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Artificial Intelligence to fight COVID-19 outbreak impact: an overview

Davide Calandra[1] and Matteo Favareto[1]

[1] Department of Management, University of Turin, Turin, Italy

Corresponding author: Matteo Favareto – matteo.favareto@unito.it

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Abstract

Artificial Intelligence (AI) is showing its strength worldwide in the healthcare sector. Today, in the aftermath of the COVID-19 pandemic, the help of technology appears to be relevant to keep the increase in new infections stable and help medical staff in treatment. Therefore, this paper aims to investigate how AI can be employed against COVID-19 outbreak. Using a multiple case study approach, researchers find out the following insights. First, AI could be used for drugs discovery and knowledge sharing, tracking and prediction, clinical decision making and diagnosis, social distancing and medical chatbots. Second, this paper provides an in-depth analysis of international best practice for tracking contacts and social distance applications. Third, AI technologies could have a transversal impact, also focusing on prevention strategies as a new corporate social responsibility vein. In the end, this paper has theoretical and managerial implications, too. On the theoretical side, we contribute to the extensive discussion about AI and healthcare considering COVID-19 outbreak. On the practical side, we provide medical personnel and policymakers with a tool to understand artificial intelligence and focus investment choices in the practical applications analysed.

Keywords: Artificial intelligence; AI applications; COVID-19; Coronavirus; Health impact; Prevention strategies

1. Introduction

The novel coronavirus disease (COVID-19) has created tremendous chaos around the world, affecting people's lives and causing many deaths. The first cases were detected in Wuhan, China, in December 2019, and now it has been spread to almost every country (Nguyen, 2020). With this growing crisis, companies and researchers over the world are looking for the ways to address the challenges of this virus considering companies and health issue, to mitigate the spread and develop a cure for this disease (Secinaro et al., 2020). In this baffling battle, science, and Artificial Intelligence (AI) technologies are playing a vital role (Kumar et al., 2020).

AI commonly refers to the computational technologies that mimic or simulate processes supported with human intelligence, for instance, reasoning, deep learning, adaptation, interaction, and sensory understanding (Tran et al., 2019). These are technologies that can perform a task that usually requires human perception and judgement (Hamid, 2016). These techniques have an interdisciplinary approach and can be applied to different fields, such as medicine and health. AI has been used in the field of medicine since as early as the 1950s when physicians made the first attempts to improve their diagnoses using computer-aided programs (Frankish & Ramsey, 2014).

The interest and advances in medical AI applications have surged in recent years, thanks to the substantially enhanced computing power of modern computers and the vast amount of digital data now available for collection and utilisation (Tran et al., 2019). AI is gradually changing medical practice. There are several applications of AI in medicine, and they can be used in a variety of medical fields such as: clinical, diagnostical, rehabilitative, surgical and predictive (Jiang et al., 2017; Hamid, 2016). As suggested by Shi et al. (2020), AI could play an essential role in COVID-19 increasing efficiency during working activities and for disease diagnosis, tracking contacts and prognosis. Despite the importance of this field, no studies reviews and discusses the role of AI in tracking services. Therefore, this paper aims to investigate how AI can be employed against COVID-19 outbreak, answering to the following questions: What are companies and labs, around the world, doing to fight COVID-19 outbreak? What could be the central role of AI against COVID-19?

To answer these challenging questions, researchers use a multiple case study theoretical and practical approach to developing the topic. We present the main fields where AI is currently being used and some organisations that are involved in those areas of research.

Finally, the paper is organised as follows. Section 2 will assess an in-depth literature review on the role of AI against COVID-19 outbreak. Section 3 elaborates on the methodology. Section 4 presents the main results obtained. Finally, section 5 will discuss and conclude the paper with future implication for research.

2. Literature review

2.1 COVID-19 and the need for AI technologies to support the research

Naudé (2020); Vaishya et al. (2020); Yassine & Shan (2020) proposed studies in which they analysed how AI technologies can be used in the fight against COVID-19 outbreak. As stated by Yassine & Shan (2020), artificial intelligence is one of the means or avenues to understand the virus and develop preventative and control measures. It includes but is not limited to the usage of mathematical modelling to understand virus transmission, structural biology to determine virus structure and develop vaccines, computational biology to understand virus evolution, as well as docking studies to screen for drugs and inhibitors. AI has the potential to help in all the stages of healthcare, from syndromic surveillance through to rapid diagnosis tests, and faster drug development (Naudé, 2020; Vaishya et al., 2020; Yassine & Shan 2020).

