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Review article

Retrospective and prospective application of robots and artificial intelligence in global pandemic and epidemic diseases

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ABSTRACT

About 4.25% of people have lost their lives due to COVID-19 disease, among SARS-CoV-2 infected patients. In an unforeseen situation, approximately 25,000 frontline healthcare workers have also been infected by this disease while providing treatment to the infected patients. In this devastating scenario, without any drug or vaccine available for the treatment, frontline healthcare workers are highly prone to viral infection. However, some countries are drastically facing a shortage of healthcare workers in hospitals.

Methods: The literature search was conducted in ScienceDirect and ResearchGate, using words “Medical Robots”, and “AI in Covid-19” as descriptors. To identify and evaluate the articles that create the impact of robots and artificial intelligence in pandemic diseases. Eligible articles were included publications and laboratory studies before and after covid-19 and also the prospective and retrospective of application of Robots and AI.

Conclusion: In this pandemic situation, robots were employed in some countries during the COVID-19 outbreak, which are medical robots, UV-disinfectant robots, social robots, drones, and COBOTS. Implementation of these robots was found effective in successful disease management, treatment, most importantly ensures the safety of healthcare workers. Mainly, the Disposal of deceased bodies and the location and transportation of infected patients to hospitals and hospitals were tough tasks and risk of infection. These tasks will be performed by employing mobile robots and automated guided robots respectively. Therefore, in the future, advanced automated robots would be a promising choice in hospitals and healthcare centers to minimize the risk of frontline healthcare workers.

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Aplicación retrospectiva y prospectiva de robots e inteligencia artificial en pandemias y epidemias globales

Palabras clave:
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COVID-19
Robots médicos
Inteligencia artificial
Tratamiento de la enfermedad
Seguridad de la atención sanitaria

RESUMEN

Cerca de un 4,25% de personas han perdido la vida a causa de la COVID-19, entre los pacientes infectados por SARS-CoV-2. En esta situación imprevista, aproximadamente 25.000 trabajadores sanitarios de primera línea se han visto también infectados por esta enfermedad, al proporcionar tratamiento a los pacientes infectados. En este escenario devastador, en el que no se dispone de fármacos o vacunas para el tratamiento, el personal sanitario de primera línea está altamente expuesto a la infección vírica. Sin embargo, algunos países se están enfrentando a un recorte drástico de personal sanitario en sus hospitales.

Métodos: Se realizó una búsqueda en la literatura en ScienceDirect y ResearchGate, utilizando los términos «*medical robots*» y «*AI in COVID-19*» como factores descriptivos, para identificar y evaluar los artículos que crean el impacto de los robots y la inteligencia artificial (AI) en las pandemias. Los artículos elegibles incluyeron publicaciones y estudios de laboratorio, antes y después de la COVID-19, y también la aplicación prospectiva y retrospectiva de robots e AI.

Conclusión: En esta situación de pandemia, algunos países utilizaron robots durante el brote de COVID-19, es decir, robots médicos, robots desinfectantes de rayos UV, robots sociales, drones, y cobots. Se encontró que la implementación de estos robots era eficaz para la gestión y tratamiento de la enfermedad y, más importantemente, la garantía de la seguridad del personal sanitario. En particular, la eliminación de cadáveres y la localización y transporte de pacientes infectados a los hospitales eran tareas duras que suponían un riesgo de infección. Dichas tareas podrán realizarse utilizando robots móviles y robots automatizados, respectivamente. Por tanto, en el futuro, los robots automatizados avanzados constituirán una elección prometedora en hospitales y centros sanitarios, para minimizar el riesgo del personal sanitario de primera línea.

