The Institution of Engineering and Technology

Artificial intelligence and engineering for healthcare crises

Improving our health emergency planning to create the resilient system we need.

theiet.org/healthcare

Foreword

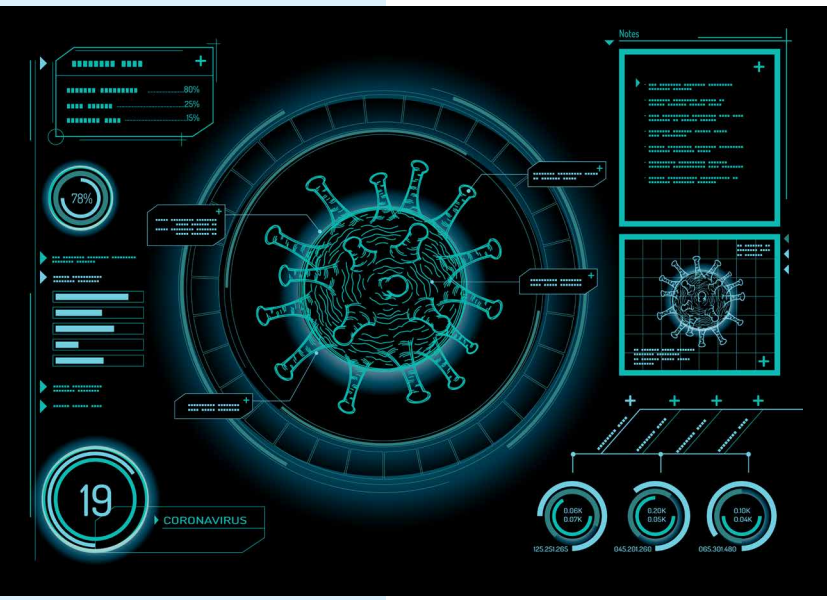
Stephen Metcalfe MP
Co-chair of the All-Party Parliamentary Group on Artificial Intelligence

Artificial intelligence (AI) is an integral part of our lives today. We interact with it on a daily basis, when we use social media, search the internet or receive emails. Governments worldwide recognise the vast economic and social potential of this emerging technology, which has applications across fields as diverse as transport, agriculture, healthcare and banking.

AI and data form one of four Grand Challenges laid down by the UK Government in its Industrial Strategy, which aims to boost financial stability and productivity across the country. As part of this challenge, which is backed by a £100 million investment fund, the Government has set a mission for health-tech innovators to transform the prevention, early diagnosis and treatment of chronic diseases by 2030.

The outbreak of COVID-19 delivered a huge shock to the global economic system. The unprecedented global healthcare crisis has galvanised scientists, engineers and medics to think outside the box and deploy big data and AI in new ways to solve the urgent problems thrown up by the pandemic. From developing novel disease detection systems to providing faster and better diagnostic tools, this report shows how AI has proven its mettle during the pandemic.

There is no time to lose in taking advantage of these gains. From 2011 to 2018, the World Health Organization tracked 1,483 epidemic events in 172 countries, and experts warn that the risk of infectious diseases becoming full-blown pandemics is growing[1]. Whether to speed recovery from COVID-19, prevent further pandemics, or advance treatment of chronic diseases, further innovations are urgently needed. And, when citizens and public services benefit from healthcare solutions developed using AI and engineering, so does the economy.



The UK is starting from a position of strength. It is ranked first in Europe and second in the world in a 2020 global index of government readiness to realise the benefits of AI in delivering public services[2]. Putting this readiness into practice and procuring innovative solutions from the UK's thriving tech sector will, in turn, benefit our economy and grow new and innovative healthcare markets.

Maximising the benefits of AI is a priority for the government. This report outlines measures ranging from the collection and regulation of data to rapid peer review systems for new technology that are aimed at leveraging AI to tackle the pandemic. I would urge stakeholders to take the ideas and proposals in this report and translate them into practice.

[1] https://apps.who.int/gpmb/assets/annual_report/GPMB_annualreport_2019.pdf
[2] https://www.oxfordinsights.com/government-ai-readiness-index-2020

Introduction

Dr Peter Bannister
CEng FIET
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Over the last half decade, the term "Artificial Intelligence" (AI) has become ubiquitous in the field of healthcare technologies, with machine learning applied to clinical tasks such as radiation oncology treatment planning, breast cancer screening diagnoses and triaging patients in primary care settings based on self-reported symptoms.

