The potential and challenges of Health 4.0 to face COVID-19 pandemic: a rapid review

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Abstract
The COVID-19 pandemic has generated the need to evolve health services to reduce the risk of contagion and promote a collaborative environment even remotely. Advances in Industry 4.0, including the internet of things, mobile networks, cloud computing, and artificial intelligence make Health 4.0 possible to connect patients with healthcare professionals. Hence, the focus of this work is analyzing the potentiality, and challenges of state-of-the-art Health 4.0 applications to face the COVID-19 pandemic including augmented environments, diagnosis of the virus, forecasts, medical robotics, and remote clinical services. It is concluded that Health 4.0 can be applied in the prevention of contagion, improve diagnosis, promote virtual learning environments, and offer remote services. However, there are still ethical, technical, security, and legal challenges to be addressed. Additionally, more imaging datasets for COVID-19 detection need to be made available to the scientific community. Working in the areas of opportunity will help to address the new normal. Likewise, Health 4.0 can be applied not only in the COVID-19 pandemic, but also in future global viruses and natural disasters.

Keywords Health 4.0 · COVID-19 · Artificial Intelligence · Machine learning · Remote clinical services · Communication networks

1 Introduction
The new coronavirus (COVID-19) appeared in Wuhan, China in 2019, and subsequently, it was declared a global emergency by the World Health Organization [1]. The COVID-19 emergency brought global challenges in industry [2–4], education [5], politics [6], economy [2, 6, 7], tourism [7], and health [5–12] services. Being one of the most important health [6, 13], having a fundamental role in the COVID-19 response [9] due COVID-19 pandemic is considered the first global health crisis in the digital age [10]. COVID-19 produces high rates of contagion in the population and medical staff [2, 10, 12, 14, 15], high spread rate [16–18], and high number of deaths [14] including medical personnel [7, 12].

The COVID-19 virus has a long incubation period that even people can be infected without showing symptoms [2]. Therefore, worldwide restrictions have been applied, such as flight limitations [16, 19], reduce or suspend public transportation [20], social distancing [7], cancellation of mass events [3], regulations on business operation [3], and partial or strict lockdown [10, 15, 16, 19, 21–23]. For all the above, the pandemic has affected people’s lifestyles [7] and routine medical procedures [11]. Likewise, there is a need in offering remote services due to the most susceptible population, suffering from diseases such as hypertension, cancer, and diabetes. In addition, it is considered that if advanced infrastructure is lacking in times of a pandemic, the pandemic will not be controlled and in the future, another type of virus could affect society [12]. Thus, technological trends are considered key to improve healthcare [24] and face the COVID-19 pandemic [7]. Hence, various proposals in the literature have emerged to fight against COVID-19, including Industry 4.0 [4, 25] which is a trend of automation and information exchange that continually evolves in various sectors of the
population and industries, allowing the development of more flexible and efficient processes and services.

Motivated by the success of revolution 4.0, Health 4.0 is developed, which focuses on the patient [24] and integrates services such as cloud/fog computing [26–30], big data [15, 26, 28], 5G network [7, 23, 27, 31, 32], 6G network [12], blockchain [33], and Internet of Things (IoT) [26–29, 31, 34]. Further, 2021 was forecast to be the year that focuses on health systems [33]. Hence, the contribution of this review is analyzing the potential and challenges of state-of-the-art Health 4.0 applications including assisted diagnosis, augmented environments, forecasts of COVID-19, medical robotics, and remote clinical services to face the COVID-19 pandemic.

In order to search for relevant works, the following key-words were used: «COVID-19», «health 4.0», «health care», «pandemic», «artificial intelligence», «machine learning», «deep learning» and «internet of things». In the studies previously located, a manual search was carried out in the located scientific papers, as follows: the cited works that were similar by title were analyzed and then the same was done with those similar. Studies from scientific databases¹ and a search engine², were included: articles, reviews, and viewpoints.

The rest of this work is organized as follows, Sect. 2 reviews the medical tasks in Health 4.0 that can be performed, including assisted diagnosis (subsection 2.1), augmented environments (subsection 2.2), forecasts of COVID-19 (subsection 2.3), medical robotics (subsection 2.4), and remote clinical services (subsection 2.5). Section 3 exposes scopes of Health 4.0, while in Sect. 4 the challenges are presented. In addition, Sect. 5 includes conclusions and future work.