According to Kumar et al. (2020), AI technologies are fundamental tools for tracking and monitoring COVID-19 spread around the world. These technologies are helping in diagnosing the virus and in processing the healthcare claims. Tracking the spread of COVID-19 can be a piece of essential information for public health authorities to design, plan, and deal with the pandemic (Kumar et al., 2020). As stated by Lalmuanawma et al. (2020), contact tracing is a crucial aspect to prevent a wider spread of COVID-19. The process of contact tracing is to identify and manage people who are recently exposed to an infected COVID-19 patient to avoid further spread. In this regard, various infected countries come up with a digital contact tracing process with the mobile application, utilising different technologies. All these digital apps are designed to collect individual personal data, which will be analysed by AI tools to trace a person who is vulnerable to the novel virus due to their recent contacted chain (Lalmuanawma et al., 2020).

Pham et al. (2020); Bragazzi et al. (2020) dealt with how big data and artificial intelligence can help better manage the COVID-19 pandemic. Thanks to the latest advancements in the field of computational techniques and information and communication technologies (ICTs), artificial intelligence and big data

can help handle the vast, unprecedented amount of data derived from public health surveillance, real-time epidemic outbreaks monitoring, trend now-casting/forecasting, regular situation briefing and updating from governmental institutions and organisms, and health resources utilisation information (Bragazzi et al., 2020). According to Pham et al. (2020) in the context of COVID-19, big data refers to the patient care data such as physician notes, X-Ray reports, case history, list of doctors and nurses, and information of outbreak areas. Same authors stated that big data potentially provide several promising solutions to help combat COVID-19 epidemic. By combining with AI analytics, big data help to understand the COVID-19 in terms of outbreak tracking, virus structure, disease treatment, and vaccine manufacturing.

Divya et al. (2018); Ahuja et al. (2020) analysed another relevant topic linked with AI and COVID-19: AI-powered chatbots and virtual health assistants. While AI may assist in the discovery of novel drugs and vaccines, it can also help ease the stress placed on medical hotlines. Call centres nationwide that are dealing with the COVID-19 pandemic are notoriously understaffed. Artificial intelligence has the potential to revolutionise public communications and deliver alternative methods to dissipate public information. AI-powered chatbots have been used with success in clinical scenarios and can advise many more people than a staffed call centre. In conclusion, AI-powered chatbots and virtual health assistants are fostering social distancing and streamlining the entire clinical process (Divya et al. 2018; Ahuja et al., 2020).

According to Mahomed (2020); Sun & Zhai (2020); Nguyen et al. (2020), AI can be used to control social distancing. As stated by Sun & Zhai (2020); Mahomed (2020), social distancing avoids direct contacts among people and reduces the potential cross-transmission of virus-carrying droplets from human respiration. By Nguyen et al. (2020) AI technologies play a crucial role in social distancing control. For instance, they allow public place monitoring and can detect, recognise, and identify whether people comply with social distancing requirements or not.

Zhavoronkov et al. (2020); Mohanty et al. (2020) dealt with the topic of AI applications to find out new drugs and treatments. AI can be used to initiate drug discovery and fast-track drug development. These technologies have the potential to improve the drug discovery, planning, treatment, and reported outcomes of the COVID-19 patient, being evidence-based medical tools. According to Mohanty et al. (2020), AI can help, as well, in drug repurposing process. Drug "repurposing" refers to the use of existing approved drugs for the treatment of a never-considered therapeutic indication, in this case, COVID-19. The AI-

based drug repurposing is a cheaper, faster, and practical approach and can minimise the failures in clinical trials (Mohanty et al., 2020; Xue et al., 2018).

Table 1 below shows the list of related work includes in the literature review section.

Table 1. List of related work

References	Field
• Naudé (2020); Vaishya et al. (2020); Yassine & Shan (2020)	AI applications in the fight against COVID-19
• Kumar et al. (2020); Lalmuanawma et al. (2020)	AI technologies for monitoring and tracking COVID-19 spread
• Pham et al. (2020); Bragazzi et al. (2020)	AI and Big data for COVID-19 fighting
• Divya et al. (2018); Ahuja et al. (2020)	AI-powered chatbots and virtual health assistants to manage medical call centers and ease public tension
• Mahomed (2020); Sun & Zhai (2020); Nguyen et al. (2020)	AI for social distancing control
• Zhavoronkov et al. (2020); Mohanty et al. (2020)	AI for drugs discovery or repurposing against COVID-19

Source: Authors' elaboration

3. Methodology

To implement the analysis, we employed a case study approach to investigate AI applications against COVID-19 (McCutcheon & Meredith, 1993). For each topic under discussion will be described theoretical items and then practical examples of companies that are currently involved in coronavirus fight.

