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The need for GIScience in mapping COVID-19

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ABSTRACT

Since first being tracked in China in late 2019, the effects of the COVID-19 coronavirus have shaped global patterns of morbidity and mortality, as well as exposed the strengths and limitations of health care systems and social safety nets. Without question, reporting of its impact has been bolstered in large part through near real-time daily mapping of cases and fatalities. Though these maps serve as an effective political and social tool in communicating disease impact, most visualizations largely over-emphasize their usefulness for tracking disease progression and appropriate responses. Messy and inconsistent health data are a big part of this problem, as is a paucity of high-resolution spatial data to monitor health outcomes. Another issue is that the ease of producing out-of-the box products largely out paces the response to the core challenges inherent in the poor quality of most geo-referenced data. Adopting a GIScience approach, and in particular, making use of location-based intelligence tools, can improve the shortcomings in data reporting and more accurately reveal how COVID-19 will have a long-term impact on global health.

1. Introduction

The global understanding of the impact of COVID-19 has grown proportionately with the use of mapping applications across the public and private sectors, most notable of which are daily publications by news agencies or near-real time online dashboards ("Johns Hopkins Coronavirus Resource Center," n. d.; Times, n. d.). Although these maps provide an important visual representation of its impact on morbidity and mortality and serve as an effective political and social tool in communicating disease impact, most illustrations are over-emphasizing their usefulness for tracking the progression of the disease and developing appropriate responses. For instance, many maps have far too low a spatial resolution to inform prevention or mitigation efforts at the local level, while others misrepresent entire areas by inappropriately using choropleth maps to illustrate absolute data instead of relative data ("A heat map of coronavirus cases in Canada - Macleans. ca," n. d.; "Canada Coronavirus (COVID-19) Tracker Map | AccuWeather," n. d.; "Map," n. d.; "Maping the Covid-19 Outbreak Globally," n. d.; Brackley, 2020; "City releases Toronto neighbourhood map of COVID-19 infections," 2020). At issue is that the rise of open-source cartographic software has made map making accessible to just about anyone with a computer and some technical know-how. While this is ultimately positive, the proliferation of "out of the box" interactive maps (e.g., ArcGIS online, Tableau) is making certain kinds of mapping of COVID events (e.g. choropleth maps, graduated symbols) more ubiquitous than ever. The result has been a plethora of mediocre maps of COVID-19 that serve little to no real benefit, some of which distort reality whether intentionally or not ("From coronavirus to bushfires, misleading maps are distorting reality," 2020).

There are two reasons for concern, and both have to do with the underlying data that power them. The first is that the available data are often messy and inconsistent. Changes in testing capacity, reporting discrepancies around fatalities, and overall differences in methodologies have made interpreting data a challenge, especially when trying to compare one geographic region or time period to another (Paul and Abbott, 2020). The second is that securing geo-located health data at a high enough spatial resolution to detect meaningful patterns has proven challenging due to privacy constraints. In North America, health data is predominantly being reported at the county, city, or state level ("LA County Department of Public Health," n. d.; nychealth/coronavirus-data, 2020; "PHSKC COVID-19 Outbreak Summary Dashboard," n. d.). While this is a start, people are not static beings and cannot be neatly summarized to a single point location or polygon as is often the case in data reported by health authorities. Furthermore, most researchers have yet to gain access to individual trajectory data of infected individuals as they move about their daily lives.

2. Putting GIScience to work

As health geographers, we know that maps can play a larger role in the toolkit of policy analysts, decision makers, and the public in building a long-term response to COVID-19. Adopting a GIScience approach, and

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in particular, making use of location-based intelligence tools, can help researchers and policy makers address the shortcomings in the data and lead to more nuanced spatial analyses of the disease. Two separate efforts can meet these needs.

The first is a top-down, "Big Brother" effort in which government surveillance can make use of smartphone apps that collect a user's cell phone location data (by way of GPS, cell phone towers, and/or WiFi), electronic wrist bands, credit card transactions, and closed-circuit television (CCTV) systems to track disease spread and, in some cases, enforce social isolation measures (Fig. 1). This surveillance method is a comprehensive and rapid way to collect data on people's movement and health status. China for example, is using a government-backed app that collects a user's name, national ID number and health information among other data, and requires them to scan their phone at various checkpoints to track user movement. The app then generates a personal infection risk rating to determine whether they are allowed passage through the checkpoint (Calvo et al., 2020). Similarly, at the start of the pandemic the Israeli government also adopted population level surveillance, authorizing the repurposing of an anti-terrorist phone-tracking application for COVID-19 purposes (Calvo et al., 2020; Halbfinger et al., 2020; Kharpal, 2020). The app was used to monitor the movements of those infected and trace potential contacts, however has since been banned following privacy concerns (Halbfinger et al., 2020; "Israel bans use of tracking app used to quarantine coronavirus patients," 2020; Kharpal, 2020). South Korea, Taiwan, Hong Kong and some states in India have also adopted similar measures (Cellan-Jones, 2020; Kharpal, 2020;Vaidyanathan, 2020).

