Robots are a Promising Investment to Fight Pandemics

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***Abstract*—Coronavirus caused pandemics as many viruses did through human history. The current pandemic causes overwhelmed healthcare system, locked down cities, and massive fatality among humans. Thus, different robots have been used since the COVID outbreak worldwide to reduce spreading infectious diseases and support frontline healthcare workers. This paper sets out the different robots implemented for hospital, non-hospital use, and possible use that can be deployed amidst the pandemic. A literature survey of versatile robots during COVID-19 is introduced. Roboticists contributed with wheeled and drone robots with various applications to assist medical care systems and society during the ongoing crisis. Pandemics are common throughout human history and difficult to avoid or prevent; thus, we intend to encourage societies, academia, engineers and innovators to invest more in robots that cannot catch the virus and consequently introduce beneficial solutions to fight such pandemic in the future.**

***Index Terms*—COVID-19, Robots, Pandemic, Drone, Frontline Workers, Exoskeleton, Sanitising, Monitoring Robots, Rehabilitation.**

I. Introduction

The virus that affected our globe since 2019 and still killing people to date is called SARS-COV-2 or COVID-19, which stands for coronavirus disease 2019 [1]. The COVID-19 causes severe respiratory pathogen with high fatality and spread rate among people [2]. It can spread through droplets, cough or sneeze if they enter the respiratory system through the nose, mouth or eyes [3]. The COVID-19 is causing massive damage for humans like the other viruses, which caused different epidemics and pandemics in the last century.

What makes COVID-19 more dangerous than other viruses like Ebola, for instance, is the ability to spread the virus by asymptomatic people. In contrast, the Ebola virus was deadly, and people could not spread the virus likely as patients became so sick with apparent symptoms [4].

Interestingly, before politicians and leaders worldwide asked people to stay at home and keep distancing, the epidemiologists knew that such a virus was coming to the human being. Others like Bill Gates, a business magnate, also talked about such pandemic early in 2015 [5] [6] since many viruses jumped from animals to human and caused many pandemics.

The critical factors that end the pandemic and fight the virus can be either with a vaccine or to reach herd immunity, where 60% of people (4.7 billion of the world population) are immune to the virus [7]. But the time that it takes to invent, develop, manufacture and distribute a safe and effective vaccine is long with twisted procedures, which leads many people to be victims of such disease before the scientists produce a vaccine. As quick solutions that slow down the high rates of fatality caused by COVID-19 were the public cooperates represented by locking down many cities, asking people to stay home and keep distancing.

The pandemic has been widespread at a rate that the globe has not experienced before; for instance, the total infected cases worldwide until the time for this manuscript is more than 130 million and over 2.85 million deaths [8]. Hospitals and healthcare workers were overwhelmed, so governments took several precautionary procedures such as locking down their citizens to reduce the high rate of spreading COVID-19. The locking down cities affected many jobs relying on human resources like industry, restaurants, transportation and education. Thus, intelligent and innovative solutions of using robots have seen worldwide, especially that some robots used before the COVID pandemic in disasters like drones in Hurricane Katrina and robotic exoskeletons in Fukushima nuclear disaster [9] [10].

As this virus is still claiming many people's lives, more public efforts from multi-disciplines need to be collaborated to overcome this pandemic as fast as possible with the minimum losses. This paper aims to highlight the robots already tackle hospital and non-hospital domains under the COVID-19 pandemic and shed lights on the other possible robots that can curb the pandemics within other domains. We focus on the apt solutions presented by different robots. We expect researchers, innovators, and society to invest more in robots as they are the best solution to fight pandemics.

II. Robots Use Against Pandemics

By locking down many cities, stop jobs with high reliance on humans, and forcing people to stay at home; have social, economic and psychological negative impacts on people during the pandemic. In order to overcome this burden, many robots with different properties have been implemented worldwide since the first cases of the Coronavirus in China.