Despite these early exemplars suggesting improved resource utilisation through automation and in some cases enhanced performance compared with the current standard of care, AI techniques hold a much greater promise of realising fundamental efficiency gains across healthcare systems by standardising otherwise labour-intensive and subjective human tasks.

Rather than doing away with clinicians, the popular narrative is that AI can free up precious clinical resource and refocus it on tasks which should remain in the hands of trained experts. This shift to experts augmented by autonomous tools suggests that the standard of care enjoyed in the first world might at last be applied to lower income settings.

This framing of AI in healthcare has stimulated a discussion around the ownership of data needed to train these algorithms, as well as the impact of bias and fundamental data quality in the clinical information they produce. For now, implementation of AI has remained in relatively narrow lanes.

The onset of COVID-19 has sparked a new level of pragmatism, breaking down pre-conceptions over the near-term role of AI and seeing it brought to bear on urgent global challenges by new multi-disciplinary consortia united by a common cause.

To prepare us against any future pandemics, we must use and share the experiences and lessons we've learnt from COVID-19. This report answers key questions from data scientists and engineers, features case studies where AI was used to tackle the pandemic, and shares the next steps and recommendations needed to improve our health emergency planning. Putting into place new systems, faster methods of data collection and diagnosis, and supporting new product innovations are the steps we need to better equip us for future challenges. Our recommendations aim to help create the resilient system we need, requiring a collaborative effort between the healthcare industry, governments and public.

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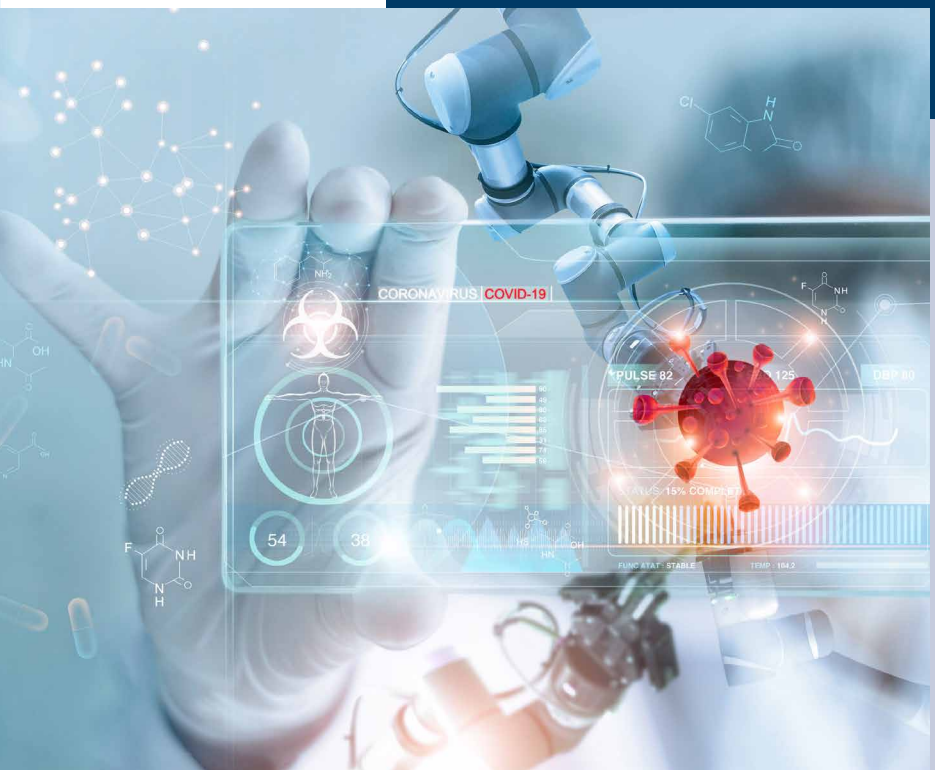

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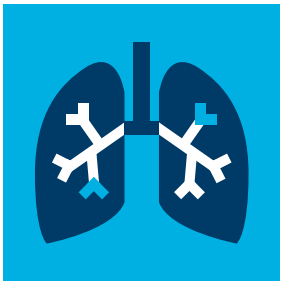
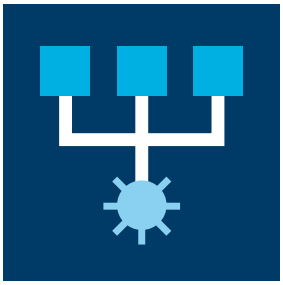
COVID-19: cracking the code

Data scientists and engineers play a key role in rapid response strategies to COVID-19 because they can accelerate solutions for urgent problems posed by a pandemic. Here are some key questions they are helping to answer.