Because of the virus and the crucial role of AI, nowadays scientific community and companies are focusing more and more on the topic. There are so many firms and labs that are studying the virus evolution to find out a remedy. For this reason, it would have been difficult to describe all of them. For the best of our knowledge, we chose only some companies, and we described strategies and contribution to fight back against COVID-19 spread.

As stated before, we decided to employ a case study approach. According to Yin (2014), case studies can be defined as qualitative research methods that support researchers when "a how or why the question is being asked about a contemporary set of events over which the investigator has little or no control". Besides, qualitative methodologies can usually be better understood by practitioners in leading to managerial practices (Dal Mas et al., 2019), helping to bridge the gap between academia and practice

(Massaro et al., 2018). Additionally, according to Crowe et al. (2011), the collective case study involves studying multiple cases simultaneously or sequentially in an attempt to generate a still broader appreciation of a particular issue.

As suggested by Granello & Wheaton (2004), to collect data, we used different types of online sources:

(1) corporate document and materials;

(2) scientific papers published in peer-review journals;

(3) YouTube interview of the founders;

(4) newspaper articles.

To answer the research questions of this paper, the authors use some study's limitation. Furthermore, all the sources extracted should:

- deal with AI in healthcare;
- link with COVID-19 pandemic topic;
- describe theoretical and practical outputs in terms of COVID-19 response.

Besides, we searched for papers that use a case study methodology to develop the analysis.

Using the criteria mentioned above, we used Scopus and Google Scholar as databases. Thus, the first one is a broad scope database essential for peer-reviewed and conference proceedings analysis (Mongeon & Paul-Hus, 2016). Finally, Google Scholar is an international open-access database that collects information on academic sources in different fields (Falagas et al., 2007).

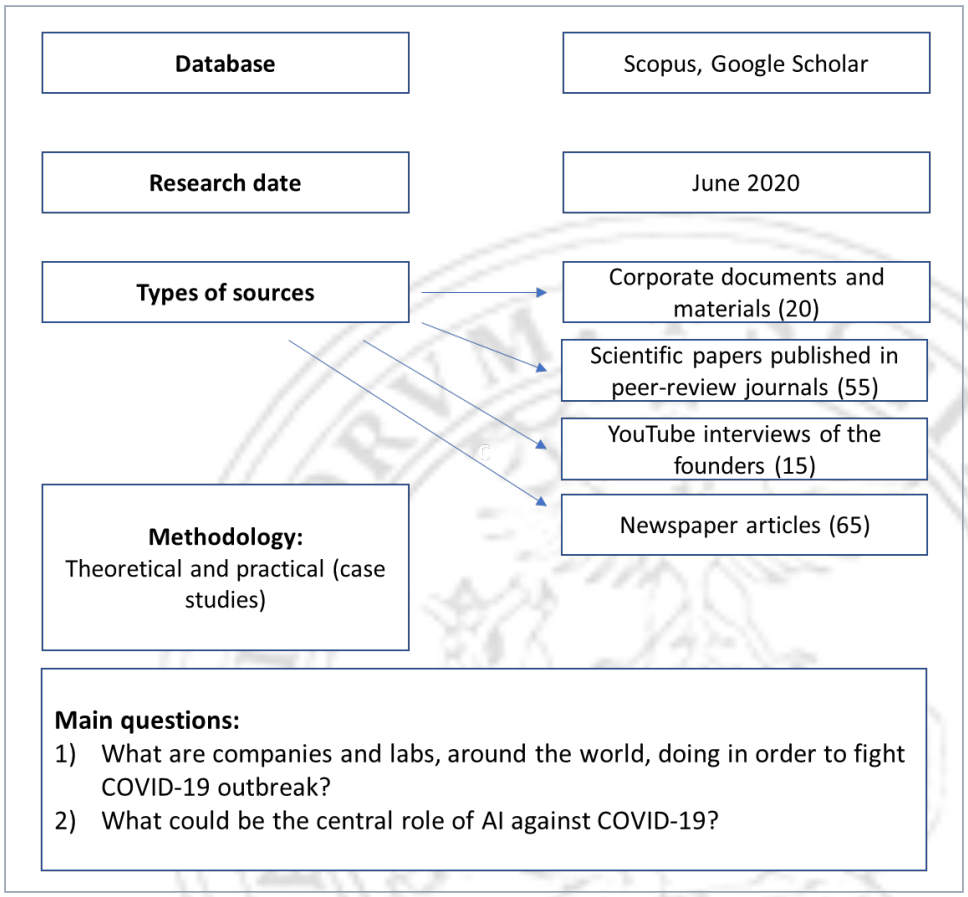
The analysis was implemented using as keywords "*Artificial Intelligence*" and "*COVID-19*" or "*Coronavirus*" and following the objective of the article. Among the search criteria, we focused on English items that were inherent to the searched object.