Introduction

The sudden cause of global pandemic disease disrupts human beings in disease management. Recently, the whole world is facing the COVID-19 outbreak, which has almost deteriorated global health and especially the economy. The COVID-19 is caused by a deadly coronavirus SARS-CoV-2 (Severe Acute Respiratory Syndrome – Coronavirus-2) the cause of the virus is creating a much negative impact and spreading overseas. As of 4th December 2020, about 44,350,473 cases have been reported globally and 1,494,668 deaths were recorded. Approximately, a gross estimate of 25,000 frontline health workers has been infected with this deadly disease across 52 countries (WHO, 2020).[1] However, disease treatment without any drug or vaccine is an additional headache among health workers, since symptomatic treatment is being carried out. Even, some countries are facing the unavailability of frontline health workers or very least in numbers for treating a huge number of the infected population. Another major issue is the inadequate supply of Quality PPE's to health workers, which might enhance disease spread.[2]

In such a tremendous crisis, it's our mission to serve and protect our frontline health workers. This global pandemic disease has taught us to bring-up innovations, and technologies for disease management, and treatment in healthcare systems. Robotics and Artificial Intelligence are promising tools with vast potential to deal with the present situation. As we mentioned above, the major success of this virus is community transmission, which could be minimized or hampered by the use of robots include Medical robots, Drones, UV-light robots, Automated robots, and Collaborative robots in hospitals and associated labs. Moreover, Artificial intelligence could be implemented to monitor every patient, categorize different stages of infection, and find out severe cases for high-end treatment.[3] These were successfully executed in some countries and found fruitful to succumb viral transmission in hospitals and major metropolis. This present study highlighting the futuristic application of Robotics and Artificial Intelligence in pandemic disease management.[4]

Robots in disease management

Robots have been invented to perform complex task or group of tasks which minimizes workload and labor. However, the current standings are ready to defend the cause and loss. In the present scenario, robotics could also be used for pandemic disease management mainly to prevent contact and spread of viral diseases.[2] The design and structure of medical microrobots minimize the physical interactions with the cells of the immune system. However, the surface-borne design and parameters are also critical in the locomotion and performance of microrobots.

Fig. 1 – Medical robots are used to take-care and monitor patients.
***Source*: Industrial Automation Magazine.**

Medical robots

There are various types of medical robots designed uniquely to perform a certain function or task. The design and structure of medical microrobots minimize the physical interactions with the cells of the immune system. However, the surface-borne design and parameters are also critical in the locomotion and performance of microrobots.[5] Some of them are described in detail below (Fig. 1).

Cleaner robots

Cleaners in healthcare systems are playing a major role in maintaining the regular cleanliness of hospitals and health care centers. During the situation like pandemic disease, the demand for such workers is skyrocketing, due to disease threat. To solve this issue, cleaner robots could be employed in health sectors coupled with human intelligence and machines to enhance cleaning efficiency and employee safety.[10] Even, cleaning labor supplying companies are facing obtuse labor shortage during this pandemic disease situation due to self-quarantine or other illnesses. Therefore, their only solution is efficiently employing commercial cleaning robots.[3] Cleaner robots could be an addition to autonomous cleaning solutions to maintain the quality of cleaning and might reduce the risk of exposure to highly pathogenic infections. In health care centers, cleaning standards were established to acquire the safety of both healthcare workers and patients. However, during the COVID-19-like pandemic situation, several criteria were included to improve the safety standards day by day. Therefore, cleaner robots designed under certain safety standards and regulations in healthcare centers would be effective and helpful.[11] The machines don't cough, sneeze, or shake hands, so they can't actively spread deadly coronavirus around the hospital, in the addition to cleaning robots are floor scrubbers, vacuum sweepers, and shelf scanners in a major metropolis. Automotive mobile robots (AMR) enable us to serve cities in labor-intensive cleaning tasks during the global pandemic situation.[42] For example, UV-disinfecting autonomous mobile robots (Sunburst UV Bots) were first implemented in the Northpoint City mall, Singapore, and consequently followed by thirteen different malls in the city.[42]

