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The Novel Coronavirus (COVID-19) Series

Webinar

Artificial Intelligence in the Battle Against COVID-19

Dr. Alaa Khamis
University of Toronto

3 May 2020

Foreword

Prof. Mostafa El Feki

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CSSP

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برنامج دراسات التنمية المستدامة وبناء قدرات الشباب ودعم العلاقات الإفريقية
Sustainable Development Studies, Youth Capacity Building, and African Relations Support Program

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Foreword

The novel coronavirus COVID-19 pandemic has posed a wide range of unprecedented challenges. Such universal challenges have placed the Bibliotheca Alexandrina (BA) more than ever before its mission and social responsibility. Therefore, the BA was keen to make all its cultural and scientific events electronically available and to host a diversity of intellectual figures to discuss the developments of the pandemic and the subsequent new realities. The BA has put its assets and human capital best to serve its enlightening mission in this delicate circumstance.

Emphasizing the BA's pioneering and enlightening role, as it is a digitally-born institution in this digital age, we have launched, through the Center for Special Studies and Programs, and the Sustainable Development Studies, Youth Capacity Building, and African Relations Support Program; at the Bibliotheca Alexandrina's Academic Research Sector, a series of webinars tackling COVID-19 pandemic from different aspects, this webinar series aimed at providing futuristic perspective, also presenting the overlapping repercussions of this pandemic on our planet, environment and public health generally, in addition to other topics closely related to this pandemic and its effects.

In this series of webinars, we were keen to present the different aspects of this pandemic by presenting the viewpoints of eminent scientists and decision-makers; politicians and government officials, who have generously contributed to enriching this series of webinars with their invaluable knowledge and expertise. This series was successful in both the general public and academic circles. Thousands of specialized and non-specialized audiences followed it.

Therefore, the Bibliotheca Alexandrina decided to publish this series of valuable booklets, which represent a summary of the distinguished scientific discussions and theses that were presented during the Bibliotheca Alexandrina virtual seminar series on the novel coronavirus COVID-19.

Prof. Mostafa El Feki

Director, Bibliotheca Alexandrina

Introduction

Throughout history, science has always played a vital role in critical times. Timely communication of research results about critical events has always been a big responsibility on the scientific community. In line with the Bibliotheca Alexandrina's (BA) enlightening mission, the BA Academic Research Sector has put all its efforts to support that role by holding various events and initiatives, as well as producing a variety of publications.

Since the outbreak of the COVID-19 pandemic, all platforms were dedicated to broadcast updates on the pandemic. It was a big challenge, especially for the public, to grasp and follow up with what science says about this vicious pandemic. Another big challenge was the dissemination of trusted information that comes from specialized calibers, who can effectively communicate scientific facts to different audience.

In line with the BA's mission to be a center for the dissemination and production of knowledge, the BA Academic Research Sector has launched a series of webinars on the COVID-19 pandemic, through both its centers: the Center for Special Studies and Programs, and the Sustainable Development Studies, Youth Capacity Building, and African Relations Support Program. This series of webinars highlighted up-to-date research results and what science says about that pandemic.

Given the vital role that Information Technology and Artificial Intelligence (AI) are playing in our life, we dedicated the first webinar in the BA Academic Research Sector Webinar Series on COVID-19 to tackle AI & COVID-19. The following pages outline the working paper that was presented by Dr. Alaa Khamis, AI and Smart Mobility Technical Leader at GM Canada and AI Lecturer at the University of Toronto, Canada, at the first webinar, which is entitled "Artificial Intelligence in the Battle Against COVID-19". The webinar highlighted the many roles AI technologies play in fighting the New Coronavirus (COVID-19) pandemic and the resources available in this area to deal with the effects of the pandemic. Potential applications of AI in this accelerating pandemic include, but are not limited to, early detection and diagnosis, massive agent modeling and simulation, data analytics, assistive robots, disinfection robots, public awareness and patrolling, contactless last-mile delivery services virtual healthcare assistants (chatbots) and drug repurposing/discovery and vaccine development. Dr. Khamis highlighted a number of potential applications to transform these challenges into opportunities. He also presented information on Artificial Intelligence types and characteristics, and how it is compared to natural or human intelligence.

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Artificial Intelligence in the Battle Against COVID-19

Dr. Alaa Khamis
General Motors Canada and University of Toronto

Summary

Since the outbreak of the novel Coronavirus (SARS-CoV-2) and its highly contagious disease COVID-19, the Artificial Intelligence (AI) and robotics communities quickly mobilized and gathered to offer solutions ranging from data analytics, predictive modeling, early detection and diagnosis, assistive robots, disinfection robots, public awareness and patrolling, contactless last-mile delivery services, drug repurposing, vaccination discovery to laboratory automation. This paper sheds light on the roles AI plays in fighting this disastrous pandemic. The paper highlights a number of potential applications to transform this unprecedented challenge for humanity into opportunities.