Overall we got 155 documents divided as follows.

To describe companies' projects, we consulted 20 corporate documents published on companies' official websites. We analysed 55 scientific papers published in peer-review journals, and we watched 15 YouTube interviews of the companies' founders to understand, in a better way, the documents we got and obtaining updates on the topic. Besides, we referred, also, to 65 newspaper articles published by international journals, in different countries, and dealing with the specific topic we analysed.

Figure 1 below shows the methodology used to carry out the analysis.

Figure 1. Characteristics of the analysis



Source: Authors' elaboration

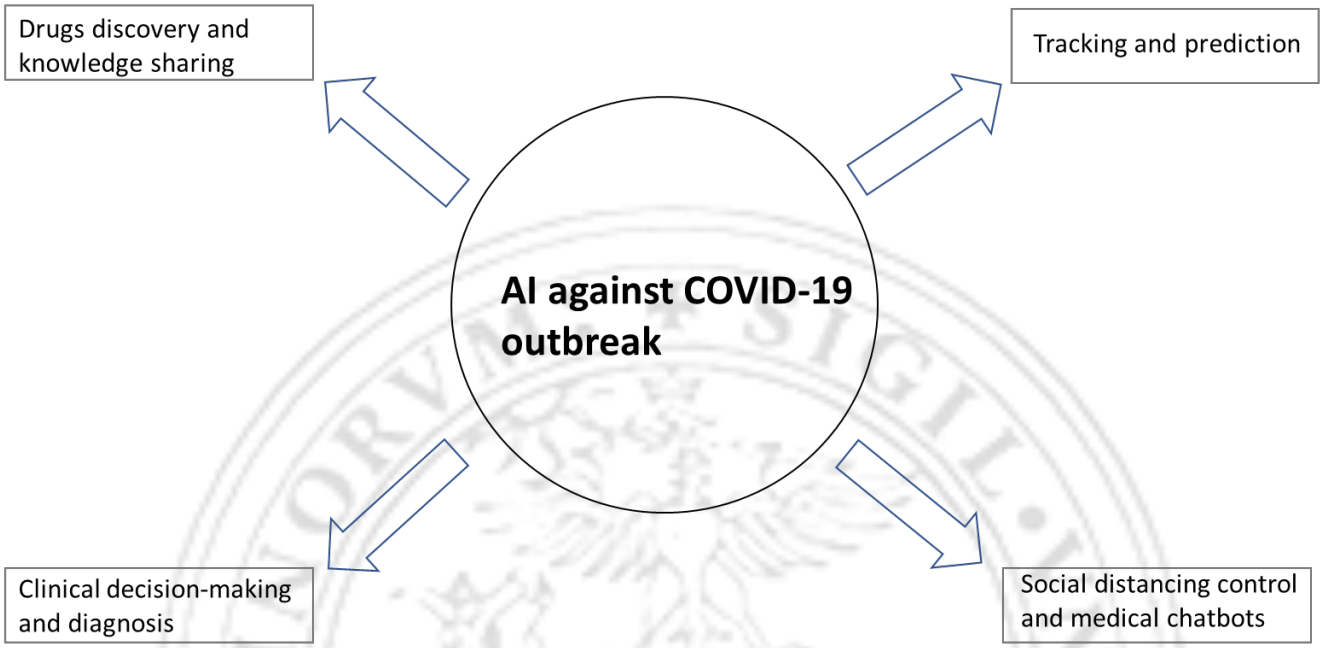
4. Results and Discussion

AI tools and technologies can be employed to support efforts of policy-makers, the medical community, and society at large to manage every stage of the crisis and its aftermath: detection, prevention, response, recovery and to accelerate research (OECD; Naudé, 2020).