Ultra-violet light robots

The spread of coronavirus is attributed to nasal or mouth droplets by sneezing or coughing of an infected person to a healthy person.[6,7] However, other modes of transmissions are direct contact with utensils by a healthy individual, already touched by the infected person.[2] It has been reported that the viral particles remain to persist on the surface of copper (4 h), cardboard (24 h), stainless steel (2–3 days), wood (2 days), paper money (4 days), surgical masks outside (7 days), cloth (2 days), glass (4 days), and polypropylene plastics (3 days).[8] Therefore, robot-controlled ultraviolet light devices could be efficient in the disinfection of materials employed in health care centers. Three types of ultraviolet rays have been categorized UV-A (320–400 nm), UV-B (280–320 nm), and UV-C; hence, UV-C is high energy radiating UV rays ranges between the frequency wavelength of 280–100 nm can cause severe skin and cornea damage and may induce carcinogenic effects in humans.[48] Although, UV-C is one of the effective rays in sterilizing objects, the PX-UV (Pulsed Xenon Ultraviolet) device is employed in disinfecting surface materials and objects in hospitals and health care centers to combat deadly viral pathogens. It has been proved that the cleanliness rating was improved from 50th to 99th percentile in hospitals while applying this device.[9] Mainly, in the UV cleaning methods, the robots are used for micro-killing, floor cleaning and able to patrol rooms and corridors performing deep cleans surfaces with concentrated UV light. The robot is employed with many sensors, and its self-driving, voice-enabled machine disinfects microbes with a high wavelength of ray which is dangerous for humans to be exposed to.[43] The robot developed by UVD Robots; the operator deploys the robot using a computer. The robots scan the environment using its lidar sensor and create a digital map of the hospital's room, the automated map indicated the rooms and points the robot should not disinfect. After that, the robot relies on Simultaneous Localization and Mapping (SLAM) to navigate. The autonomous robot was emitting 20 joules per square meter per second of 254-nm light to eliminate bacterial and other harmful microorganisms.[44] The Xenex robots (Fig. 2); use the xenon lamp to generate bursts of high-intensity full germicidal spectrum (200–315 nm), this Light strike robot destroys the virus in two minutes achieving a four-log (99.9 percent) and also reduction in that time.[44] The application of Ultra-violet Robots are used for sanitizing patients room after they discharge from hospitals, for example, Vanora Robotics Company in Mangalore have developed UV light disinfection robot named "Vanora" which can sterilize the entire room in 4 min, and was employed in Tejasvini Hospital in Mangalore, this device would be most helpful for frontline workers and workers engaged in the COVID-19 battle.[39]

Mobile robots

Mobile robots are engineered to navigate and transport high-risk patients in any contaminant areas to avoid direct contact with health workers. Mobile robots were equipped with high-end sensors and cameras to record the patient's

Fig. 2 – Ultra-violet robots are used for sterilizing purposes. *Source*: Xenex Disinfection services.

temperature, blood pressure, and pulse rate, and regular monitoring using a vision algorithm[11,12] (Fig. 1). In addition to this, these robots help deliver medicines and food for isolated and quarantined patients in hospitals and health care centers.[13] Therefore, we could monitor, study the condition of patients, and categorize the stages of disease under treatment and doctors could attend the patients based on the severity. During COVID-19, mobile robots were most helpful in delivering food and medicines to isolated patients in hospitals to secure the health of frontline workers including doctors.[35,36]

Social robots

Social robots are the most important need of society to supply and deliver the basic needs of the people during the complete lockdown in the pandemic situation.[14] For example, Care-O-Bot supports adult and old age individuals by delivering basic needs like meals and drinks.[13] PARA robots could be helpful for entertaining children at home during the lockdown.[13,14] Telepresence robots have been involved to serve, surveillance, and health monitoring of people during the lockdown.[11] Hence, social robots are the most needful in maintaining proper social distancing during the pandemic lockdown.[14] During social distancing, isolation, and quarantine in-home, mental health challenges could be screened, diagnosed, and provided on-demand mental therapy with the use of social robots.[2] Therefore, beyond the use of robots in industries, which could also help in dynamic human environments evolved to serve societies and maximize positive social impact. The application of social robots is also useful in automatic temperature monitoring in public places, most importantly airports.[37,38] These automatons have become more useful for staff available to handle incoming patients has been reduced. This robot works on QR codes and that makes it more affordable to helping direct patients without exposing human staff to COVID-19.[41]

