disinfected everything at all points in time to avoid transmission of the virus. Moreover, the use of any CT scan or X-rays were limited to only need-based to avoid exposure of harmful rays to the nurses, doctors and the patients themselves. (Staiger et al., 2020)

After going over all these cases, we believe that it is important that a government when trying to implement AI-based technology such as CT Scan should put the patient's privacy first and ensure that their data is always protected. Moreover, if any of these types of technologies are being implemented then there should be a benchmark. For example, when AI-based CT Scans were utilized, they were used with a 98.9% accuracy of diagnosing covid-19 using chest CT images. (Mbunge et al., 2020)

3.1 CONCLUSION

In this paper, we went through various sections on what is needed for implementing AI-based CT Scans for the diagnosing of COVID-19. Overall, it has been understood that every government needs to put their citizens as a priority in terms of safety and ethical practices. As a government official, there are still some concerns with this emergent technology as it is still not as widespread in other countries due to factors such as costs and legality issues. In this case, world leaders should come together and find a solution to implement it as soon as possible because COVID-19 is spreading day by day and needs immediate measures to curb the spread and save the lives of millions of people who may succumb to the virus if we are too late.

TOTAL WORDS: >4000 (does not include references and cite-ins)

4.1 REFERENCES

1. Alhasan, M. and Hasaneen, M. (2021). Digital imaging, technologies and artificial intelligence applications during COVID-19 pandemic. *Computerized Medical Imaging and Graphics*, [online] 91, p.101933. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8123377/ [Accessed 18 Jul. 2021].
2. Arora, N., Banerjee, A.K. and Narasu, M.L. (2020). The role of artificial intelligence in tackling COVID-19. *Future Virology*, [online] 15(11), pp.717–724. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7692869/ [Accessed 15 Jul. 2021].
3. Betuel, E. (2021). Aidoc raises over $66M for AI radiology analysis technology. [online] TechCrunch. Available at: https://techcrunch.com/2021/07/14/aidoc-raises-over-66m-for-ai-radiology-analysis-technology/?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJ5tcU4SWSXI4Xwd-Gdj-CXUUvqxLg2IUbZztlwdn-ZR49G8QlLByKHIAJQ1p19KprItNPRyQ_4GVrJuIH1qslsBKWn1nxo1DQyZBqxwBCSRaLegKPPgwj_f-NkXyiUhjvhlkhCsVyo1_P8J2zt-Y3xDMoU_AgPqXbceekpIqE7H [Accessed 16 Jul. 2021].
4. Bisarya, S. (2020). *Significance Of Intellectual Property Rights In Current Era*. [online] Mondaq.com. Available at: https://www.mondaq.com/india/trademark/1020686/significance-of-intellectual-property-rights-in-current-era [Accessed 16 Jul. 2021].
5. Buschman, H. (2020). *Artificial Intelligence Enables Rapid COVID-19 Lung Imaging Analysis at UC San Diego Health*. [online] UC Health - UC San Diego. Available at: https://health.ucsd.edu/news/releases/Pages/2020-04-07-artificial-intelligence-enables-rapid-covid-19-lung-imaging-analysis.aspx [Accessed 18 Jul. 2021].
6. Catalina Imaging (2019). *History of the CT Scan | Catalina Imaging*. [online] Mobile CT Rental - Mobile Imaging Rental And Lease. Available at: https://catalinaimaging.com/history-ct-scan/ [Accessed 15 Jul. 2021].
7. CB Insights (2019). From Drug R&D To Diagnostics: 90+ Artificial Intelligence Startups In Healthcare. [online] CB Insights Research. Available at: https://www.cbinsights.com/research/artificial-intelligence-startups-healthcare/ [Accessed 15 Jul. 2021].
8. Chaganti, S., Grenier, P., Balachandran, A., Chabin, G., Cohen, S., Flohr, T., Georgescu, B., Grbic, S., Liu, S., Mellot, F., Murray, N., Nicolaou, S., Parker, W., Re, T., Sanelli, P.,

Sauter, A., Xu, Z., Yoo, Y., Ziebandt, V. and Comaniciu, D., 2020. Automated Quantification of CT Patterns Associated with COVID-19 from Chest CT. *Radiology: Artificial Intelligence*, [online] 2(4), p.e200048. Available at: <https://pubs.rsna.org/doi/full/10.1148/ryai.2020200048> [Accessed 20 July 2021].

9. Hassounah, M., Raheel, H. and Alhefzi, M. (2020). Digital Response During the COVID-19 Pandemic in Saudi Arabia. *Journal of Medical Internet Research*, [online] 22(9), p.e19338. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7473704/ [Accessed 23 Jul. 2021].
10. Harmon, S.A., Sanford, T.H., Xu, S., Turkbey, E.B., Roth, H., Xu, Z., Yang, D., Myronenko, A., Anderson, V., Amalou, A., Blain, M., Kassin, M., Long, D., Varble, N., Walker, S.M., Bagci, U., Ierardi, A.M., Stellato, E., Plensich, G.G. and Franceschelli, G. (2020). Artificial intelligence for the detection of COVID-19 pneumonia on chest CT using multinational datasets. *Nature Communications*, [online] 11(1). Available at: https://www.nature.com/articles/s41467-020-17971-2 [Accessed 14 Jul. 2021].
11. HSA (2018). *Safety and Health Managment*. [online] Health and Safety Authority. Available at: https://www.hsa.ie/eng/Topics/Managing_Health_and_Safety/Safety_and_Health_Management_Systems/ [Accessed 20 Jul. 2021].
12. Kent, J. (2020). *Artificial Intelligence Tool Identifies COVID-19 in CT Scans*. [online] HealthITAnalytics. Available at: https://healthitanalytics.com/news/artificial-intelligence-tool-identifies-covid-19-in-ct-scans [Accessed 18 Jul. 2021].
13. Lewis, T. (2014). *A Brief History of Artificial Intelligence*. [online] livescience.com. Available at: https://www.livescience.com/49007-history-of-artificial-intelligence.html [Accessed 15 Jul. 2021].
14. Liang, V. (2020). *Baidu's AI-related Patented Technologies: Doing Battle with COVID-19*. [online] Wipo.int. Available at: https://www.wipo.int/wipo_magazine/en/2020/02/article_0003.html [Accessed 16 Jul. 2021].
15. Lim, M.Y. (2020). *Prevalence of burnout syndrome and its associated factors among doctors in Sabah, Malaysia*. [online] Psychology, Health & Medicine. Available at: https://www.tandfonline.com/doi/abs/10.1080/13548506.2021.1891265 [Accessed 18 Jul. 2021].