2 Medical tasks

2.1 Assisted diagnosis

Assisted diagnosis helps to receive proper treatment in time [35]. Research has reported that artificial intelligence (AI) and machine learning help to develop decision support systems. They can even surpass the finding of correct diagnosis compared with physicians [36] mainly in pathologies using images [35]. Automatic diagnosis can be performed by integrating AI algorithms with applications in cloud/fog computing [36] allowing portability and data analysis from anywhere [29, 36] through different IoT devices [30]. In addition, automatic diagnosis is especially useful when there is a lack of specialized physicians [37].

Figure 1 depicts the general Health 4.0 pipeline for assisted diagnosis, involving data acquisition, network interconnection, data processing and assisted diagnosis. Patient data comes from different sources, including smart implants, sensors, and biomedical images. Data is collected through different computer networks. Heterogeneous data processing is done using preprocessing, selection, and feature extraction techniques. Finally, the assisted diagnosis is carried out by AI techniques mainly machine learning and deep learning.

2.2 Augmented environments

Strict quarantine makes learning difficult, so Augmented Reality (AR) and Virtual Reality (VR) can be used [25]. AR and VR are novel ways to explore medical conditions [38] and enhancing visual diagnosis [39]. VR can help to explore the COVID-19 virus in a three-dimensional way [23]. Also, it can be applied for teaching (i.e. anatomy, dermatology [39], nursing [38] physiotherapy [40]), procedure planning (i.e. dermatology [39], maxillofacial [41]), lesion tracking (i.e. dermatology [39]), simulation and procedural training [38] such as the training of physicians in orthopedics and surgery [34, 41]. Balian et al. analyzed the feasibility of a training system that uses AR to simulate cardiopulmonary resuscitation, where 98% of study participants recognized that visualization helps training [42]. Likewise, Kelly et al. concluded that clinical reasoning strategies can be made explicit when AR is used [40]. Further, computer vision applied in AR and VR allows to obtain, process, analyze and understand images and videos [43], hence, computers can understand the context of the physical world. Also, the application of

¹ ScienceDirect and IEEE Explore
² Google Scholar
AI in AR allows the automatic recognition of objects [43]. Therefore, AI and computer vision can be applied to improve the experience of health care providers and offer personalized environments for clinical teaching. Health 4.0 allows connecting the physical and virtual worlds [44].

2.3 Forecasts of COVID-19

Forecasting models furnish valuable quantitative information and help to make decisions in the short-term [45]. Hence, forecasting models can help to prevent the spread of COVID-19 and assign medical supplies [45]. Machine learning and deep learning can predict outbreaks of COVID-19 [25, 46, 47], and discover disease trajectories in geographic zones [48]. Also, machine learning and deep learning can predict COVID-19 cases [3, 23, 49–52], deaths [50] and recovered cases [50]. In addition, forecasts have allowed the generation of COVID-19 spread maps and dashboards [17]. Further, using mobile geographic information systems (GIS), tracking of COVID-19 in near-real-time can be carried out [17]. Likewise, natural language processing (NLP) helps to carry out translations of mapping dashboards into various languages [17]. In Fig. 2, we present an illustrative example of a layout of COVID-19 forecasts.

2.4 Medical robotics

Robots are machine-based agents that interact with the environment and can be adapted to perform certain tasks [14]. Medical robots can assist in various tasks such as treatment of patients [34], surgery, and recognition of surgical activities. Robot-assisted surgery provides advantages like minimal invasiveness [53], better vision, and better instrument control [54–56], thereby allowing its application in difficult environmental conditions [34] and facilitating complex surgeries [57].