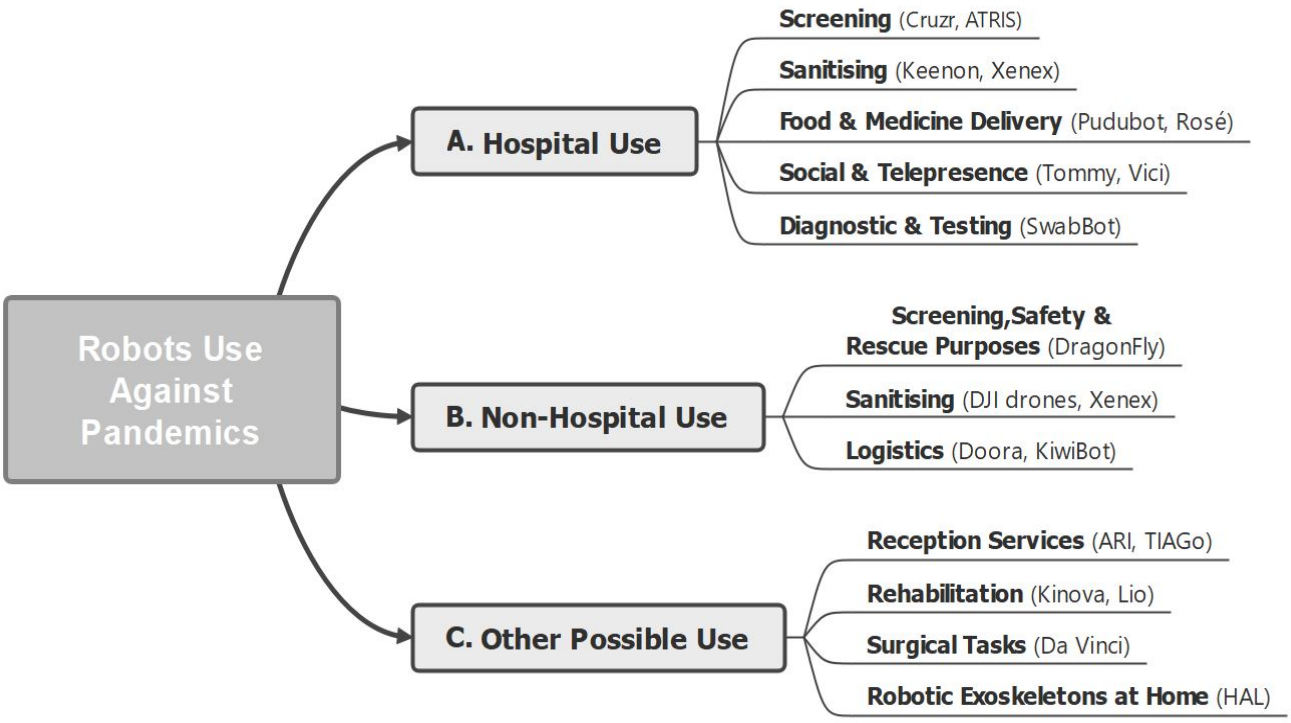

Fig. 1. Robots Against Pandemics

Many attempts have been implemented to identify where robots can be used to decrease spreading infectious diseases and save lives [11].

Robots have been already used in a large number of domains with different forms: mobile or stationary robots in various indoor and outdoor activities [11].Robots can be seen in hospitals,shopping centres and office enviroments for social interaction, care services,and logistics [12]. This section focuses on robots that have been implemented for hospitals, non-hospital use, and the other possible use. Figure 1 shows some robot examples used and can be exploited under the COVID-19 pandemic.

A. Hospital Use

The biggest challenges for hospitals are saving lives, reducing the fatality rate and protecting their professional staff who care for infected patients. The healthcare workers in hospitals and care centres are at a high risk —7 times than other workers— of being ill of Coronavirus as they take care of infected people daily under the pandemic [13]. Besides, the high number of patients in hospitals around the globe, shortage of masks for healthcare workers and other personal protective equipment (PPE) leads to the use of robots in hospitals as an intelligent and sustainable solution [14].

As a result, many robots deployed to minimise unnecessary contact between people and prevent virus transmission. Various robots were used in hospitals for versatile tasks such as screening, sanitising, food and medicine delivery, social and telepresence tasks, and diagnostic and testing.

1) Screening: The best ways to prevent virus transmission are not getting Coronavirus and performing many tests to identify the patients for early treatment and isolation [15]. In the first and early-stage to identify the COVID symptoms, healthcare workers measure the patient temperature, which can put the front- line workers in hospitals at high risk. Thus, a "Cruzr" robot from UBTECH used first in China to screen the patient temperature. This robot can measure 150 persons/min with a mask detection alert. UBTECH also has an "ATRIS" robot that can measure patients' temperature both indoors and outdoors [16].