Introduction

Globally, as of the last week of June 2022, there have been 540,923,532 confirmed cases of COVID-19, including 6,325,785 deaths, reported to World Health Organization (WHO). This accelerating pandemic changes all the aspects of our lives and will leave some scars in the post-pandemic world as well. It impacts the way we learn, work, entertain, purchase, interact with each other; how government organizations provide services; how education institutions teach and conduct research and how companies run, grow and deal with a world continuously changing in unprecedented and unpredictable ways. Since characterizing COVID-19 as a pandemic on 11 March 2020, WHO recommends several public health measures to deal with the pandemic such as social distancing, wearing masks, finding, isolating, testing and treating every case and trace every contact. Since the beginning of this pandemic, the artificial intelligence and robotics communities quickly mobilized and gathered to offer solutions ranging from data analytics, predictive modeling, early detection and diagnosis, assistive robots, disinfection robots, public awareness and patrolling, contactless last-mile delivery services, drug repurposing, vaccination discovery to lab automation.

Artificial Intelligence (AI) is an evolving technology not a totally new one as its seeds can be traced back to the classical philosophers and their efforts in modelling human thinking as a system of symbols that led to "connectionism" as process of thinking. AI aims at mimicking/reverse-engineering and augmenting biological intelligence to build intelligent systems/processes able to function and interact autonomously within structured/unstructured, static/dynamic and fully/partially observable environments. This usually involves borrowing characteristics from human intelligence such as situation awareness, decision making, problem solving, learning from the environment and adapting to its changes(1). AI encompasses many sub-fields such as perception (including object recognition, image understanding, speech recognition, speech synthesis, natural language understanding), knowledge representation, cognitive reasoning, machine learning, data analytics (such as descriptive, predictive, diagnostic and prescriptive analytics), problem solving (such as constraint satisfaction, problem solving using search and optimization), distributed AI and acting (such as virtual assistants and robots) as illustrated in Figure 1.

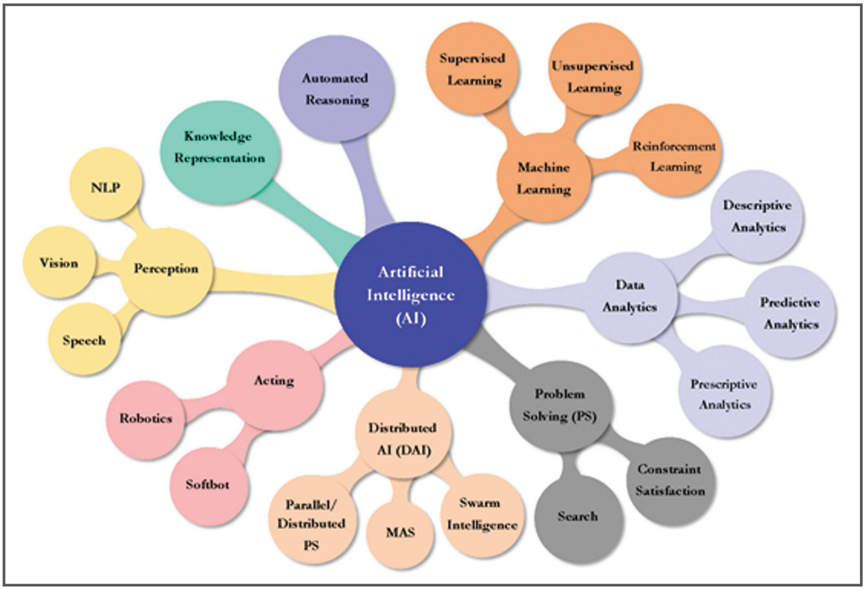

Figure 1. AI sub-fields(2).

This paper describes a number of current and potential future applications of AI and robotics in the battle against the novel Coronavirus and its disease COVID-19. The remainder of this paper is organized as follows: Section 2 describes data analytics and predictive modeling proposed during the pandemic. Different applications of AI and robots as essential workers are discussed in Section 3 covering monitoring, early detection and diagnosis, indoor and outdoor disinfection, public awareness and patrolling, medical robots for infectious diseases, virtual healthcare assistants and chatbots. Section 4 focuses on the role of contactless last-mile delivery in fighting the coronavirus pandemic and provides some examples of delivery robots tested during the pandemic as a contactless way to deliver medicine, food or grocery. Section 5 highlights AI and robotics applications in the area of drug repurposing/discovery and vaccination discovery and describes lab automation during vaccine discovery and production. Finally, concluding remarks are summarized in Section 6.