Robots in collaborative automation

In recent decades, the manufacturers have employed robots for simple to complex tasks and thereby enhancing the interactions between humans and robots.[18,19] When robots collaborate with humans in performing a task are termed collaborative robots (COBOTS).[12,19] Since traditional robots are employed in close fenced areas, hence, collaborative robots are implemented with humans without any fence and ensure interactions between humans and robots.[20] That we mentioned above the collaborative robots are equipped with many sensors like Lidar, Motion, and acceleration, and much more. So, robots are not harmful to humans who are all working with them. The closeness level of engagement with humans have made COBOTS interesting criteria,[21,22] and the level of automation in any scope of the study.[23] The COBOTS have a wide range of applications in medical devices and the diagnostic industry rely on automation. For example, blood sample collection was done by COBOTS at Copenhagen University Hospital in Gentofte, Denmark.[45] COBOTS can deliver more than 90 percent of results within 1-hour despite a 20 percent increase in sample arriving for analysis[46]. In Singapore, NovaHealth Traditional Chinese Medicine (TCM) clinic has a physio-massage robot to dole out back and knee massages in serving patients.[46] The COBOTS are not only used in the hospital in pandemic situations is also useful on the labor shortage in industries and laboratories have had affected the economy and disease management during the COVID-19 pandemic. Since several solutions have been implemented in the past few years by using COBOTS as co-workers in factories, however, it needs to evolve further.[24]

Drones

The drone is a promising technology playing a major role in COVID-19 like the pandemic era also by monitoring and preventing clustering of people during the lockdown.[15] It is the next level of surveillance reduces human energy and disease threat. For example, China has implemented drones for multipurpose broadcast purposes.[16] To avoid human contact, drones could be useful to communicate with people to know the field status of the pandemic disease to gather health information and status. In some countries, drones help spray disinfectants to prevent the spread of the pathogens which is 50 times faster and efficient than any other traditional method.[17] Most recently, drones have been developed and evolved to hold a capacity of 16 l of disinfectant to cover an area of 100,000 square meters are in an hour. In China, drones equipped with infrared cameras were helpful to record the large-scale temperature measurement of people to ensure the safety of health workers and avoid the spread of coronavirus[16] (Fig. 3). Drones are equipped to supply PPEs, medicines, and food to the people undergoing quarantine in red zones. In China, drones were implemented to deliver testing samples from a hospital at Xinchang County, Zhejiang Province to the Chinese Disease Control and Prevention center located at a distance of 3 km in 6 minutes. It might take 20 minutes to travel the same distance on road.[40]

Artificial intelligence in COVID-19

Till now, the diagnosis of SARS-CoV-2 virus infection is based on RT-PCR (Reverse Transcriptase Polymerase Chain Reac-

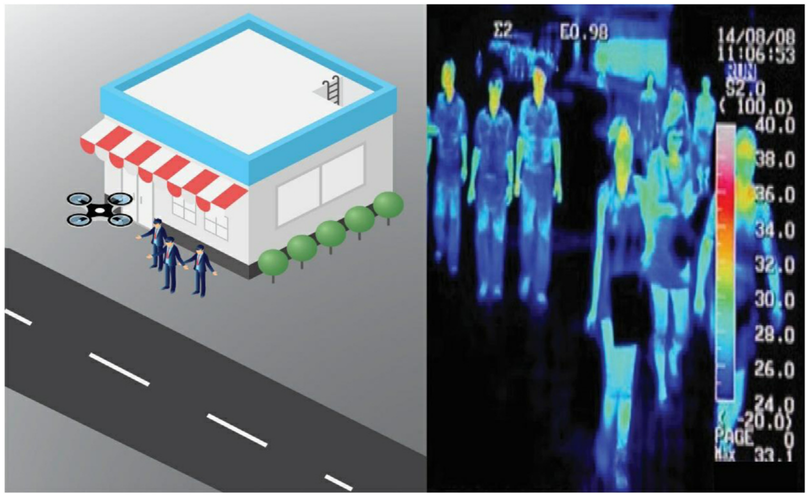

Fig. 3 – Drones equipped with infra-red cameras are useful to check people temperature in their home itself.