Another example is a robot called "Dr Spot", created by MIT and Boston Dynamics- used in a hospital in Boston under the pandemic. The Spot robot could present the temperature, oxygen and pulse rate of patients. This robot's excellent feature is the ability to handle different obstacles and the stairs inside the hospital.

2) Sanitising: Reducing the number of viruses is the main goal for all places under pandemics, specifically in hospitals. The practical solution of killing the Coronavirus and reducing their numbers is sanitising the places that humans can reach. However, the high rate of infectious disease, shortage in masks and PPE, and the high demand for sanitised rooms in hospitals led to the implementation of many sanitising robots. Besides, sanitising robots save healthcare workers' lives—these workers who have taken massive responsibility and pressure under this pandemic. Sanitising robots can operate autonomously with less human interventions [11].

The mobile wheeled disinfection robots used in hospitals were Ultraviolet based systems (UV) and liquid base systems. The UV Disinfection robots use UV-C lamps because their lights penetrate the Coronavirus cell and damage their DNA. This light ensures killing the virus and germs on surfaces to 99.9% [16]. Among the disinfection robots are "Keenon", "TMiRob" used in China; "XDBOT" used in Singapore; "Tru-D SmartUVC", "Xenex Disinfection" robots used in the US; "Violet" robot used in Ireland; and the "Danish UVD" robots that are already launched in hospitals since 2015 [18]. It is worth mentioning that a drone was also tested for sanitising a hospital in Ireland [19].

3) Food and Medicine Delivery : Robots are unable to transmit viruses and can work 24/7 [11]. Thus, many robots were used for food and medicine delivery to reduce the workload for healthcare staff and the interaction with patients in hospitals.

Some of the robots like "Pudubot" and "Rosé" were already used to deliver food in hotels before the pandemic. However, they were adapted to be used for food and medicine delivery in hospitals under the outbreak. These robots make it easier for staff to focus on tasks where people can do so well, like caring, decision-making, and supporting labours.

The "Aethon TUG" robot is another example of a delivery service in hospitals that can deliver surgical instruments, drugs, meals and beverages, bed linen, and waste. This robot can perform whether scheduled delivery or tasks in demand [20]. "Zipline" drones used to deliver COVID samples, blood products, and drugs in Ghana and Rwanda [21]. While "Terra" drones were used to deliver medical samples in China [22].

4) Social and Telepresence : The fact that many hospitals are full of infected patients with overwhelmed staff is a challenge for many countries under the pandemic. Social robots were deployed in many hospitals to reduce the medical staff's work-life with less interaction with patients and connect the patients with their families [23]. In addition, the social robot can also reduce the social isolation caused by COVID-19 and improve the mental health of well-being [24].

Some examples of social robots are the "LHF-connect" robots that connect patients to their families and medical staff without any physical connection [25]. "Tommy" robot is the other robot that helps doctors and nurses during the COVID-19 pandemic in Italy. It has a touchscreen to record messages to the medical staff, allowing the patients to be connected to medical staff and reduce their isolation [26]. Another telepresence robot that connects doctors with their patients is the "Vici" robot from InTouch Health Company. These robots show practical and safe cases of using robots under the pandemic [27].

5) Diagnostic and Testing: The capacity of the COVID-19 tests has been increased enormously for containing the outbreak of this pandemic. The COVID test can perform either by a nasopharyngeal swab or an oropharyngeal sample through the mouth. In order to achieve the swab with less human intervention and minimise the overall exposure during the test, swab robots are safe and beneficial solutions.

The swab robot was tested at the University of Southern Denmark, showing a reduction in the sampling time to 50% [11]. "SwabBot" in Singapore was registered recently at the health sciences authority as a class A medical device with low to moderate risk to the user. This robot could reduce the workforce for the COVID test effectively [28].

The other domains where robots can tackle during the COVID pandemic and reduce the spread of the virus in hospitals are reception services, rehabilitation, and surgical tasks, which are presented later in the "Other Possible Use".