Data Analytics and Predictive Modeling

The ongoing and accelerating pandemic of COVID-19 has generated substantial interest in data analytics and predictive modeling for infectious diseases. AI-powered data analytics provides the ability to discover, recognize and predict complex patterns and trends in different types of data at different levels of abstractions. During the pandemic of SARS-CoV-2, multimodal data is collected by robots, cell phones and wearable devices. This data can be archived, steaming, and/or live data, structured and/or unstructured data, numerical and/or non-numerical (text, image, audio, and video) and multimodal data. Examples of the data include, but are not limited to, body temperature, heart rate, breathing rate, SpO2 (also known as oxygen saturation), blood pressure, acoustic data, accelerometer data, ultrasound, Computerized Tomography (CT) scans/chest radiography, depth camera data and mobility data, to name just a few. Insights are the new gold not the data as data is worth very little unless this data is turned into critical actionable insights. In the context of coronavirus and COVID-19 pandemic, the insights play a crucial role in the understanding, prediction, and decision-making processes. Researchers use four main types of data analytics, namely, descriptive analytics, predictive analytics[3].

Descriptive data analytics provides insight into the past and the present while predictive analytics forecasts the future. Diagnostic analytics detect anomalies and provides root-cause analysis. Perspective analytics advises on possible outcomes and their anticipated impacts. Some more details are provided here about descriptive analytics and predictive modeling. Descriptive data analytics provides a better understanding of the data and its nature and identifies patterns or relationships in the data. Various web-based tools and mobile apps provide different forms of descriptive analytics for COVID-19 such as the Johns Hopkins Coronavirus Resource Center, Worldometer, COVID visualizer and DOMO Coronavirus Tracker. This publicly available information helps achieve public health measures advocated by WHO. Some tools were developed to facilitate contact tracing (CoronaMap), search for masks (Maskmap), visualize the disease transmission and show how the community is responding differently due to COVID-19. Apple and Google built a coronavirus tracking system into iOS and Android allows users to share data through Bluetooth Low Energy (BLE) transmissions and approved apps from health organizations.

Predicting future states using hand-crafted mathematical models or using data-driven approaches depends on a number of factors such as targeted prediction (exact values, reasonable range, trend, seasonality, etc.), type of data (stationary versus non-stationarity), desired forecast window and availability of a priori knowledge. Generally speaking, predicting exact values of non-stationary variables for an extended forecast window is challenging unless there is enough multimodal data and a priori knowledge about the variables of interest. For example, COVID-19 cases cannot be accurately predicted using only past and current case counts reported by WHO and applying oversimplified data mining algorithms such as moving average, auto regressive moving average, logistic regression, etc. Infectious disease models or epidemiological models that incorporate transmission dynamics and clinical dynamics should be considered. Existing infectious disease predictive models are oversimplified or a repurposed version of similar disease models assuming that the novel coronavirus SARS-CoV-2 behaves like influenza or SARS-CoV. These models cannot be fully trusted to make decisions. This is mainly due to lack of sufficient information about the novel coronavirus and COVID-19 such as self-mutation capability of the virus, incubation period, how it spreads, what are all the different ways the virus can be transferred between people, what is the transmission time or how long does it take to transmit the virus to other persons from the moment the virus enters a person’s body, how temperature and humidity can impact virus transmission, a priori knowledge and demographic information as age, gender, blood type, other diseases, previous vaccination record, etc.

Robert Koch Institute developed a predictive model based on not only current case counts of WHO but also using a novel epidemiological model that integrates the effect of population behavior changes due to government measures and social distancing. This predictive model can provide 6-day forecasts of COVID-19 case counts by country. However, Robert Koch Institute stopped providing any further updates in May 2020 as many countries implemented strategies to contain the further spread of the disease, which slowed growth of cases over time. This effect violates some assumption in the model. The predictive model of Institute for Health Metrics and Evaluation(4) at the University of Washington has a wide range of projections for deaths from COVID-19 based on different underlying assumptions and how they change, such as the effect of social distancing or widespread testing. Due to lack of sufficient data, trustable predictive models need to focus on predicting trends and reasonable ranges, rather than exact numbers. As we collect more unbiased and consistent data and gain more information about this novel virus, these predictive models will get better and more trustworthy.

AI and Robots as Essential Workers

Since the pandemic began, several AI and robot-making companies mainly in China, Europe and North America deployed smart medical devices and services and an army of robots to serve as essential workers in the hospitals and for many other tasks to help fight coronavirus and COVID-19. During the early stage of the pandemic, inexpensive, pocket-size portable ultrasound was used as a diagnosis tool(5). Non-invasive method for early detection and diagnosis was tested as it does not require specialized medical imaging equipment and uses footage from Kinect depth cameras to identify respiratory patterns of patients(6).

A Gated Recurrent Unit (GRU) neural network is applied first with Bidirectional and Attention Mechanisms (BI-AT-GRU) to classify six clinically significant respiratory patterns. Li and Qin, *et al.*(7) proposed a three-dimensional deep learning framework to detect COVID-19 using chest CT, named COVID-19 detection neutral network (COVNet). University of Waterloo VIP Lab develops a COVID-Net: a convolutional neural network for COVID-19 detection via chest radiography (13,800 chest X-rays of 13,725 cases from around the world).