There are different areas where AI technologies can contribute to the fight against COVID-19 (Naudé, 2020; Vaishya et al., 2020; Yassine & Shan, 2020): drugs discovery and knowledge sharing (1), tracking and prediction (2), clinical decision-making and diagnosis (3), social distancing control and medical chatbots (4).

Figure 2 shows dominant variables that have been analysed for AI against COVID-19 outbreak.

Figure 2. Dominant variables for AI against COVID-19 outbreak



Source: Authors' elaboration

4.1 AI for drugs discovery and knowledge sharing: the DeepMind and Insilico Medicine case studies

The first application of AI to fight the coronavirus is certainly assistance to researchers to develop drugs and treatments to contain the pandemic.

Even long before the COVID-19 outbreak, AI was used for its potential to contribute to new drugs discovery (Naudé, 2020). AI technology is used in speeding up drug testing in real-time, where standard testing takes plenty of time and hence helps to accelerate this process significantly, which may not be possible by a human (Vaishya et al., 2020).

In the case of COVID-19, several research labs and data centres have already indicated that they are recruiting AI to search for treatments for a vaccine against COVID-19 (Naudé, 2020).

According to Ledford (2020) "It is likely to be one of the biggest drug-making challenges the world has ever faced". Several companies are currently involved in this big challenge, and AI technology certainly can help to understand the virus and to accelerate medical research on drugs and treatments.

This case could consider Google's DeepMind with the AI-based model AlphaFold. AlphaFold system can release structure predictions of several under-studied proteins associated with SARS-CoV-2, the virus that causes COVID-19. DeepMind has used AI to predict the structure of the proteins of the virus information that could be useful in developing new drugs (Naudé, 2020).

US company Insilico Medicine represents another example. It is a biotechnology company that was able to use its integrated AI-based drug discovery pipeline to generate new drug compounds against COVID-19. The results revealed a novel method of developing new treatments against COVID-19 while also demonstrating cost-effectiveness and time efficiency (Zhavoronkov, 2020; Mahomed, 2020). Through the use of AI technology, the company was able to categorise thousands of molecules for potential medications in only four days, and these data were then made available for free to researchers (Mahomed, 2020).

Also, AI techniques can support physicians to analyse the thousands of research papers published around the world on the pandemic. Many promising initiatives, however, have been started to gather and share data and to train new AI models. These include the World Health Organization's (WHO) Global Research on Coronavirus Disease Database, which also provides links to other similar initiatives. One of these is the open-access data of the GISAID Initiative. Amongst other initiatives, perhaps the most ambitious is the joint initiative between Semantic Scholar, the Allen Institute for Artificial Intelligence, Microsoft, Facebook, and others, to make openly available the COVID- 19 Open Research Dataset (CORD-19) which contains around 44.000 scholarly articles for data mining (Naudé, 2020).

4.2 AI as an observer and predictor of the evolution of the pandemic: the BlueDot case study

With the help of real-time data analysis, AI can provide updated information which is helpful in the prevention of this disease. It can be used to predict the probable sites of infection, the influx of the virus, need for beds and healthcare professionals during this crisis (Vaishya et al., 2020).

In this sector, the contribution of the Canadian company BlueDot has already become remarkable. It is a global AI database company which uses outbreak risk software, combined their health and medical expertise with advanced data analytics to build solutions that track, contextualise and anticipate infectious disease risks (Mahomed, 2020). BlueDot predicted the outbreak of the infection at the end of 2019, issuing

a warning to its clients on 31st of December 2019, before the World Health Organization did so on 9th of January 2020 (Naudé, 2020; Kreuzhuber, 2020).

BlueDot uses an AI-driven algorithm that scours foreign-language news reports, animal and plant disease networks, and official proclamations to give its clients warning to avoid danger zones. BlueDot's reports are then sent to public health officials in a dozen countries, airlines, and frontline hospitals where infected patients might end up.

BlueDot's "Global Early Warning System" combines more than a hundred datasets with proprietary machine learning and Natural Processing Language algorithms in 16 languages, providing an automated surveillance platform that can analyse risks of the virus spread.

Also, according to the information reported on the Council of Europe website, several COVID-19 apps allow tracking and prediction of the virus spread around the world (table 2). For each country is reported: name of the application (1), main functionality (2) and the origin (3). Data are updated on the 10th of June 2020.