How can we develop early warning systems for prediction of COVID-19 outbreaks?

The potential of AI to produce early warning systems for epidemics was vividly demonstrated by Canadian start-up BlueDot, which predicted the COVID-19 outbreak 10 days before it was announced by the World Health Organization (WHO).

The AI-driven algorithm uses data including official alerts, animal disease bulletins and airline ticketing data to predict outbreaks of contagious diseases[3]. Data scientists are now working on an array of machine learning architectures for modelling and forecasting the incidence and spread of COVID-19[4].

How can we ease the collection of data to support rapid innovation and disease detection?

Lack of data is widely acknowledged to be the key obstacle in unleashing AI's potential as a rapid response tool for COVID-19. Machine learning requires vast amounts of data to train new algorithms and architectures, and data sets must be compatible to produce reliable outcomes.

The urgency of the COVID-19 pandemic has prompted myriad efforts to accelerate research by creating open access data sets on the timeline and geography of the disease; its genomic structure; chemicals for treating it; and the scientific literature it has generated[5].

How can we enhance the speed and accuracy of COVID-19 diagnosis in pandemic conditions?

Many initiatives are in progress to develop AI tools for identification of COVID-19 from medical images. X-rays and computed tomography (CT) scans show promise as an alternative approach to diagnosis of the disease, which displays distinct patterns in the lungs[6].

Machine learning architectures are being developed that extract fine detail from the images to enable more rapid identification. The approach potentially offers faster, cheaper and more sensitive diagnosis than existing tests for COVID-19[7]. Other researches are focused on using AI for prognosis.

How can we address the issue of asymptomatic carriers spreading the disease?

A significant proportion of people infected with COVID-19 are estimated to be asymptomatic[8] and the symptoms take up to two weeks to appear[9]. This poses a huge challenge for containment of the highly contagious disease.

Early detection – before symptoms appear – would enable public health measures to be targeted more precisely. Research is now being conducted into whether COVID-19 can be detected early through changes in vital signs picked up by a wearable device, with the aim of finding an alternative approach to existing test and trace strategies[10].

[3] https://www.wired.com/story/ai-epidemiologist-wuhan-public-health-warnings
[4] Joseph Bullock, Alexandra Luccioni, Katherine Hoffmann Pham, Cynthia Sin Nga Lam, Miguel Luengo-Oroz, Mapping the landscape of Artificial Intelligence applications against COVID-19. 23 Apr 2020 https://arxiv.org/abs/2003.11336
[5] https://arxiv.org/abs/2003.11336
[6] Jeffrey P. Kanne, Brent P. Little, Jonathan H Chung, Brett M Elicker, Loren H Ketai, Essentials for Radiologists on COVID-19: An update – Radiology Scientific Expert Panel. Feb 27 2020 https://doi.org/10.1148/radiol.2020200527
[7] Wim Naude, Artificial Intelligence against COVID-19: An Early Review, IZA Institute of Labor Economics Discussion Paper Series, April 2020.
[8] https://www.cebm.net/covid-19/covid-19-what-proportion-are-asymptomatic
[9] https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html
[10] https://innovations.stanford.edu; https://www.sealab.ucsf.edu/tempredict; https://news.northwestern.edu/stories/2020/04/monitoring-covid-19-from-hospital-to-home-first-wearable-device-continuously-tracks-key-symptoms; https://oxfordbrc.nihr.ac.uk/new-wearable-technology-used-to-monitor-covid-19-patients

Applying artificial intelligence in solutions

Artificial intelligence has offered great opportunities to advance health and care and the COVID-19 crisis has accelerated its adoption in the healthcare industry. With the aim to reduce the spread of COVID-19, researchers and developers have deployed rapid solutions. Here are some examples.

ZOE leads the way

App pinpoints new symptoms for COVID-19

An app used to collect self-reported symptoms from more than 3.7 million people can predict whether someone has COVID-19 with nearly 80% accuracy, researchers have found[11].

Analysis of data from the COVID Symptom Study[12] has also led to the identification of new symptoms for the disease, including loss of taste or smell, known as anosmia.

The finding prompted the UK's National Health Service to include anosmia in its official list of COVID-19 symptoms[13].

The app, which was developed by King's College London, Massachusetts General Hospital and health science company ZOE, uses an AI model to predict COVID-19 infection by comparing aggregated data on reported symptoms and test results.