B. Non-Hospital Use

Robots have been implemented outside hospitals to minimise spreading the virus and reduce the infected cases. Thus, several robots have been deployed for non-hospital use for various tasks as screening, safety and rescue purposes; sanitising; and logistics.

1) Screening, Safety and Rescue Purposes: Mobile robots like drones were used since the outbreak in different countries like China, Spain, Italy, UK, France, UAE, Germany, India, the US and Australia. The police could announce some safety recommendations related to the pandemic, screen the crowd for wearing masks and social distancing, and detect people with high temperature, which is initially one of the COVID symptoms [29].

Some drones were commercially available, like "DraganFly", which is mounted with infrared cameras. In contrast, others like "Corona combat drones" were equipped with thermal, night vision cameras, and loudspeakers [30]. The "DraganFly" can detect fever, cough, heart rate, respiratory rate and blood pressure [31]. Nevertheless, other usages of drones are damage assessment in disaster, rescue people and searching for missing persons, especially when person-to-person contact puts humans in danger of spreading infectious disease [32] [33].

2) Sanitising: In Wuhan, where the COVID-19 emerged, robots with different forms were used to sanitise the city. Different robots such as drones, wheeled robots, and miniature tanks were deployed for indoors and outdoors disinfection tasks. Some robots used liquid sanitising, while others used UV light. UV Robots were used to disinfect trains like "VHP" Robots in Hong Kong, while others used in airports in Qatar [34], Hong Kong and the US [35].

Disinfection robots have attracted Airlines like Qatar airways to use "Honeywell's UV cabin cleaning" robot for disinfecting their aeroplanes [36]. Warehouses also found their way of using sterilisation robots like the "MIT" robot, which works at a speed of 744 square meters per hour [37].

Other cities like Dubai in the UAE has used agriculture drones for disinfecting the city [38], which was the same in China, where "DJI drones" were used for disinfecting public spaces. More disinfecting robots will be seen in restaurants, hotels and schools where some are already deployed like the "Xenex" robot [39].

3) Logistics : Since the COVID outbreak, many cities were locked down to slow down the spread of Coronavirus. For this

reason, ferries, aeroplanes, trains, public transport, and trucks negatively affected the delivery time and made it difficult for some goods to reach their destinations. But robots will solve the logistic problem by using drones or self-driving trucks.

In 2020, Amazon received approval from the Federal Aviation Administration (FAA) to use the drone to deliver customers' goods. Another drone is "Wing aviation" by Alphabet, which was also tested to deliver coffee and pastries in Virginia. It took 6 minutes to deliver a package to a destination that lies 6 miles away [40].

Wheeled robots for delivering food have also been used in many countries under pandemic. Some examples are "Doora" in Sweden [41], "KiwiBot", "Scout robot", and "DoorDash" in the US and the UK. "Nuro R2" robot for delivering groceries is also a promising solution under pandemics. Robot trash collectors like "DustCart" will also contribute to clean cities, especially in pandemics, when little human interventions are needed [42].

C. Other Possible Use

To date, not all robots are used under the pandemic, but still, several possible robots can be exploited for different usages to fight the pandemic in both hospital and non-hospital use. Several robots for reception services, rehabilitation, surgical tasks, and robotic exoskeletons at home are presented.

1) Reception Services : Humanoid robots are the eye-catcher that can also be used in the hospitals' receptions. Robots like "Nao" and "Pepper" from Softbank robotics, "ARI" and "TIAGo" from PAL robotics are practical social robots that can be used in receptions due to their adaptability for different services [43]. They offer potential tasks such as temperature screening and asking questions related to COVID symptoms without spreading the virus [44].

As the "Cruzr" robot that deployed for hospital use, it is a suitable solution for reception outside the hospitals due to sensitive facial and emotional recognition with many communications forms: text, voice and gesture [45]. Other reception robots for hospital and non-hospital use are "Snow", "Amy", "Alice" [46].

2) Rehabilitation : Rehabilitation sessions are necessary to reduce patients' disability and need to be continued under and after the pandemic due to its impact on an individual's health. However, many hospitals postpone the rehabilitation sessions offered for their patients due to a shortage of medical staff and in order to reduce the Coronavirus spread [47]. Thus, robots like "Armeo Spring", "Kinova", "ROBERT", "Lio", and "robotic exoskeletons" can be used to continue rehabilitation during the pandemics.