tion) from the nasal swab of patients. However, this could not provide the severity of patients infected with the virus, because it takes 6–48 h to complete and to get results and also lack of PCR kits to attain samples. Therefore, Computed Tomography (CT) scan is used as a valuable component in assessing the severity of the patients. In this scenario, Artificial Intelligence (AI) could be implemented to assess the stages of infection and severity of cases in a real-time manner.[28] Researchers demonstrated that an AI algorithm could be trained to classify COVID-19 in Computer Tomography (CT) scans with up to 90 percent accuracy. However, the CT is not always recommended as a diagnose tool for COVID-19 because the disease often looks similar to influenza-associated pneumonia on the screens.[47] There are many AI-based algorithms like deep convolutional neural network (CNN) to an initial CT scan, for example, Support Vector Machines (SVM), Random Forest, Multilayer Perceptron (MLP), and Decision-tree Classifier.[29] Moreover, decision-tree classifiers have shown the best performance on the tuning set. Because the accuracies in decision tree classifiers are enormous compared to other models. The Deep-learning-based decision-tree classifier will be designed to integrate the CT scan of the chest, symptoms of patients, exposure history, and laboratory testing to rapidly diagnose and record the different stages of viral infection and inform about the number of cases that need high-end disease treatment.[29] This neural network model is fully comprising of the PyTorch framework, proposed model classifier for detecting COVID-19 form CXR images (Chest X-ray) as normal and abnormal, the normal was a detection coronavirus infection, and abnormal was a sign of tuberculosis.[29] The accuracies of the first and second decision trees are 98% and 80% where the average accuracy of the third decision tree is 95%. Besides, the AI was also used to determine the symptomatic and asymptomatic cases during the disease treatment for their segregated levels of treatment (Fig. 4). Specifically, the Department of Radiology, Shenzhen Second People's Hospital, and University Health Science Center, Shenzhen developed "COVNet" (COVID-19 detection neural network) which was also developed to extract visual features from the volumetric chest CT for the detection of COVID-19. In this model, the collected dataset consisted of 4356 chest CT samples of 3322 patients from 6 medical centers in China between Aug 16, 2016, and Feb 17, 2020. The final dataset has compiles of 1296 (30%) were infected with COVID-19, 1735 (40%) of community-acquired pneumonia, and 1325 (30%) of non-pneumonia. All the COVID-19 confirmed cases as positive by RT-PCR were acquired from Dec 31, 2019, to Feb 17, 2020.[30] AI has already been used in high throughput medical imaging for deep learning technology. Chest Radiography imaging such as X-ray or computed tomography for diagnosing pneumonia, but also provides a highly sensitive diagnosis with COVID-19. The Automated X-ray Imaging Radiography systems (AXIRs) were used to distinguish patients infected severely with SARS-CoV-2. Finally, doctors review the images and their classifications

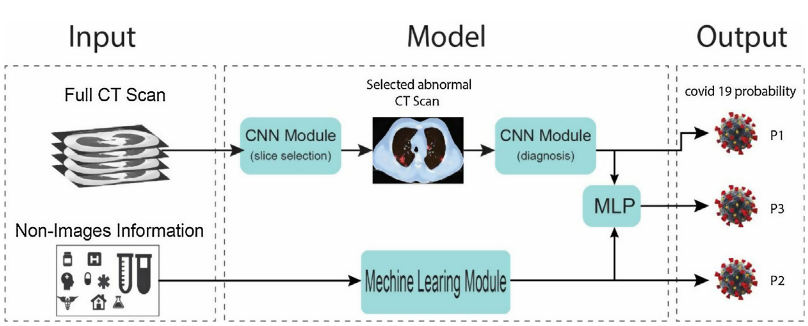

Fig. 4 – Artificial intelligence is used to enhance the CT scan analysis to detect and report different stages of infection.

Fig. 5 – 3D Printing Technology is used for manufacturing PPE's.[26]

before making decisions further for clinical assessment.[29] In the "COVNet" detection method the imaging system was performed for different standard imaging protocols. Therefore, it could also be applied to study and detect viral pneumonia infection in chest radiographs.[30] The two major limitations of the use of Chest CT. First, the health systems during an epidemic may be overburdened, which may limit the timely interpretation of the CT by radiologists. Second, the morphology and severity of pathologic findings on CT are variable. In particular, mild cases may have few if any abnormal finding on the chest CT.[28]

Reduce workload in healthcare

Sudden cause of pandemic disease outbreak and an elevated number of patients' admission in hospitals and healthcare centers becomes havoc for frontline healthcare professionals due to heavy workload for the treatment and disease management. In such cases, AI would be more helpful in handling big data analysis of patients every day to cope up with their disease treatment. As a solution, AI becomes a promising tool providing more predictive and preventive healthcare.[31]