A peer-reviewed study into its effectiveness examined data from nearly 2.5 million users in the UK and US[14]. The app can predict whether an individual is likely to have COVID-19 based on their age, sex and four key symptoms: anosmia, severe or persistent cough, fatigue and skipping meals, the study found.

Clinical trials of the app have been launched in the UK and US with a view to using it as an early detection tool alongside test and trace systems[15].

The big crunch

US puts AI to work on COVID-19 research

The urgent need to halt the COVID-19 pandemic has prompted an outpouring of scientific papers on every aspect of the disease. While the sheer volume of scholarly literature is too great for timely processing by traditional methods, AI algorithms can be trained to rapidly track down new findings that may support further research and development.

To this end, the US federal government and leading research organisations have set up the world's largest open-access collection of scientific literature on COVID-19. The consortium has called on America's data scientists to help answer high-priority research questions about COVID-19 using text and data mining.

The expanding COVID-19 Open Research Dataset (CORD-19) is held on the free, AI-powered research tool Semantic Scholar[16] and the challenge is being hosted by Google's data science site Kaggle[17].

Data scientists are urged to answer key questions using natural language processing or create summary tables that address the research topics. Kaggle hosts 17 such tasks and is offering a US$1,000 prize in each category.

[11] https://www.kcl.ac.uk/news/new-ai-diagnostic-can-predict-covid-19-without-testing
[12] https://covid.joinzoe.com
[13] https://www.itv.com/news/2020-05-18/loss-of-smell-or-taste-added-to-nhs-covid-19-symptoms-list
[14] https://www.nature.com/articles/s41591-020-0916-2
[15] https://covid.joinzoe.com/post/science-covid-diagnosis
[16] https://www.semanticscholar.org/cord19
[17] https://www.kaggle.com/allen-institute-for-ai/CORD-19-research-challenge

CAD4COVID goes live

Dutch firm releases free AI tool for COVID-19 triage

A Dutch company has developed an AI software tool for triage of suspected COVID-19 patients using X-rays and is making it available free of charge.

Delft Imaging specialises in tuberculosis screening and its AI-based CAD4TB system has been used to screen more than 6 million people in 40 countries. Now the firm and its partners have adapted the model for use in the fight against COVID-19[18].

CAD4COVID-Xray is based on a deep-learning system that was trained to detect COVID-19 on chest X-rays. It uses U-net for pre-processing, followed by a convolutional neural network for patch-based analysis, and an ensemble of networks for image-level classification.

It was trialled using 468 chest X-rays of patients screened for COVID-19 at a Dutch hospital against a panel of six expert radiologist readers. The system achieved a score of 0.81 on a receiver operating characteristic (ROC) curve - deemed "good" predictive capability - and was found to be comparable to the readers' consensus in both positive and negative predictive values[19].

CAD4COVID is intended for use in "resource-constrained settings and high-prevalence areas" to support hospital triage of suspected COVID-19 cases and will be "continually improved and optimised", according to the company.

Stanford probes wearable data

Researchers seek smart solution for asymptomatic cases

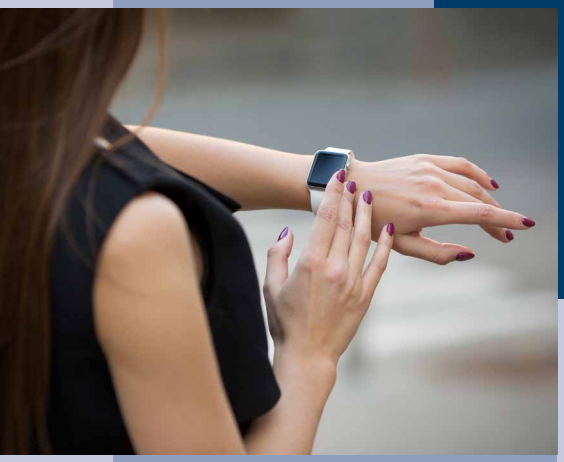
Researchers at Stanford University have launched a research programme that aims to detect early signs of viral infections such as COVID-19 using data from wearables.

The COVID-19 Wearables Study is collecting measurements such as heart rate and skin temperature from volunteers who use smartwatches and activity trackers including Apple Watch, Fitbit and Oura Ring[20].

The team will use the data to train a series of algorithms to spot changes in vital signs that indicate the body is fighting off infection. The study aims to establish whether data collected from wearables can be used to detect the onset of a viral infection before symptoms begin.

It is led by Professor Michael Snyder, director of Stanford's Centre for Genomics and Personalized Medicine, and builds on a study he published in 2017, which found sensors on smartwatches could detect inflammation through changes in the resting heart rate[21].