In China, supercomputer Tianhe-1 is used to provide doctors around the world with free access to an artificial intelligence diagnostic tool for early identification of COVID-19 patients based on a chest scan. This AI system on the Tianhe-1 computer can go through hundreds of images generated by Computed Tomography (CT) and give the diagnosis in about 10 seconds[(8)].

Robots perform many assistive tasks during the pandemic to mitigate the risk to healthcare professionals. Applications of assistive robots include, but are not limited to, helping medical staff avoid infection from virus patients, early detection and diagnosis, medical care, nursing, patient monitoring, performing lab work, cooking and serving medication, meal delivery to patients in isolation wards, indoor and outdoor disinfection and public awareness and patrolling. For example, Saskatchewan Remote Presence Robots are used to deliver health care to rural and remote regions of Saskatchewan, Canada, in order to protect physicians on the front lines fighting the COVID-19 pandemic. Doctors use the mounted iPad on Spot to remotely interact with coronavirus patients, ask them questions in order to assess the patients. Tommy helped Italian medical teams in treating COVID-19 patients (see Figure 2).

Figure 2. Tommy, the robot nurse. Credit: Flavio Lo Scalzo/Reuter, see:
Flavio Lo Scalzo, phot., "A Robot Helping Medical Teams Treat Patients Suffering from COVID-19 Is Pictured at a Patient's Room, in the Circolo Hospital, in Varese, Italy on April 1, 2020", online e-picture, under "Tommy, the Robot Nurse Helps Italian Doctors Care for COVID-19 Patients", *The World*, 8 April 2020, https://theworld.org/stories/2020-04-08/tommy-robot-nurse-helps-italian-doctors-care-covid-19-patients.

University of Southern Denmark and Lifeline Robotics researchers developed fully automated swab robot (Figure 3) that uses computer vision and machine learning to identify the perfect target spot inside the person's throat; then a robotic arm with a long swab reaches in to collect the sample—all done with swiftness and consistency that humans cannot match[9].

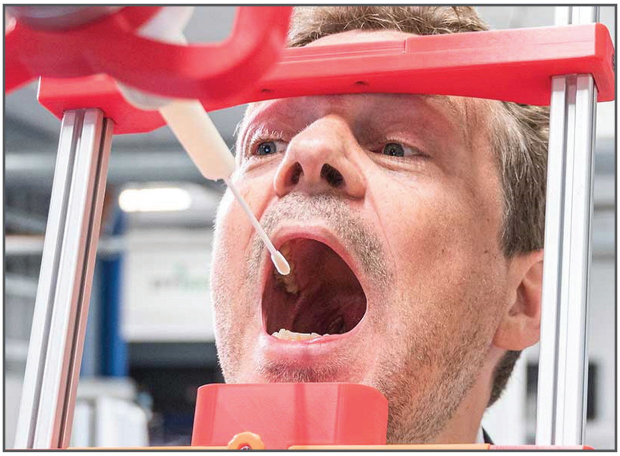

Figure 3. Swab Robot. Credit: University of Southern Denmark, see: "Lifeline Robotics' Throat Swabbing Robot Collecting a Sample from Co-founder Esben Østergaard", online e-picture, under "Danish Startup Develops Throat Swabbing Robot for COVID-19 Testing", *The Robot Report*, 27 May 2020, www.therobotreport.com/danish-startup-develops-throat-swabbing-robot-for-covid-19-testing.

Monitoring, detecting and tracking patients and the transmission on a large scale in a timely manner, and publishing the data of infected and suspected infections are crucial in prevention and control measures to minimize further transmission. For example, pandemic drones equipped with temperature and computer vision sensors are used in China to detect symptoms of infectious respiratory disease. Recently, drones with infrared thermal imaging are used to monitor temperatures, heart and respiratory levels from a distance up to 10 m and can detect coughing and sneezing. This can provide researchers with a clear view of infections in public areas and other crowded places such as airports and health care facilities. AI helmets and AI-powered glasses are used by the Chinese police to identify faces of vehicle occupants and license plates. Alerts are triggered if the vehicle occupant's information is found in the database of confirmed cases. AI-driven smart wearable medical devices are used in personnel positioning, contact tracing and alarms, and in early warning of areas with potential risks and for continuous monitoring of the patients. For example, the Advanced Internet Technology has developed INSEE, an auxiliary device that attaches to an incentive spirometer that helps patients improve their lung function by measuring their air volume as they breathe[10]. Moreover, wearable integrated sensor patches can be used to simultaneously capture multiple vital signals and send the data to the COVID-19 patient's phone. These patches can integrate a number of sensors to measure respiratory rate, heart rate, body temperature through skin sensing, SpO2, Pulse Transit Time (PTT) and Electrocardiogram (ECG). Access to this data will enable precision healthcare services to COVID-19 patients based on real-time rapid response to significant clinical changes. A microphone and accelerometer can be also integrated to capture the coughing and sneezing sounds and vibration of the body during coughing/sneezing to support the analysis of severity detection. The accelerometer provides rich information to correlate with the breathing sensor to accurately profile respiratory conditions. Machine learning models can be trained with this data to capture progressive deterioration or improvements in the patient's status.