Table 2. Overview of COVID-19 apps

Country	**Name of the application**	**Main functionality**	**Origin**
Argentina	Covid-19 Ministerio de Salud	Self-diagnostic	Governmental
Australia	Coronavirus Australia	Quarantine enforcement	Governmental
Australia	CORONAlert	Alerting	Governmental
Australia	COVIDSafe	Contact tracing	Governmental
Austria	StoppCorona	Contact tracing	Governmental
Bahrain	BeAware Bahrain	Quarantine enforcement	Governmental
Brazil	Coronavírus - SUS	Information	Governmental
Brazil	The Spread Project	Contact tracing	Private
Bulgaria	ViruSafe	Contact tracing	Governmental
Canada	Canada Covid-19	Self-diagnostic	Governmental
Canada	Covid Shield	Contact tracing	Private
Canada	Covi	Contact tracing	Private
Chile	CoronApp	Self-diagnostic	Governmental
China	Alipay Health Code	Contact tracing	Private
Colombia	CoronApp - Colombia	Medical reporting	Governmental
Czech Republic	eRouška	Contact tracing	Governmental
Denmark	Smittestopp	Contact tracing	Governmental

Finland	Ketju	Contact tracing	Private
France	StopCovid	Contact tracing	Governmental
France	uTakeCare	Contact tracing	Multistakeholder
France	Alertanoo	Contact tracing	Private
Georgia	Stop Covid	Contact tracing	Governmental
Germany	Coronika	Contact tracing	Private
Germany	Our Health In Our Hands (OHIOH)	Contact tracing	Multistakeholder
Germany	Ito	Contact tracing	Multistakeholder
Ghana	GH COVID-19 Tracker App	NA	Governmental
Greece	DOCANDU Covid Checker	Self-diagnostic	Multistakeholder
Hong Kong	Stay Home Safe	Quarantine enforcement	Governmental
Hungary	VirusRadar	Contact tracing	Governmental
Iceland	Rakning C-19	Contact tracing	Governmental
India	Test Yourself Goa	Self-diagnostic	Governmental
India	Corona Watch	Contact tracing	Governmental
India	Quarantine Watch	Quarantine enforcement	Governmental
India	Mahakavach	Contact tracing	Governmental
India	Test Yourself Puducherry	Self-diagnostic	Governmental
India	COVA Punjab	Contact tracing	Governmental
India	Aarogya Setu	Contact tracing	Governmental
India	COVID-19 Feedback	Medical reporting	Governmental
India	COVID-19 Quarantine Monitor	Contact tracing	Governmental
India	GoK Direct - Kerala	Not Covid-19 specific app	Governmental
India	Trackcovid-19.org	Self-diagnostic	Private
Indonesia	PeduliLindungi	Contact tracing	Governmental
Iran	NA	NA	Governmental
Israel	Hamagen	Contact tracing	Governmental
Italy	allertaLOM	Medical reporting	Governmental
Italy	diAry “Digital Arianna”	Contact tracing	Private
Italy	Immuni	Contact tracing	Private
Italy	Rintraccia dei contatti	Contact Tracing	Private
Italy	SM-COVID-19	Contact Tracing	Private
Italy	CovidApp - Covid Community Alert	Contact Tracing	Private
Jordan	AMAN	Contact Tracing	Governmental
Kuwait	Shlonik	Self-diagnostic	Governmental
Latvia	Apturi Covid	Contact Tracing	Governmental

Malaysia	Gerak Malaysia	Contact Tracing	Governmental
Malaysia	MySejahtera	Information	Governmental
Malaysia	MyTrace	Contact tracing	Governmental
Morocco	Wiqaytna	Contact tracing	Governmental
Mexico	Plan Jalisco Covid-19	Contact tracing	Governmental
Mexico	COVID-19MX	Self-diagnostic	Governmental
Netherlands	PrivateTracer	Contact Tracing	Private
North Macedonia	StopKorona!	Contact tracing	Governmental
Norway	Smittestopp	Contact tracing	Governmental
Poland	Kwarantanna domowa	Quarantine enforcement	Governmental
Poland	ProteGO	Contact tracing	Multistakeholder
Qatar	COVI	Information	Private
Republic of Angola	Covid-19 AO	Quarantine enforcement	Private
Russia	Social Monitoring	Contact tracing	Private
Saudi Arabia	Tawakkalna (Covid-19 KSA)	Quarantine enforcement	Governmental
Singapore	TraceTogether	Contact tracing	Governmental
Singapore	SafeEntry	Contact tracing	Governmental
South Africa	Covi-ID	Contact tracing	Governmental
South Korea	Self-Isolator Safety Protection	Quarantine enforcement	Governmental
South Korea	Mobile self-diagnosis	Self-diagnostic	Governmental
South Korea	Self Quarantine App	Quarantine enforcement	Governmental
Spain	STOP COVID19 CAT	Information	Governmental
Spain	COVID-19.eus	Contact tracing	Governmental
Spain	CoronaMadrid	Medical reporting	Governmental
Sri Lanka	Self Shield	Quarantine enforcement	Governmental
Switzerland	Alertswiss	Not Covid-19 specific app	Governmental
Switzerland	SwissCovid	Contact tracing	Multistakeholder
Thailand	MorChana	Contact tracing	Governmental
Turkey	Korona Önlem	Self-diagnostic	Governmental
Ukraine	Action	Not Covid-19 specific app	Governmental
United Arab Emirates	Tawakkalna (Covid-19 KSA)	Quarantine enforcement	Governmental
United Kingdom	COVID Symptom Study	Medical reporting	Private
United Kingdom	NHS App	Contact tracing	Governmental
United States	Coalition App	Contact tracing	Private
United States	COVID-19 Apple App	Information	Multistakeholder