Another method of meeting spatial data needs is occurring in a bottom-up manner; citizens are *themselves* participating in the surveillance of data by volunteering or consenting to share their own location and personal information in a collective effort to tackle the pandemic. Volunteered geographic information (VGI) is not a new concept; the renowned geographer Michael Goodchild first coined the term in 2007 to discuss the increasingly popular phenomena of the widespread engagement of citizens in the creation of geographic information (Goodchild, 2007). While VGI has been used to track health information and illness before ("Flu Near You," n. d.), the urgency of the COVID-19 pandemic has fueled a rapid increase in the number of localized VGI web and mobile apps and, in turn, the number of people volunteering their data ("'COVID Near You' crowd sources coronavirus tracking," 2020; "COVID Symptom Tracker - Help slow the spread of COVID-19," n. d.; "Flatten," n. d.; Lets Beat; "Private Kit: Safe Paths; Privacy-by-Design Contact Tracing using GPS + Bluetooth | safepaths," n. d.; Nicas and Wakabayashi, 2020; ServickMar. 22 et al., 2020). For example, a new crowdsourcing app, called Private Kit: Safe Paths, led by a researcher at the Massachusetts Institute of Technology, logs and stores a user's GPS location data every 5 minutes for up to 28 days ("Private Kit: Safe Paths; Privacy-by-Design Contact Tracing using GPS + Bluetooth | safepaths," n. d.). If a user tests positive for COVID-19, they can choose to share that data with the app, which will then notify health officials ("Private Kit: Safe Paths; Privacy-by-Design Contact Tracing using GPS + Bluetooth | safepaths," n. d.; Servick, 2020). A soon-to-be released future iteration of the app will go further, comparing the path of infected individuals to users' recent locations, alerting those who may have been put at risk of infection ("Private Kit: Safe Paths; Privacy-by-Design Contact Tracing using GPS + Bluetooth | safepaths," n. d.;Servick, 2020).

Companies like Kinsa Inc. are also stepping up to use the tools and data they have at their disposal to track and respond to COVID-19. The U.S. based public health technology company is making use of volunteered health and location data collected from their smart home thermometers to track feverish illness across the country ("US Health Weather Map by Kinsa," n. d.). While the data they collect does not distinguish between COVID-19 and other illnesses that cause fever, it is a robust database with the capability to identify and forecast unusual spikes in fevers and can provide early indicators of the effects of physical distancing and isolation measures at the community level (McNeil Jr., 2020).

Of course, both government and citizen surveillance strategies have weaknesses. With top-down government surveillance efforts, activists and researchers alike have voiced serious concern over privacy and infringement on civil liberties. Calvo, Deterding, and Ryan (2020) further raise the alarm over issues of "surveillance creep" when it comes to these new government measures (Calvo et al., 2020). On the other hand, the bottom-up approach struggles to ensure enough data is collected to be accurately used for cartographic or analytic purposes. Given that this data is volunteered, it takes longer to reach a minimum sample size than mandated top-down measures.

