Perspective

Combat COVID-19 with artificial intelligence and big data

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In December 2019, a novel coronavirus (COVID-19) broke out in Wuhan, China, rapidly spreading across China and the rest of the world. As of 10 May 2020, there have been more than 4.10 million confirmed cases of COVID-19 in 187 countries/regions, with 282 719 deaths worldwide.[1] As this is a novel disease, effective pharmaceutical interventions are not expected to be available for months; meanwhile, community containment measures such as stay-at-home orders and lockdowns have been widely implemented by affected countries aiming to flatten the epidemic curve impacting an estimated 3 billion people globally.[2] While European countries and the USA seek ways to exit lockdown and return to some semblance of normalcy during the ongoing pandemic, China reached the 1-month milestone of its official end of the nation-wide lockdown (on 8 April 2020). Similar to mainland China, South Korea also has managed to flatten the curve quickly after seeing the initial outbreak. Commonalities of these successful responses include swift and decisive interventions to promote or impose social distancing, active case detection and prompt isolation of all cases, government responsibility for all associated costs, relentless public messaging about containment measures and the wide use of big data to trace individuals who may have come into contact with infected individuals.

South Korea first developed tools for aggressive testing and contact tracing during the 2015 MERS outbreak. In response to COVID-19, South Korea's Centers for Disease Control and Prevention deployed the contact tracing system, known as the COVID-19 Smart Management System (COVID-19 SMS), that uses data from security camera footage, credit card records and even GPS data from cars and cellphones to trace the movement of individuals with COVID-19. For people who might have been exposed to COVID-19, health officials send notification to them. Among people who test positive, those requiring treatment are hospitalized at the COVID-19 special facilities and those without symptoms are asked to remain self-quarantined for 14 day with their compliance to quarantine actively monitored. To date, South Korea has managed to contain the spread of COVID-19 without resorting to lockdowns.

To contain the outbreak, the Chinese government has implemented large-scale social distancing policies, including quarantine, isolation and travel restrictions to limit cross-regional population movement and minimize non-essential social contacts.[3,4] Checkpoints were set up at community entrances, major traffic entrances, exit points and airport stations for temperature screening and travel history inquiry for all travelers. Given the large population size, the extent of the outbreak in the country and the labor-intensive nature of contact tracing, the Yuhang District in Hangzhou City first developed and launched a smartphone mini-program, known as 'Health Barcode', to replace traditional, paper-based access permits; the program was implemented within 2 weeks of the nation-wide lockdown, on 7 February 2020. Health Barcode was quickly expanded and subsequently adopted by national authorities affecting over 900 million residents by the end of February.[5] Similar to South Korea's COVID-19 SMS, Health Barcode is a product of public–private partnership. It enables a dynamic epidemic risk management of COVID-19 using individual self-report health status and travel history in combination with big data from aviation, railway and ground transportation systems, social media, COVID-19 database and mobile GPS and payment records to retrace individuals' movement. Complex and sophisticated artificial intelligence (AI) and machine learning algorithms are then employed to retrace the movement of the infected person and all persons in close contact, feeding into individual risk assessment of three levels—low, medium and high. The green color indicates that the individual has not been infected with or exposed to COVID-19; yellow identifies the individual is new to the city and not completed the quarantine period, while the red colour

Table 1. Combat COVID-19 with AI and big data in East Asia[16–19]

Big data source	Country/region			
	Mainland China	Hong Kong	Taiwan	South Korea
Transportation systems (aviation, railway and ground)	X			
Immigration and customs databases			X	
COVID-19 database/Healthcare data	X		X	
Mobile data	X	X	X	X
Mobile technology	X	X	X	X
Social media	X			
Credit-card transaction				X
Closed-circuit television/Security camera	X			X
Car GPS				X
Wearable tracking device		X		
AI application	AI-based tools used to facilitate targeted-lockdown/reopening, monitor temperature, enable quick diagnosis and classification of patients and assist in vaccine development.[16]			AI-based tools used to enable quick diagnosis and classification of patients, as well as to facilitate public communication and notifications.
Enforcement of containment measures/	Strict home quarantine for those exposed with active monitoring and police enforcement. Only people with a Green Barcode can pass checkpoints set up at all entry points.	Strict home quarantine for those exposed with active monitoring and police enforcement. Violators fined up to HK$25000 (US$3200) and face six months jailtime.[17]	Strict home quarantine for those exposed with active monitoring and police enforcement. Violators fined from NT$200 000–1 000 000 (US$6702–33 510).[18]	Strict home quarantine for those exposed with active monitoring and police enforcement. Widespread testing. Violators face jailtime (or deportation for foreigners).[19]

indicates that individual needs to be quarantined due to COVID-19 like symptoms or exposure. Residents with a Yellow or Red Barcode are required to be under home-bound isolation for up to 7 or 14 days, respectively; barcodes will switch to green after receiving continuous daily health status reports with normal results during the period of isolation. Residents with a Green Barcode can return to work and travel freely. The system effectively reduced close quarters, congestion and crowds at these checkpoints and later facilitated the reopening of the economy (Table 1).