A robotic exoskeleton is a mechanical structure worn externally to compensate or empower human muscle weakness around limb joints [48]. Robotic exoskeletons can be implemented as aid devices in rehabilitation sessions as well as to support nurses in hospitals and reduce the number of employees.

3) Surgical Tasks : The elective surgery operations have been postponed in many hospitals under COVID pandemics. This has physical and mental negative implications due to the social isolation for patients who already have other physical difficulties.

The robots have already been tested in telesurgery operations where a surgeon manipulates the robot's arms from a counsel, which lies away from the robot, with less human interactions. The telesurgery robots can reduce the recovery time and save both patients and physicians from transmitting the COVID- 19 [11]. Thus, the "Da Vinci" robot is a solution to continue performing surgical operations, eliminate exposure to contagious patients and reduce the PPE, which is sustainable to the environment. Finally, there is also an early-stage of telenursing robot as "TRINA version 1.0", which uses Baxter robot from Rethink Robotics company to support nurses under the pandemic [49].

4) Robotic Exoskeletons at Home : Robotic exoskeletons help in hazardous environments and disasters like (HAL) which used in Fukushima Daiichi nuclear disaster, Japan [9]. Thus, more affordable robotic exoskeletons will also save lives in bad times as pandemic situations.

At present, many people are infected by the Coronavirus, and older adults are among the most affected and killed groups. Many older adults usually depend on humanitarian assistance in their daily lives. The human assistants can be asymptomatic carriers of COVID-19 and help to spread the virus among elderly people. However, robotic exoskeletons can reduce infected cases among individuals by making older adults independent in their daily activities and reducing close contact with people [50].

Robotic exoskeletons can be implemented as aid devices for patients during their incubation of the self-isolation period. Accordingly, the more available robotic exoskeletons in our daily lives will reduce the spread of infections and deter such contagious diseases in the future.

III. Discussion

The pandemic is like a war as no one has the advantage of it. However, this pandemic has collected scientists from multiple disciplines to beat this virus. The roboticists contributed by offering the latest robots innovated before the pandemics, and others were adapted to the critical situation associated with COVID-19.

We found that robots — wheeled and drones— have been deployed in different domains both in hospital and non-hospital use. The robots for hospital use have been dominated for multiple reasons: reduce the spread of the Coronavirus in hospitals where many infected patients gathered; reduce the work burden for overwhelmed healthcare workers; and overcome the shortage of healthcare staff and PPE in hospitals worldwide. Robots are sustainable solutions under pandemics because they reduce the number of employees, and the PPE and masks that are made of plastic.

Non-hospital use of the robots was also restricted to government use, as robots mentioned in this paper are still expensive devices and used by rich countries. Several possible usages of different robots that can also be used under pandemics are

reception services, rehabilitations, surgical tasks and robotic exoskeletons at home.

Interestingly, robots demand will be high under the time of pandemics, thus Robot Operating System (ROS) will offer a robust framework where many ROS developers and roboticists can collaborate faster to provide various robots that operate for various applications and environments.

IV. Conclusion

COVID-19 is still claiming humans lives and causing overwhelmed medical staff and hospitals full of infected patients. Many politicians lockdown their cities, and some recommendations like washing hands, keeping distance, and staying at home were announced worldwide to stop spreading the virus that causes a massive fatality.

In fact, it takes time to invent, develop, manufacture and distribute a new vaccine that eliminates such diseases, and to slow down the spread of such infectious disease, robots with different forms have been used. Since the latter cannot catch viruses that are restricted to living medium. Different robots are still used in hospital, and non-hospital use as this pandemic continues.

Robots for hospital use have potential roles in multiple domains such as screening, sanitising the surfaces, food and medicine delivery, and social and telepresence activities.Robots for non-hospital use contributed to screening, safety and rescue purposes, sanitising and logistics.

Still, this paper does not cover all the robots under the pandemic as the pandemic is ongoing. However, other possible usages of different robots are discussed, which can be implemented for both hospitals and non-hospital use under this pandemic. Thus, as robots help to slow down the spreading of a deadly virus, more investments to innovate affordable robots are needed for fighting such pandemic in the future.

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