Recently, an increase in robotic-assisted surgery has been observed, showing applications such as radical prostatectomy [55], radiosurgery of gastrointestinal cancer [57], liver resection [54], knee arthroplasty [56], laparoscopic gynecology [53], bariatric [58] and endoscopic skull base surgery [59]. Studies have shown that recovery after carrying out robot-assisted radical prostatectomy occurs in a shorter time [55]. In addition, treatments can be carried out through telesurgery by incorporating AI, 5G-tactile internet, and fog computing [32]. Equally well, deep learning can be implemented in robotic surgery for solving inverse kinematics of the spatial snake-like robot [57], showing good performance in accuracy and speed. Additionally, deep learning has been

![Fig. 2 Example of COVID-19 forecast layout](image-url)
applied to carry out the recognition of surgical activities (such as the detection of tools and people) in videos captured in the operating room [60, 61], hence it improves the surgeon’s control capabilities [61].

2.5 Remote clinical services

Advances in telecommunications such as 5G network [7, 26, 32], 6G network [12], tactile internet [32]), wearable devices [26, 31] and sensor networks [62] make remote clinical services telemedicine feasible and useful even in remote places [32]. Telemedicine services help to decrease the risk of contagion of COVID-19 [7, 10, 25, 63] by reducing the number of people who need to attend the hospital [12, 64].

Telemedicine is successful in both emergencies and routine check-ups [10]. Telemedicine has applications in teledentistry [11], remote care [6, 12], routine monitoring [6, 65], consultations [2, 7, 66], electronic prescriptions [10], chatbots [67], tactile/haptic robots [12], telesurgery [12], medical drones [2, 17], telenursing [7], managing stress [68] and symptom checking [2, 64]. Figure 3 illustrates the general Health 4.0 pipeline for monitoring systems interconnecting patients with healthcare providers and hospitals for continuous patient monitoring and generating alarms when they have a critical condition. Medical sensors can help to obtain information [34], such as the temperature of the patients [2]. In addition, smart implants allow the capture in real-time physical data within the body [34, 69] having therapeutic and diagnostic benefits in postoperative care and rehabilitation [70]. Smart implants have been used in corpectomy implants [70], postoperative evaluation in the spine [71], orthopedic surgery [70], joint replacement [69], fracture treatment [69], and fixation of spine [69].

3 Scopes of Health 4.0

In this section, we report the Health 4.0 tasks to face the COVID-19 emergency (Table 1). Figure 4 illustrates stakeholders, tasks, and technologies in Health 4.0. The integration of AI, computer vision, and other technologies offer great advantages in different tasks of Health 4.0, such as carry out health care in a more preventive, predictive, and personalized way [24, 27, 72, 73]. Also, Health 4.0 connects patients with healthcare professionals even in remote places [32], improves collaboration using technology [24, 74], enhances health care [75], reduces the risk of infection [10, 25], and facilitates pandemic strategies [15]. Further, advances in AI, algorithms, 5G networks [7], 6G networks [12], cloud computing, IoT, mobile GIS [17], and computational power make it possible to develop near-real-time systems [17, 76], remote health monitoring [12, 77], and measurement of clinical parameters (i.e. temperature, heart rates, sugar levels, blood parameters) [2, 12, 78]. Furthermore, it is expected that in 2030 IoT will be replaced by the Internet of Everything and that 6G technology offers global coverage with great importance in the healthcare market [12]. The 6G network coverage will be in space-air-water, therefore, it will have an important role in Health 4.0 [12].

Due to recommendations that patients with mild symptoms of COVID-19 be managed at home [2], Health 4.0 applications are a great alternative to offer remote services. Hence, health 4.0 has shown the potential to carry out assisted diagnosis, augmented environments, forecasts of COVID-19, medical robotics, and remote clinical services. Also, significant multinational collaboration has been shown between medical experts, epidemiological leaders, and data scientists [48]. Collaboration between health, government, and industry leaders has an important role in modeling
forecasts of COVID-19 [45]. Likewise, timely decision-making helps reduce the transmission rate [45]. The results obtained by COVID-19 prediction models can not only be applied in the health area, but also in the government and industry, to implement rapid response to outbreaks [45] and generate reopening strategies.