During the pandemic, many health care providers managed to reduce in-person visits for a variety of patients by providing consultations over the phone or by video conference as a way to protect both patients and staff and to stop the spread of COVID-19. Virtual telemedicine assistants and chatbots have been employed as communicative agents that provide remote diagnosis and resources to protect people and advise users whether or not they need to visit medical care centers.

The widespread COVID-19 disease has sparked a need for the continuous disinfection for hospitals, public places, public transit and airplanes. Disinfecting surfaces and the environment, performed routinely in hospitals, has always been essential for infection prevention and control. Beyond regular surface wiping with highly efficient detergents, a key strategy has been to allow the active ingredient to spread to all areas of the room, however this also needs complete lockdown and heavy air ventilation. Several disinfection robots equipped with Ultraviolet (UV)-C irradiation (200–280 nm) are used during the pandemic in disinfecting hospital rooms. Germicidal UV lamps can destroy vicious viruses without harming humans and the ubiquity of this UV technology should make it much harder for an outbreak to spread[11]. Robots equipped with UV lamps are considered as an effective technology for disinfection, preventing any harm to humans (Figure 4).

Figure 4. Disinfecting robot consisting of a mobile base equipped with multiple LIDAR sensors and an array of UV lamps mounted on top. Credit: UVD Robot, see: "Hundreds of These Ultraviolet Disinfection Robots Are Being Shipped to China to Help Fight the Coronavirus Outbreak", online e-picture, under "Autonomous Robots Are Helping Kill Coronavirus in Hospitals", *IEEE Spectrum*, 11 March 2020, https://spectrum.ieee.org/autonomous-robots-are-helping-kill-coronavirus-in-hospitals.

Robots equipped with high-power speakers have been widely used for the fight against COVID-19 to raise public awareness and for patrolling large gatherings. Warnings are broadcasted to the crowd. For example, drones in China are used to identify people not wearing masks. People are reminded by drones to wear masks. At the same time, drones can detect people quickly through thermal imaging and target recognition systems. Another example is Boston Dynamics' Spot that is used at parks to remind visitors of social distancing measures. A police robot is used in Tunisia for patrolling the streets of the capital calling out suspected violators of the lockdown(12).

Contactless Last-mile Delivery Services

Social distancing is the main measure taken to reduce the spread of this highly contagious virus through minimizing the contact between people. However, frontline workers who treat the patients or deliver medicine or food to them and even people at home who order essential goods like medication or grocery are still at risk. Last-mile delivery is the last leg of transportation that focuses on the movement of goods from a warehouse or a distribution store to the final delivery destination, which is usually located around 11 miles or 17 kilometers from the warehouse. Various innovative solutions for last-mile delivery are currently being developed or tested to reduce the delivery cost, increase customer satisfaction and minimize the negative environmental impact. These solutions include, but are not limited to, cargo-bikes, semi and fully autonomous last-mile delivery, delivery Droids (Bots), e-palette, postal delivery, smart lockers, driverless deliveries and privately-owned autonomous vehicles. Contactless last-mile delivery has witnessed an unprecedented importance and a sharp demand rise during the pandemic as a way to ensure sufficient social distance between medical staff and patients in the hospitals and between people during delivery. Contactless last-mile delivery systems and services can result in avoiding physical contact between caregivers and patients, or between delivery workers and the recipients. Several systems have been deployed and tested during the pandemic for medical supplies(13), medications(14), food, grocery and other goods(15),(16). For example, Nuro(17) driverless vehicle has been approved for delivery tests in California in April 2020. This delivery robot uses its small fleet of road-legal delivery robots to transport pharmaceuticals to CVS customers in Houston, Texas, as shown in Figure 5.

Figure 5. Nuro driverless vechiles. Credit: Nuro, see: “Nuro: Now Ready to Deliver Prescriptions”, online e-picture, under “CVS Pharmacy Prescriptions Go High-Tech with Self-Driving Delivery”, *CNET*, 28 May 2020, www.cnet.com/roadshow/news/cvs-pharmacy-prescriptions-delivery-nuro-self-driving/.

Customers who live in the service area can choose the autonomous delivery option when they are placing prescription orders via CVS.com or the CVS app. Nuro has a high security level as customers will need to confirm their identity to unlock their delivery when Nuro’s autonomous vehicle arrives curbside at their home.