United States	CovidSafe	Contact tracing	Multistakeholder
United States	How We Feel	Self-diagnostic	Private
United States	Private Kit: Safe Paths	Contact tracing	Private
United States	Covid Watch	Contact tracing	Private
United States	NOVID	Contact tracing	Private
United States	coEpi	Medical reporting	Private
Uruguay	Coronavirus UY	Self-diagnostic	Governmental
Vietnam	COVID-19	Self-diagnostic	Governmental

Source: Authors' elaboration on Council of Europe data

4.3 AI to support physicians in clinical decision-making and diagnosis: the Infervision and Alibaba case studies

Due to a sudden and massive increase in the numbers of patients during COVID-19 pandemic, healthcare professionals have a very high workload. Here, AI is used to reduce the workload of healthcare workers. It helps in early diagnosis and providing treatment at an early stage using digital approaches and decision science (Vaishya et al., 2020).

AI applications can support doctors and medical researchers in the clinical decision-making process. According to Jiang et al. (2017), AI can assist physicians in making better clinical decisions or even replacing human judgement in specific functional areas of healthcare.

For instance, Infervision, a Chinese high-tech enterprise in artificial medical intelligence, created an AI software that flags possible lung problems on Computed Tomography (CT) scans, using hundreds of thousands of lung images collected from major Chinese hospitals. Originally used to diagnose lung cancer, the software is also capable of detecting pneumonia associated with respiratory diseases such as coronavirus. This AI-based technology allows a better understanding of coronavirus cases and makes the process quicker. It represents good support for physicians in their clinical decision-making process.

Another example is the Alibaba DAMO Academy that is dedicated to exploring the unknown through scientific and technological research and innovation. The technology, developed by Alibaba DAMO Academy and Alibaba Cloud, can analyse CT images within 20 seconds for diagnosing suspected novel coronavirus cases with an accuracy rate of 96 per cent. Doctors usually spend around 5 to 10 minutes diagnosing CT images of a patient. The AI diagnosis system can ease the already strained hospital resources (Pham et al., 2020).

Finally, robots can be used to support medical professionals in their daily routine; for example, in China, robots that are typically used in the catering industry are used to clean, sterilise, and deliver food and medicines to reduce human contact. The use of AI technologies should not attempt to replace healthcare professionals entirely but rather assist in improving and fast-track diagnosis while alleviating bottlenecks in the healthcare system (Mahomed, 2020).

4.4 AI to control social distancing and medical chatbots: the Microsoft Healthcare Bot case study

One of the biggest challenges of implementing a defence mechanism against a pandemic is to ensure public participation and acceptance of any mechanism proposed by the authority (Young, 2013). Physical distancing from one another is a critical part of ensuring that the virus does not spread.

AI has been argued to be necessary to manage the pandemic by using thermal imaging to scan public spaces for people potentially infected, and by enforcing social distancing and lockdown measures (Rivas, 2020). For example, China's sophisticated surveillance technology uses facial recognition and body temperature to identify whether an individual has a fever and therefore, could be a carrier of the virus (Mahomed, 2020).

An AI-based computer vision camera system has been used in the UK to monitor adherence by individuals to social distancing measures. More controversially, Israel's cyber monitoring system enables its security services to identify and quarantine people who may be infected (Naudé, 2020).