Applications of artificial intelligence in COVID-19

The AI-based COVID-19 scan analyzer was installed in Baguio General Hospital in the Philippines to support doctors to segregate COVID-19 patients by analyzing CT scans of patients very quickly.[32] Similarly, researchers at Brunel University, London have developed an AI algorithm that scans the images of health reports of patients to identify COVID-19 patients for quick monitoring and treatment.[34] As a powerful tool, AI was implemented to identify highly infected zones and moderately infected zones in New York City by Mount Sinai Hospital. Consequently, in collaboration with Hospitals in China, they have compared the CT scan images of patients with China using AI, which was fruitful to identify COVID-19 patients most efficiently with 84%, which was only 75% by radiology-based evaluation.[33]

Development of drug and medicines

The AI is used to identify and design an appropriate drug for treating many human pathogenic diseases, which could also be implemented on COVID-19 disease based on drug discovery or drug delivery design and its development. This technology would be more efficient and impact in speeding up drug discovery and testing in real-time. Therefore, it is the most powerful tool for both diagnosis and drug development.[31]

Role of 3D Printing

3D printing technology has evolved drastically to manufacture various medical devices in a short time without affecting the demand. To maintain the supply chain of medical devices during COVID-19 like pandemic situations, 3D printing technology would be more efficient to produce and manufacture to compensate for huge demand-supply.[25,26] The 3d printable medical models described below would likely be evolved in respirators and other PPEs.[27]

Respiratory support systems

Italy was facing the worst cause of regional shortages of respiratory masks, and non-invasive ventilation in CPAP/PEEP (Continuous Positive Airway Pressure/Positive End-Expiratory Pressure) respiratory support during COVID-19. Even though, reverse-engineered 3D printable model value is not available in the present situation. In the future, automated ventilators with a flow-driven pressure-controlled respiratory support system would be found efficient to support severely ill patients.[26]

Personal protective equipment

Realizing this present scenario, the global 3D printing community have had come forward to design a plethora of reusable personal protein equipment to support both the patients and healthcare workers.[25] Respiratory masks with insertable, filter cartridges were primarily manufactured with low-cost desktop filament extrusion printers (Fig. 5). The 3D printed face masks were implemented by the medical staff and doctors in Madrid, Spain during the COVID-19 global pandemic.[50] Despite, researchers at the University of East Anglia, England have launched a project to 3D print ventilators parts, masks, and other critical equipment to battle the COVID-19 disease.[49]

Future prospective

- Automatic hand sanitizer and hand wash dispenser in hospitals, industries, and healthcare centers.
- Real-time supply of medicinal goods and PPEs through Drones.
- Artificial Intelligence-based drug design and discovery.
- Mobile robots could be employed in the disposal of deceased bodies to prevent human contact and spread of the viral pathogens.
- Big data analysis coupled with AI would be efficient in reducing workload in real-time monitoring of a larger proportion of patients.
- Social robots are used in traffic management to reduce of mass gathering of people.
- Automated guided robots and mobile robots might be helpful to navigate and transport stranded infected patients to healthcare centers or hospitals.
- Mobile robots will be helpful in the collection of samples for testing.

Conclusion

Global pandemic disease outbreak like COVID-19 had taught us about the preparedness for such invasion of pandemic disease shortly. With pandemic status, COVID-19 is a high incidence of contagious disease, spreads rapidly through community dispersal. However, frontline healthcare workers are risk-takers, highly prone to SARS-CoV-2 infection. To protect, aid, and support them, automated robots are a promising technology for this global issue. In some countries, robots include medical robots, UV-disinfectant robots, cleaner robots, mobile robots, social robots, drones, and COBOTS were employed during this COVID-19 outbreak and found much support for healthcare workers for their safety. However, in the future, mobile robots are used for deceased body disposals and automated guided robots for navigation and transportation of infected patients from their location to healthcare centers would be fruitful. Therefore, is clear that advanced and evolved automation and robots will be implemented in healthcare centers and hospitals to limit the risk of frontline healthcare workers.

Conflict of interest

The authors declare that they have no conflict of interest.

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