Vaccination Discovery and Lab Automation

Various research labs, businesses and start-ups have innovatively changed their work goals in order to use AI to speed up the quest for a cure against COVID-19. The White House Office of Science and Technology Policy announced the COVID-19 High Performance Computing Consortium, a partnership that includes IBM, the Energy Department National Laboratories, Alphabet Inc. Google Cloud, Amazon.com Inc. Amazon Web Services, Microsoft Corp. and others. To help researchers easily synthesize and test new candidate molecules against COVID-19, the European IA-centric starting Molecule.one has laid down a proprietary synthesis method for open access to the scientific community. IBM's AI frameworks have been used to cover three COVID-19 targets, and 3000 novel molecules have been developed. Such molecules were published to the science community for synthesis, processing and optimization, under the Creative Commons License (CCL). A list of 97 small molecules candidates intended to inhibit the SARS-CoV-2 3CL protease has been published by In Silico Pharmacy, a Hong Kong based drug development company. A variety of fast virtual screening AI models with existing public and commercial compound libraries as key repositories have been developed and evaluated against COVID-19, respectively. Essentially, numerous research avenues have combined AI models for future therapeutics to be produced at an unparalleled speed for COVID-19.

At the beginning of the pandemic several researchers focused on repurposing existing drugs to treat COVID-19 using Biomedical Knowledge Graphs (BMKG). BMKG are networks that show the relationships between proteins and drugs in order to facilitate higher level exploration of how they connect to each other. By employing AI search techniques, IBM supercomputer—called "Summit" and housed at the Oak Ridge National Laboratory in Tennessee—has identified 77 treatments that may have a potential to stop COVID-19. Stanford Research Institute (SRI) International and Iktos started collaborating earlier this year to combine AI and novel automated discovery platform in order to accelerate the development of new anti-viral therapies. Iktos is a start-up AI company specialized in the development of AI technologies and software for ligand-based and structure-based de novo drug design focusing on multi parametric optimization. SRI International and Iktos managed to design and synthesize a first round of antiviral candidates for COVID-19 virus in four months. Figure 6 illustrates the used automated inkjet printer platform (SynJet) to test the routes by printing out tiny quantities of chemical ingredients to see how they react. If the right compound is produced, the platform tests it[18].

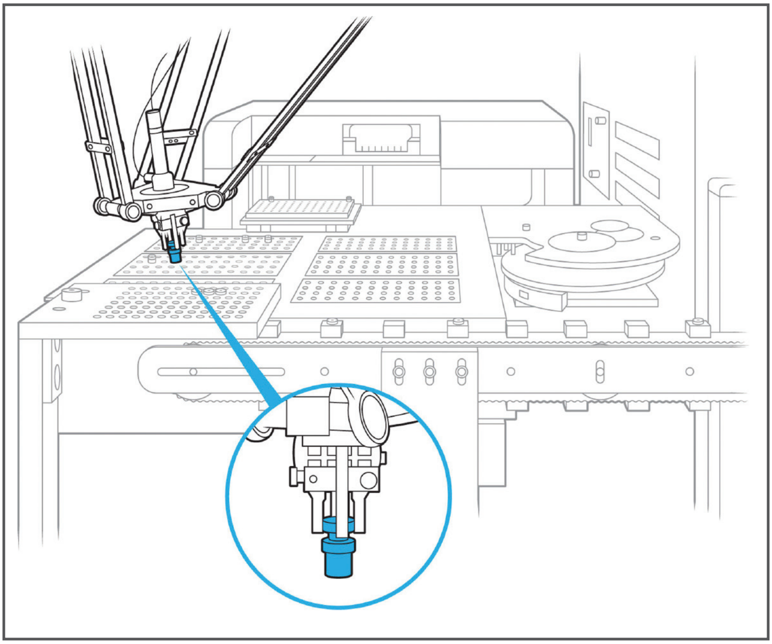

Figure 6. The Automated Inkjet Printer Platform (SynJet)[19], see:
"SRI 의 로봇은 잉크젯 프린터 기술로 항바이러스 분자를 극소량 시험 합성해 설계대로 치료제가 만들어지는지 확인한다. IEEE 스펙트럼 제공", online e-picture, under "[코로나19 연구속보] 인공지능, 코로나와의 전쟁 끝낼 주력군 양성한다", **과학동아**, https://m.dongascience.com/news.php?idx=39918.

Cell culture system is the first step in drug testing and drug development. Knowing protein structure is important to understand how it functions. Figuring out what shapes proteins fold into is known as the "protein folding problem", and has stood as a grand challenge in biology for the past 50 years. Experiments may take a few months or longer. Researchers developed computational methods to predict protein structure from amino acid sequence much faster. To solve the protein folding problem, DeepMine has recently developed the AlphaFold model based on a dilated ResNet (Residual Neural Network) architecture. This system has been applied to predict the structures of six proteins related to SARS-CoV-2 (SARS-CoV-2 membrane protein, protein 3a, Nsp2, Nsp4, Nsp6, and papain-like proteinase)[20].