Also, several companies are investing in the development of medical chatbots based on AI. These technologies can screen people and advise whether they should be evaluated for the infection. They enable "at-home risk assessments" in a few minutes. AI-powered virtual health assistants and chatbots, enable self-service, drive better outcomes, and reduce costs (Divya et al., 2018). Moreover, they can ease the stress placed on medical hotlines (Ahuja et al., 2020). Chatbots are fostering social distancing and streamlining the entire clinical process.

The Microsoft Healthcare Bot is an example of this technology. The service combines built-in medical intelligence with natural language capabilities, extensibility tools and compliance constructs. That service allows healthcare organisations such as Providers, Payers, Pharma, Health Maintenance Organisations (HMOs), Telehealth to give people access to trusted and relevant healthcare services and information.

Virtual health assistants and chatbot technology will never replace medical personnel. Nevertheless, technology can help make better use of medical personnel's time and relieve some of the burdens from the healthcare system (Bitran, 2019).

4.5 AI-based technologies: a transversal impact

As we described, AI technologies have a crucial role in the fight against COVID-19 and can be used in different ways and applied for a wide range of purposes. AI is not only helpful in the treatment of COVID-19 infected patients but also for their proper health monitoring (Mahomed, 2020). It is also useful to facilitate the research on this virus using the available data. AI can help in developing proper treatment regimens, prevention strategies, drug and vaccine development (Vaishya et al., 2020).

In this sense, AI-based technologies are essentials because they can generate a positive transversal impact on society and healthcare organisations (Naudé, 2020). These technologies, also, can contribute to the optimisation of logistics processes in hospitals and allow a better allocation of resources for firms (Jiang et al., 2017).

In the end, considering prevention strategies, AI-based technologies can support companies' enhancing their social responsibility (Pan, 2020). In this sense, as discussed by Zhao (2018), COVID-19 could allow businesses to consider alternative corporate social responsibility challenges.

5. Conclusion

Digital technology, including information technology and AI, are therefore proving to be essential tools to help build a coordinated response to this pandemic. In our research, we focused on central areas of applications where AI technologies are currently impacting against COVID-19, and we analysed some practical cases. Table 3 shows the elements under discussion and case studies that have been analysed in our paper.

From our analysis came up with some crucial insights.

First, we described how AI technologies play a crucial role in terms of contact tracing and monitoring of the pandemic spread. For this reason, governments around the world are investing more and more to

develop COVID-19 apps. These AI-based technologies can allow storage of data that could be useful for tracking "*hot zone*" and create global alert of high-risk pandemic areas.

Secondly, we observed that high-tech companies around the world are embracing a more healthcare-oriented approach. Big players are even more oriented to create a positive impact on society and are developing new technologies that can help to fight the virus.

This paper showed that the use of modern technology with AI improved the screening, prediction, contact tracing, forecasting, and drug/vaccine development with extreme reliability (Lalmuanawma et al., 2020). Considering these platforms assists AI experts to analyse massive datasets and help physicians train machines, set algorithms, or optimise the interpreted data for dealing with the virus with more speed and accuracy (Jamshidi et al., 2020). The analysis highlights, as well, that AI techniques are a fundamental tool for clinical decision-making. They can be used in different ways and applied for a wide range of purposes. Applications based on AI simplify work for physicians and medical staff providing them meaningful insights.

This paper has theoretical and managerial implications; in fact, it could be useful either for researchers or professionals (*i.e., policymakers, physicians, managers, healthcare, and administrative staff*). We wanted to underline that artificial intelligence applications are fundamental to contain the spread of the virus and to find out a vaccine as soon as possible. Analysing some AI applications, we aimed, also, to help healthcare organisations to allocate their financial resources better and investing more in these technologies. Finally, we chose to describe AI applications against COVID-19 to allow a better understanding of these techniques and help other professionals to gather what currently exists.

Like any research, this paper has some limitations.

First, the writing period did not allow the researchers to deepen their knowledge in the practical field. This element represents a future strength that will lead to a more in-depth analysis considering new methodologies. For example, future investigations could include the targeted analysis of individual case studies.

Moreover, at the level of business models, it would be interesting to analyse how the perception of Tech companies has changed compared to the previous and current period of COVID-19.

Table 3. Elements under discussion and case studies analysed for each topic

Macro variables	Case studies
• Drugs discovery and knowledge sharing	DeepMind; Insilico Medicine
• Tracking and prediction	BlueDot
• Clinical decision-making and diagnosis	Infervision; Alibaba
• Social distancing control and medical chatbots	Microsoft Healthcare Bot

Source: Authors' elaboration

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