One of the interesting areas of assisted diagnosis is the detection of COVID-19 where respiratory symptoms, antibody studies, and biomedical imaging are mainly analyzed [83]. In addition, studies have emerged based on the analysis of cough to detect COVID-19 [22]. Machine learning and deep learning approaches have shown applications in virus diagnosis [79], without manual feature extraction [83]. Table 2 reviews the AI techniques applied in the diagnosis of COVID-19 and the biomedical imaging analyzed, including CT and X-rays. Likewise, the results obtained are shown in terms of accuracy (ACC), area under the curve (AUC), sensitivity (RE), specificity (SP), and precision (PRE).
Challenges

In the field of Health 4.0, the potential to face COVID-19 has been shown. However, there are ethical [66], moral [10], technical, privacy [15], security [12, 23], and legal challenges. Also, to increase the acceptance of Health 4.0, it is necessary to adapt to the population, considering the culture and religious backgrounds of the users [10]. In the field of automatic diagnosis of COVID-19, more image datasets for screening need to be made publicly available, having a greater number of samples will help to develop more robust systems [80]. In Table 3, we show the challenges that exist in tasks of Health 4.0.

Table 2  AI techniques applied in the diagnosis of COVID-19

| AI field       | Biomedical imaging | Techniques                                 | Results          |
|----------------|--------------------|--------------------------------------------|------------------|
| Deep learning  | CT                 | Lesion-attention deep neural network [81]  | 88.6% ACC        |
|                |                    |                                            | 94% AUC          |
|                |                    |                                            | 88.8% RE         |
|                |                    |                                            | 87.9% PRE        |
|                | X-ray              | Multi-Task deep learning [80]              | 98.78% ACC       |
|                |                    | Deep transfer learning [88]                | 98% RE ± 3       |
|                |                    | EfficientNet family of models [82]         | 93.9% ACC        |
|                |                    |                                            | 96.8% RE         |
|                |                    | Faster R–CNN [83]                          | 97.36% ACC       |
|                |                    |                                            | 97.65% RE        |
|                |                    |                                            | 99.28% PRE       |
| Machine learning| CT                 | Inception V3 [16]                          | >96% ACC         |
|                |                    | Multi-Task deep learning [80]              | 84.67% ACC       |
|                | X-ray              | Support Vector Machine [89]                | 99.68% ACC       |
|                |                    | Support Vector Machine [84]                | 100% ACC         |
|                |                    | Support Vector Machine [90]                | 99.27% ACC       |
Conclusions and future directions

COVID-19 pandemic promotes disruption in different sectors of the population. This research analyzed Health 4.0 applications involving AI and communication technologies to be applied in assisted diagnosis, augmented environments, forecasts of COVID-19, medical robotics, and remote clinical services. Through the use of technologies such as 5G/6G networks, cloud/fog computing, and tactile internet, can be carried out various complicated tasks such as near-real-time medical data collection, simulation tasks, and inter-connectivity with various sectors of medicine. Studies based on robotics and augmented reality emerge to improve health education in a less invasive and more interactive way. In addition, Health 4.0 will allow improving diagnosis and rehabilitation treatments. Conversely, there is still a long way to go in Health 4.0, areas of opportunity must be addressed, so that Health 4.0 can be applied not only in the COVID-19 pandemic, but also in future global viruses and natural disasters. Future research work should focus on:

- Carry out COVID-19 studies by cough analysis, to be able to carry out studies in countries that lack medical equipment such as CT scanners to perform virus studies.
- Develop AI techniques that use fewer computational resources.
- Include different sectors such as the medical, business, legal, and political sectors, to develop highly reliable health services using AI.
- Implement more personalized mobile applications according to the patient.
- Make more COVID-19 datasets publicly available.
- Optimize the electronic components of smart sensors. Also, look for ways to reduce costs, so that its use is feasible in semi-developed countries.
- Perform telesurgery studies using AI.
- Promote Health 4.0 services in developing countries.

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Cecilia-Irene Loeza Mejía: Conceptualization of this study, Investigation, Methodology, Writing - Original draft preparation. Eddy Sánchez-DelaCruz: Project administration, Supervision, Formal analysis, Writing- Original draft preparation. Pilar Pozos-Parra: Investigation, Methodology, Writing - Original draft preparation. Luis-Alfonso Landero-Hernández: Investigation, Methodology, Writing - Original draft preparation.

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