16. Mao, X.H. and Yap, D. (2020). *Covid-19 shows promise of AI tools – innovators need IP protection, and fast | IAM*. [online] Iam-media.com. Available at: https://www.iam-media.com/market-developments/covid-19-shows-promise-of-ai-tools-innovators-need-ip-protection-and-fast [Accessed 16 Jul. 2021].
17. Mbunge, E., Akinnuwesi, B., Fashoto, S.G., Metfula, A.S. and Mashwama, P. (2020). A critical review of emerging technologies for tackling COVID -19 pandemic. *Human Behavior and Emerging Technologies*, [online] 3(1), pp.25–39. Available at: https://onlinelibrary.wiley.com/doi/full/10.1002/hbe2.237 [Accessed 17 Jul. 2021].
18. McGrail, S. (2020). *AI-Based CT Scans Can Distinguish COVID-19 Cases from Influenza*. [online] HITInfrastructure. Available at: https://hitinfrastructure.com/news/ai-based-ct-scans-can-distinguish-covid-19-cases-from-influenza [Accessed 16 Jul. 2021].
19. OECD. (2020). *Using artificial intelligence to help combat COVID-19*. [online] Available at: https://www.oecd.org/coronavirus/policy-responses/using-artificial-intelligence-to-help-combat-covid-19-ae4c5c21/ [Accessed 17 Jul. 2021].
20. Phaneuf, A. (2021). *AI in Healthcare in 2021: Medical Benefits & Examples*. [online] Business Insider. Available at: https://www.businessinsider.com/artificial-intelligence-healthcare [Accessed 18 Jul. 2021].
21. Ray, S. (2018). *History of AI - Towards Data Science*. [online] Medium. Available at: https://towardsdatascience.com/history-of-ai-484a86fc16ef [Accessed 15 Jul. 2021].
22. Sachs, J.D. (2021). *Share the intellectual property on Covid-19*. [online] Theasset.com. Available at: https://theasset.com/article-esg/43504/share-the-intellectual-property-on-covid-19 [Accessed 16 Jul. 2021].
23. Sarvamangala, D.R. and Kulkarni, R.V. (2021). Convolutional neural networks in medical image understanding: a survey. *Evolutionary Intelligence*. [online] Available at: https://link.springer.com/article/10.1007/s12065-020-00540-3 [Accessed 15 Jul. 2021].
24. Simonite, T. (2020). *Chinese Hospitals Deploy AI to Help Diagnose Covid-19*. [online] Wired. Available at: https://www.wired.com/story/chinese-hospitals-deploy-ai-help-diagnose-covid-19/ [Accessed 15 Jul. 2021].
25. Singh, D., Kumar, V., Vaishali and Kaur, M. (2020). Classification of COVID-19 patients from chest CT images using multi-objective differential evolution–based convolutional neural networks. *European Journal of Clinical Microbiology & Infectious Diseases*, [online] 39(7), pp.1379–1389. Available at: https://pubmed.ncbi.nlm.nih.gov/32337662/ [Accessed 15 Jul. 2021].

26. Soomro, T.A., Zheng, L., Afifi, A.J., Ali, A., Yin, M. and Gao, J. (2021). Artificial intelligence (AI) for medical imaging to combat coronavirus disease (COVID-19): a detailed review with direction for future research. *Artificial Intelligence Review*. [online] Available at: https://link.springer.com/article/10.1007/s10462-021-09985-z [Accessed 19 Jul. 2021].
27. Staiger, T., Medverd, J., Linnau, K., Lynch, J., Wener, M., Kicska, G., Sahani, D. and Mossa-Basha, M., 2020. Policies and Guidelines for COVID-19 Preparedness: Experiences from the University of Washington. *Radiology*, 296(2), pp.E26-E31.
28. Vafea, M.T., Atalla, E., Georgakas, J., Shehadeh, F., Mylona, E.K., Kalligeros, M. and Mylonakis, E. (2020). Emerging Technologies for Use in the Study, Diagnosis, and Treatment of Patients with COVID-19. *Cellular and Molecular Bioengineering*, [online] 13(4), pp.249–257. Available at: https://link.springer.com/article/10.1007/s12195-020-00629-w [Accessed 18 Jul. 2021].
29. Watson, I., Jeong, S., Booth, T. and Hollingsworth, J. (2020). *Inside the company that used AI to create a coronavirus test*. [online] CNN. Available at: https://edition.cnn.com/2020/03/12/asia/coronavirus-south-korea-testing-intl-hnk/index.html [Accessed 17 Jul. 2021].