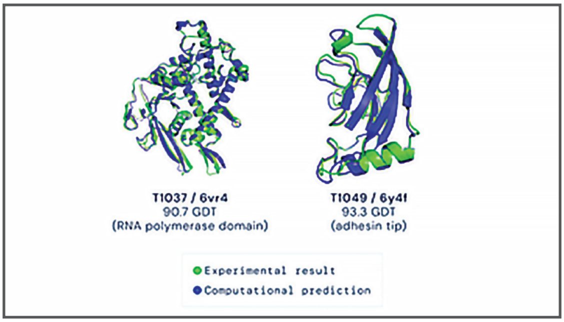

Figure 7. DeepMine's AlphaFold model accurately predicts 3D structures measured against experimental results. Credit: DeepMind, see: "Two Examples of Protein Targets in the Free Modelling Category", online e-picture, under "Developing an AI Solution to 50-Year-Old Protein Challenge", *Phys.org*, 30 November 2020, https://phys.org/news/2020-11-ai-solution-year-old-protein.html.

According to a recent Critical Assessment of Protein Structure Prediction (CASP13)—a blind assessment of the state of the field—AlphaFold created high-accuracy structures for 24 out of 43 free modelling domains, whereas the next best method, which used sampling and contact information, achieved such accuracy for only 14 out of 43 domains[(21)]. Figure 7 shows two examples of protein targets in the free modelling category.

Vaccine discovery and production require a massive amount of experiments and processes. This arises the need to use robots in laboratories in order to automate repetitive and time-consuming tasks such as sample processing, goods delivery, and for conducting experiments. Lab automation is the application most frequently requested during Ebola and COVID-19 pandemic[(22)]. To address the need for expanded testing capacity, the Innovative Genomics Institute (IGI) at UC Berkeley established a clinical testing laboratory for SARS-CoV-2 (Figure 8) in three weeks[(23)].

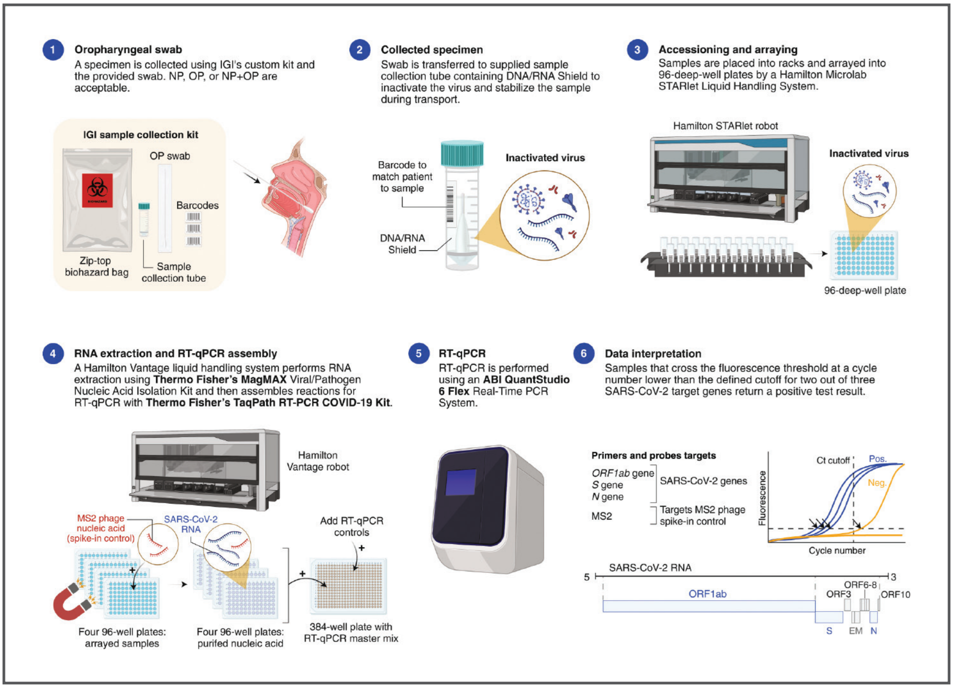

Figure 8. Innovative Genomics Institute (IGI) SARS-CoV-2 Testing Lab[24].

The Rapid Automated Biodosimetry Tool (RABIT)[25] is designed to be a completely automated, ultra-high throughput robotically-based biodosimetry workstation that can output dose estimate without human intervention after placing the test tubes. It is planned to increase the test capacity of this workstation from approximately 6,000 samples per day to reach 30,000 samples per day after parallelizing various steps.

Codex DNA, Inc. created several automated tools to expedite vaccine development, drug discovery, and diagnostics. For example, the BioXp 3200 system (Figure 9) was the world's first fully automated system for high-throughput writing of DNA. Both Pfizer and Moderna vaccines both use mRNA technology. The BioNTech/Pfizer vaccine, also known as BNT162b2, Tozinameran or Comirnaty has a 4284 characters long digital code at its heart. This code can be uploaded to a DNA printer (Figure 9), which converts the bytes on disk to actual DNA molecules. RNA is the working memory version of DNA that is volatile similar to the RAM in computers. As messenger RNA (mRNA) is a single-stranded fragile molecule, the Pfizer/BioNTech vaccine must be stored in the deepest of deep freezers.