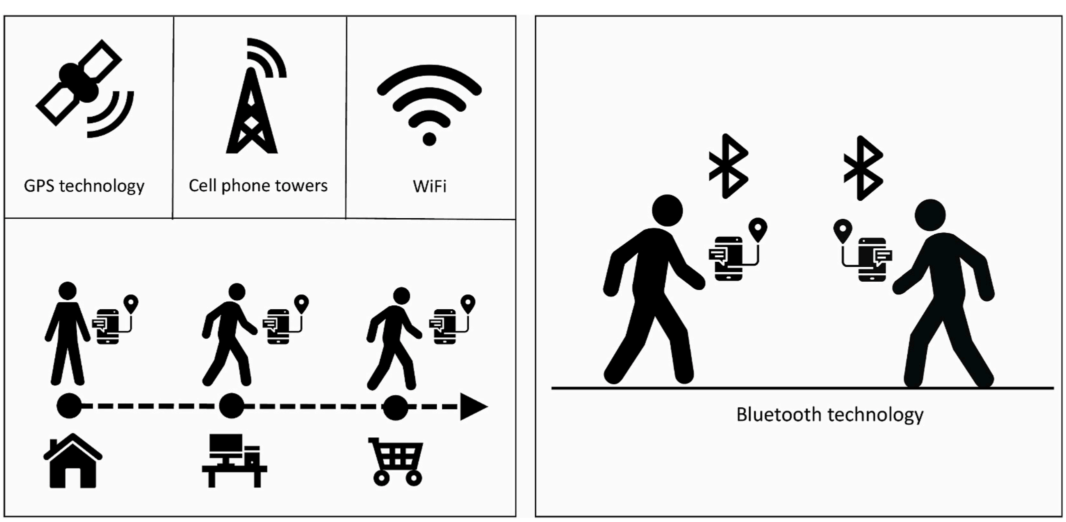

Fig. 1. Geo-surveillance of an individual's daily trajectory. On the left, a smartphone's GPS receiver, cell phone tower signals or Wi-Fi connections can be used to track and collect data on people's daily trajectories. Coupled with other data, such as COVID-19 infection status, trajectory data can be used to identify the recent locations of infectious patients and warn others who were potentially exposed at these locations to self-isolate. On the right, Bluetooth technology can be used to identify individuals who have come in close proximity to each other. While the use of this technology does not allow identification of the location of these users, it can track users who have come into close contact with each other. Coupled with other location data, such as GPS or the use of cell phone towers, Bluetooth technology can play an important role in identifying if individuals have come into close contact with someone infected by COVID-19.

3. Telling a bigger story

Whatever the method of collection, the increase of higher resolution and dynamic geo-located data on COVID-19 can allow researchers to go beyond the simple maps of present to tell a much bigger, more detailed story. For example, geo-located data can allow a more explicit understanding of its impact on near- and long-term health and social conditions within communities. At issue, particularly in the United States, is that trends in COVID-19 events are highlighting deeply rooted health disparities across the country along ethnic and racial lines. Early reports of COVID-19 testing have shown that physicians are less likely to refer African Americans for testing when they show up for care with signs of infection than other races (28). These trends mirror long-standing findings that race directly (e.g., by providers) and indirectly (e.g. providers locating outside of minority neighborhoods) leads to discrimination in health care access (Farmer, 2020).

At the same time, disparities in access to testing highlight only part of the picture. Reports have also emerged that both federal and state governments are not collecting data on race or ethnicity (Akilah Johnson and Buford, 2020). Nor has there been systemic testing and coding of mortality-related events, which is likely leading to substantial undercounts of events ("Fatal Flaws: Covid-19's death toll appears higher than official figures suggest," 2020). Combined, the current limitations in data coding lay the groundwork for GIS Scientists to monitor changes in the underlying causes of death and search for abnormal patterns of mortality that could be attributed to racial disparities in care access during the outbreak. While it is a precarious time for the most vulnerable, we are unlikely to grasp the true significance of COVID-19 on long-term changes in population health outcomes without also harnessing the data linkage and analysis properties of GIS to overcome limitations in current data reporting and release statistics.

In a similar vein, investigations will be needed to assess whether the likelihood of receiving treatment, as well as ensuing social and economic interventions, varies by community, particularly those that were already experiencing the brunt of other disease burdens. Well established geospatial methods can be used to investigate this. For instance, one method to model these effects could be through distance decay analyses, a technique which could both help uncover selection bias in community recovery evaluations as well as variations in outcomes attributed to resource access. Another is through multinomial classification models based on overlapping spatial clusters of recovery and socioeconomic conditions. Such models become particularly important for revealing familiar patterns of racial and economic bias in light of COVID-19 effects and could also reveal which communities recovered well in spite of these factors, leading to new hypotheses associated with the role of community cohesion during periods of isolation.

Finally, as society begins to transition back to 'normal', high resolution geo-located data will also play a critical role in managing COVID-19 outbreaks until the virus can be controlled. The current non-pharmaceutical intervention (NPI) measures being implemented to curb the spread of the virus (e.g. social isolation, lockdowns, etc.) are effective tools at our disposal but, due to resulting economic slowdown, they cannot be utilized for long periods of time. In the near future, the easing of these measures to allow increased economic activity will be a critical step, and real-time surveillance of COVID-19 outbreaks will be essential to implementing targeted NPI measures in specific locations while limiting nation-wide economic disruption. Through the use of anonymized smartphone data to track human movement coupled with spatial analysis techniques, researchers can identify where increased group activity correlates to new outbreaks of COVID-19, enabling a more complete understanding of how human movement and large gatherings relate to potential new outbreaks of the disease. Such data is also valuable to predictive geospatial modelling which can be used for a variety of purposes, including forecasting community-based transmission and ultimately predicting where hotspots might emerge.

4. Conclusion

The story of COVID-19 is much greater than what maps currently show, and the examples provided above are just a small sampling of what can be asked and answered by tapping into the full potential of GIScience. Capturing geo-located data on a more granular scale (e.g. higher resolution), whether via a top-down (i.e. government surveillance) or bottom-up (i.e. volunteered GIS) strategy is essential for conducting the types of analyses we need to address the multiple social, economic, and health care challenges brought on by the disease, and develop a more considered response. Access to these data by spatial analysts is the basis for informed, evidence-based decision making as well as maintaining social order via clear communication to the public.

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Appendix A. Supplementary data

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