If successful, the programme is expected to lead towards the development of personalised health wearables that alert individuals when they catch an infection.



[18] https://www.delft.care/cad4covid
[19] https://doi.org/10.1148/radiol.2020201874
[20] https://innovations.stanford.edu/wearables
[21] https://journals.plos.org/plosbiology/article/file?id=10.1371/journal.pbio.2001402&type=printable

The next steps

1. Early warning systems

- Set up government-industry review boards to support development of app based early warning initiatives and iron out any issues.
- Devise incentive schemes to encourage citizen engagement in contact-tracing and virus-detection initiatives.
- Rapidly scale up successful app based contact tracing and virus detection systems.

2. Data collection

- Ensure all data on COVID-19 meets regulatory requirements and make it available globally on an open-access basis[22].
- Journals to immediately share findings relevant to the outbreak with the WHO upon article submission[23].
- Data holders to jointly develop global standards for electronic health records and for COVID-19 case and mortality data.

3. Faster diagnosis

- Rapid response peer review system to be set up for fast-tracked diagnostic technology.
- Quality control measures should be reviewed after pandemic to ensure compliance and enhancement of equipment devised under emergency conditions.
- Hold online conferences to disseminate knowledge on promising techniques.

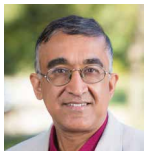
4. Innovative health products

- Legislation and emergency powers that allow organisations working on pandemic solutions to access anonymised personal health data should have an end clause requiring its deletion.
- Ensure appropriate licensing arrangements are in place for the collection and use of such data and its outputs, and data deletion is monitored and enforced.
- Regulator findings and recommendations on pandemic data arrangements should be published and constructive citizen engagement should be encouraged.

5. Pandemic management

- Commission global comparative studies on the efficacy of policy responses to COVID-19.
- Use AI to analyse international data on COVID-19 cases, deaths, symptoms, transmission routes and mitigation measures to inform policy studies.
- Compare COVID-19 policy outcomes with management of recent epidemics such as Ebola to inform the WHO policies for future pandemics.

Leveraging AI to tackle COVID-19 is challenging. How can innovators contribute to this effort?



COVID-19 has prompted new levels of data sharing and research collaboration that present a unique opportunity for the AI community. Many hackathons and ad-hoc groups are working on the problem – join one that resonates with your ideas. Look at what existing companies are doing to tackle the pandemic and any gaps in provision. How can you help? Start working on the data – either aggregating the data stuck in silos or creating charts of the statistics available at county level.

Dr Ronjon Nag, Interdisciplinary Distinguished Careers Institute Fellow, Stanford University, and Founder, R42 Institute.

[22] https://wellcome.ac.uk/coronavirus-covid-19/open-data
[23] https://www.who.int/bulletin/online_first/16-170860/en

We say...

The COVID-19 pandemic has prompted extraordinary efforts to protect public health and collaborate on novel health solutions. However, it has also exposed the weakness of health emergency planning in many countries. National efforts are required to implement the WHO guidance and foster innovative health technologies. The following are our recommendations to ensure that we are better prepared for further waves of COVID-19 and future global pandemics.

1 Establish a volunteer national engineering corps and national AI corps to get emergency teams to disaster situations.

Professional bodies should work together with government and industry to form an "engineers without borders" team to address international emergencies and a "national guard" to help with domestic ones.

2 Governments, intergovernmental organisations (IGO) and international businesses should work together to create a global pandemic warehouse to stockpile items for future emergencies.

A virtual storehouse of anonymised medical data for combatting COVID-19 and other contagious diseases and a physical stockpile of personal protective equipment and testing equipment are both required.

3 Governments, IGOs and industry bodies should collaborate to create a pandemic world bank for funding responses to health emergencies.

Leaders of global initiatives such as Gavi, Coalition for Epidemic Preparedness Innovations (CEPI), the WHO Solidarity Trial and the AMR Action Fund[24] could exchange expertise and consolidate efforts to provide regular funding for unprofitable remedies and fast finance for new cures in pandemics.

4 Governments and leading research bodies should set up competitions to develop ready to go contact tracing apps for use in health emergencies.

Contests should require apps to obtain permission from users before collecting their data and impose safeguards for health data to be removed and deprecated once the emergency is over.

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If you would like to get in touch, please contact us at **sep@theiet.org**

[24] https://www.gavi.org; https://cepi.net; https://bit.ly/3gu0sBK; https://amractionfund.com

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