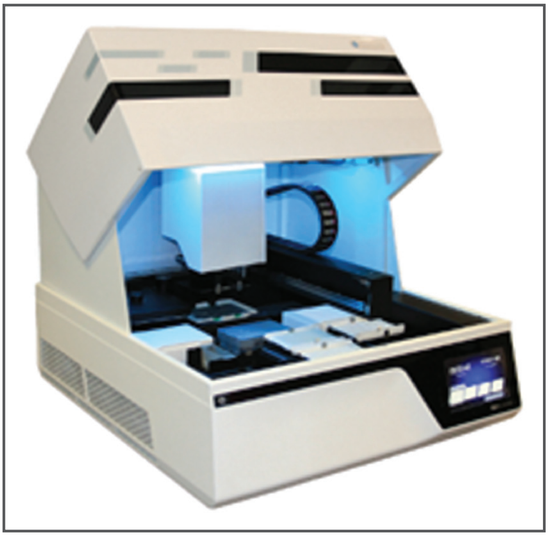

Figure 9. BioXp 3200 DNA printer. Credit: Codex DNA, see: “DNA Printer”, online e-picture, under “SGI-DNA Receives Frost & Sullivan New Product Innovation Award for BIOXP 3200 Product”, *NOVO Engineering*, https://novoengineering.com/news-blog/sgi-dna-new-product-innovation-award/.

Automated tools and systems[26] developed by Codex to accelerate the development of solutions to combat COVID-19 include:

- Codex SARS-CoV-2 diagnostic RNA controls: Safe and robust positive controls that replace the need for live virus in RT-PCR and NGS testing protocols;

- Codex SARS-CoV-2 antigen panels: Allow for rapid design and iteration of antigens (such as Spike protein) for the development of vaccines using the BioXp system (Figure 9);

- Codex SARS-CoV-2 antibody libraries: Allow for rapid design and generation of antibody libraries for the development of therapeutics using the BioXp system;

- Codex SARS-CoV-2 Spike protein DNA vaccine construct: Wild-type Spike protein cloned in the DNA vaccine vector of your choice;

- Codex SARS-CoV-2 mRNA vaccine scaffold: mRNA vaccine scaffold design and synthesis on the BioXp system;

- Codex SARS-CoV-2 live attenuated vaccine scaffold: Leverage the Codex full-length, synthetic SARS-CoV-2 genome for the development of live attenuated vaccines;

- Codex SARS-CoV-2 synthetic DNA parts: Spanning the whole genome useful for developing DNA, RNA and viral vector vaccines and pan-genome diagnostics; and

- Codex SARS-CoV-2 full-length, synthetic genome: Leverage the Wuhan-Hu-1 strain of SARS-CoV-2 (GenBank number MN908947.3) cloned in a bacterial artificial chromosome for the development of vaccines, therapeutics, and diagnostics.

Major companies as Pfizer and BioNTech, Moderna, Johnson & Johnson, Novavax, AstraZeneca, Sanofi and GlaxoSmithKline acquired manufacturing capacity needed to produce and supply the world with a COVID-19 vaccine in 2021. These companies have already started producing millions of doses of potential vaccine by end-2020. Some logistical challenges are still facing the mass distribution of the vaccine specially in case of Pfizer and BioNTec vaccine that requires storage in ultra-low temperature (about –70 degrees Celsius). In order to solve this problem, Pfizer has built packaging equipped with a cooling system that can keep the vaccine cold for up to 30 days if it is refilled with dry ice every five days.

Conclusion

The outbreak of the novel coronavirus and its disease COVID-19 presents an unprecedented challenge for humanity. AI is an evolving technology that plays several vital roles in the COVID-19 pandemic. This paper sheds light on the roles AI plays in fighting this disastrous and accelerating pandemic by describing a number of potential applications to transform this unprecedented challenge into opportunities. These applications include, but are not limited to, early detection and diagnosis, data analytics and predictive modeling, assistive robots, disinfection robots, public awareness and patrolling, last-mile delivery services, chatbots for medical care, vaccination discovery and lab automation. However, we need to fully understand both the strengths and the limitations of AI-based systems for not over-trusting the technology and creating false arguments especially in critical health-related tasks. AI has to be regulated and smartly directed toward the benefit of humanity. Measures have to be taken to protect digital rights, stop the surveillance once the pandemic is over, ban new totalitarianism of surveillance technology and digital totalitarian states. This pandemic has shown us and the world leaders the urgent need to invest more in sustainable development and in life-saving machines, healthcare services and medical research. The pandemic created an unprecedented spirit of collaboration in the global science community and showed the need for open source knowledge, information and data, resource sharing, and global solutions for the global challenges as a new norm in the post-pandemic world.

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