COVID-19 is highly contagious and can transmit before and after the onset of symptoms. To enable successful containment, contact tracing and quarantine have to comprehensively cover all those with symptoms and effectively separate individuals who are infected from those who are not. Unlike Hong Kong and Taiwan, which focused on isolating imported cases (and managed them successfully), mainland China and South Korea were stricken with wide community spread early on, which prompted technology and big data to enable health officials to effectively identify probable cases and avoid recall and/or reporting bias. Nevertheless, all four use big data and AI in contact tracing and strict enforcement. Mandatory electronic wristbands, paired with a mobile app, have been issued to some 60 000 travelers

arriving in Hong Kong; the device notifies authorities when people under quarantine leave their homes.[6] In Taiwan, the government integrated the universal health insurance database with its immigration and customs databases, enabling real-time alerts of probable cases based on symptoms and travel history. About 55 000 residents have gone under 'mobile geofencing'[7] at home, during which the government tracks their cellphone signals with police enforcement.[8] In South Korea, the government broadcast detailed information about infected people's whereabouts with detailed maps. Violators in the above countries/regions face jail time and/or hefty fines, whereas in mainland China, Health Barcode focuses on prevention—people without a green QR code are not able to pass checkpoints. These governments are backed by a strong shared public support of collective well-being over individual freedom during large-scale emergencies, for the use of big data and AI for contact tracing and strict enforcement of quarantine, contributing to their success in flattening the curve. During the pandemic, the current South Korea government even held (and won) parliamentary elections without lockdown. A recent poll of 2016 U.S. adults finds the public concern about the health and economic risks of pandemic might outweigh that of individual privacy. Data from this nationally representative sample showed a widespread public support for government

to conduct aggressive mobile location tracking in exchange for more information about personal exposure to risk, and mandatory health screening in public places to curb the spread of the virus.[9]

COVID-19 is not the first health crisis for which mobile technology and big data have been used to fight epidemics. A mobile app, FluPhone, was introduced in 2011 by Cambridge University in UK to track the spread of regular flu. Similarly, between 2014 and 2016, mobile phone data and applications were used in Africa to fight the Ebola outbreak.[10] To date, at least 29 countries/regions have introduced contact-tracing apps as a solution for a more targeted approach to lockdown and containment of COVID-19.[11] What works in one place may seem implausible for other countries. Apart from the four cases from East Asia mentioned above, most of these apps are voluntary and anonymous, without support from big data and AI, and generating aggregated maps or reports that might not have direct benefit to users who populate the database. Whether or not these apps are successful will depend on large uptake coupled with strong public health enforcement because contact tracing and isolation are a very individualized undertaking—one loose 'super-spreader' out on the street can cause an outbreak in the community. As an estimate, for UK's 'Test, Track and Trace' strategy to be effective in slowing the spread of the virus, epidemiologists calculated that at least 60% of the residents need to become users of the contact-tracing app.[12] Yet, even in the city-state of Singapore, fewer than one-fifth of the country's population voluntarily used the national BlueTooth tracing app, TraceTogether.[13] These data might be informative to health officials to develop population-based interventions, but the 'unit' of contact tracing, case isolation and quarantine is 'individual'—inability to 'personalize' the benefits for app users might limit the uptake. Apple and Google have proposed a Bluetooth-based application programing interface that warns participants if their phone has been near the phone of a COVID-19 case; again, it requires wide-uptake for the app to have reasonable impact. Furthermore, because these Bluetooth apps cannot distinguish the level of COVID-19 exposure during the interaction between two users that come in contact (e.g. mask-wearing, shielded cashiers, etc.), both false positives and false negatives will likely to be high.

Most importantly, there appears to be an inevitable tradeoff between individual privacy and public health. Like in other respects, the application of big data and AI in contact tracing can be a double-edged sword. Combined with facial recognition technology and big data, sophisticated AI can theoretically pinpoint anyone, anytime, anywhere and what they have done. It supports modelling efforts, predicts the flow of a pandemic and informs preparation and response strategies. Critics of the technology are concerned about hackers or governments violating individual privacy for unrightful use, criminal activities or political surveillance during or after the pandemic. The consideration we are facing, as pointed out by law experts,[14] is not about whether to use big data and AI for epidemic control but how to use them—'sometimes it is unethical not to use available data'.[14] In Taiwan and South Korea, the legal basis and data governance structure for responsible accessing and managing personal information during a health crisis was prepared after the 2003 SARS and 2015 MERS outbreaks, respectively, when the government learned that

tracing the movement of infected and exposed individuals is crucial. The U.S. Health Insurance Portability and Accountability Act Privacy Rule guides how entities and their business associates may share patient information in an emergency situation, which was highlighted during the Ebola outbreak and may serve as a foundation for the guidance framework. Europe has recently introduced a new privacy law, the General Data Protection Regulation (EU) 2016/679 (GDPR), which ensures data protection and social media privacy for all individual citizens of the European Economic Area and the European Union (EU) and might be further expanded to address the need of digital disease surveillance during a pandemic. Researchers and technology companies are exploring ways to improve cryptography that would enable contact-tracing systems without mass surveillance in order to achieve the benefits of location-tracking while protecting individual privacy.[15]

Funding

Conflict of interest/disclosure

The authors have declared no conflicts of interest.

Author contribution

L.L. conceived of the presented idea, and collected and analysed the data. L.L. drafted the manuscript with input from Z.H. Both authors have reviewed, commented on and approved the final version of the manuscript.

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