



# COVID-19 in the era of artificial intelligence: a black swan event?

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Artificial intelligence (AI) has played a crucial role in the management of the COVID-19 pandemic. BlueDot, an AI application which uses machine learning and language processing to process big data and predict disease outbreaks, flagged an unusual cluster of pneumonia in Wuhan, China on December 31, 2019. BlueDot had identified a new viral infection which would become recognized as the COVID-19 pandemic, nine days before the World Health Organization sent out the alert about a novel coronavirus infection.

The COVID-19 pandemic came at a time of innovative progress in AI applications. The lockdowns, social distancing and isolation has forced much of the population to become dependent on digital networks for school, work, healthcare and commercial transactions. This has caused a rapid digital transformation in education, the economy and industry (1). The digital acceleration has led to rapid adoption and scaling of AI and analytics. The remoteness has led to unexpected collaboration between different disciplines, different scientific institutions and science and industry. Entities which were previous competitors cooperated, leading to sharing of data and ideas resulting in pioneering applications (2). Mobile phones, wearable devices, social media networks, online commercial and other transactions have enabled us to track and analyze behavior on a digital scale. Such social computational data has multiplied as a result of the pandemic.

The COVID-19 pandemic has produced a large amount of clinical, laboratory, radiological, genomic, transcriptomic,

and structural data. AI needs outcomes to validate it and COVID-19 has multiple outcomes (asymptomatic, mild, severe, death and long COVID). The magnitude of the pandemic has generated massive amount of data in a brief time along with quick outcomes leading to pioneering AI applications.

Although big data has been around, the pandemic has provided big data with quick outcomes in an environment of widespread digital usage and interdisciplinary cooperation. This has led to expedited processing and analysis of the data resulting in AI solutions for the diagnosis, vaccine development and management of COVID-19 (3).

The large amount of social computational data generated by the pandemic may lead to breakthroughs in AI that can greatly alter human behavior. Newer COVID-19 variants and behavioral changes are causing resurgence of the pandemic. AI can use social computational data to devise novel non-pharmaceutical interventions to prevent newer outbreaks. "How we feel" a web and mobile application that longitudinally tracks COVID-19 symptoms, behavior and testing, can predict likely COVID-19 positive individuals and outbreaks (4). Genomic, structural data and outcomes can be used to make COVID-19 simulations, predict mutations, outbreaks and guide therapy leading to drug discovery, drug repurposing and precision medicine (5). Multiple applications for predicting severity using imaging and lab data in real time have been developed and have been externally validated (6). These applications have played a pivotal role in the management of the pandemic.

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The proliferation of social computational data and easily programmable AI applications like AutoML (which allows non experts to develop novel AI applications) will make AI available to the masses and democratize the process. COVID-19 can lead to revolutionary AI applications, but we should be cautious about unforeseen negative consequences and oversight is required. Cultural, moral and legal and ethical values should be incorporated in the development and implementation all AI algorithms so that we develop an ethical AI (7).

AlphaFold, a novel machine learning approach to predict protein structures with atomic accuracy (8) can predict COVID-19 protein structures. This has helped determine which hotspot regions in the virus are most immunogenic and played an important role in the rapid development and production of COVID-19 vaccines (9). Many of these applications use the transformer architecture. Transformer is an AI architecture which uses “attention mechanism” for natural language processing and vision. Transformers use transfer learning when the knowledge used to solve one problem can be used for a different problem resulting in applications which are generalizable. Applications developed for COVID-19 can become more optimized with robust data and increased computing power and can be adapted for other solutions.

AI applications developed for COVID-19 can become more resilient, versatile, scalable and generalizable and can be used to solve problems in other fields. This has led to the “perfect storm” for developing fundamentally new AI applications. The COVID-19 pandemic has thus come as “a black swan event” in AI. A black swan event is an unexpected event that has potentially major consequences. The COVID-19 pandemic has unexpectedly spawned pioneering applications that are scalable and generalizable and significantly transformed AI.

The Artificial Intelligence Index Report 2021 showed that the number of AI journal publications grew by 34.5% between 2019 and 2020 compared to 18% between 2018 and 2019 (10). In 2020, China surpassed the USA in the total number of AI journal citations in the world and we have seen a significant increase in AI applications developed there. There was also a 9.3% increase in the AI private investment from 2019 to 2020 compared to a 5.3% increase from 2018 to 2019. The United States Patent office has seen a significant increase in the applications for AI patents in 2020. The most patent applications in 2020 were for AI applications. An analysis of the fastest growing technologies patent claims shows that that machine

learning and computer systems based on biological models had the highest growth rate and the largest number of patent applications.

AI has played a crucial role in the management of the pandemic and development of vaccines and in countering misinformation. Pioneering applications in machine learning, vision, speech, evolutionary computation and language processing have been developed in the last few years. The dramatic development of AI in 2020 and 2021 may be the natural growth of a transformative technology. But COVID-19 has disrupted the landscape by digital transformation, bringing various entities together and generating big data with definite outcomes. This has resulted in significant advances as evidenced by the substantial growth in AI applications, publications and patents. This pandemic has come like a black swan event in AI design, development and innovation and will have major repercussions for the future of AI.

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