Methods from weather forecasting can be adapted to assess risk of COVID-19 exposure

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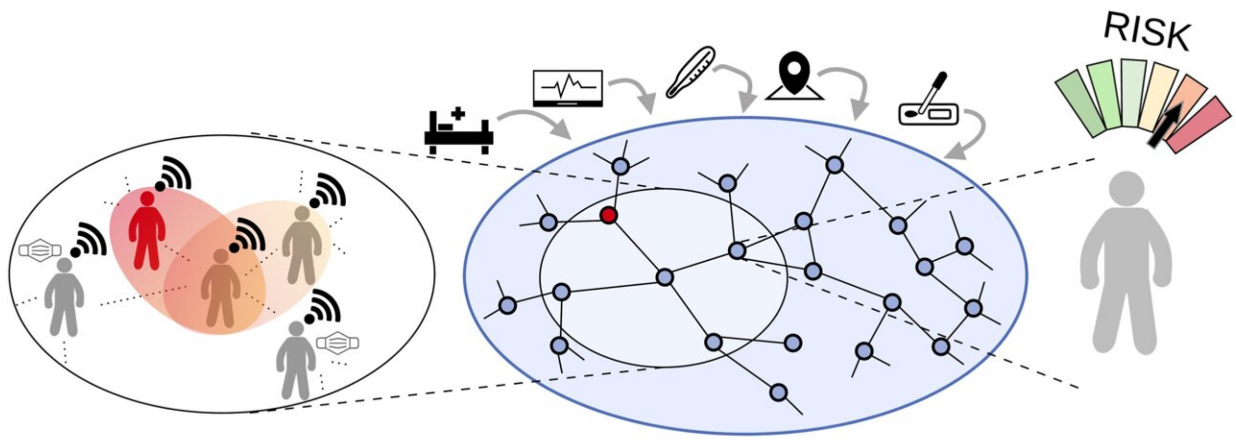

Proximity-tracking data from mobile devices is used to assemble a contact network, in which nodes represent individuals and edges represent close contacts between individuals. An epidemiological model defined on the contact network is then fused with diverse health data, including diagnostic tests, hospitalization status, and possibly data such as body temperature readings. The model spreads risk of infectiousness from a positive individual (red) to others, taking into account knowledge about disease progression, the time and duration of contacts, and the use of personal protective equipment (PPE), among other factors. The result of the network DA is an assessment of individual risks, for example, of being infectious, which then can be used to target contact interventions. Credit: Tapio Schneider et al, *PLOS Computational Biology* (2022). DOI: 10.1371/journal.pcbi.1010171

Techniques used in weather forecasting can be repurposed to provide individuals with a personalized assessment of their risk of exposure to COVID-19 or other viruses, according to new research published by Caltech scientists.

The technique has the potential to be more effective and less intrusive than blanket lockdowns for combating the spread of disease, says Tapio Schneider, the Theodore Y. Wu Professor of Environmental Science and Engineering; senior research scientist at JPL, which Caltech manages for NASA; and the lead author of a study on the new research that was published by *PLOS Computational Biology* on June 23.

"For this pandemic, it may be too late," Schneider says, "but this is not going to be the last epidemic that we will face. This is useful for tracking other infectious diseases, too."

In principle, the idea is simple: Weather forecasting models ingest a lot of data—for example, measurements of wind speed and direction, temperature, and humidity from local weather stations, in addition to satellite data. They use the data to assess what the current state of the atmosphere is, forecast the weather evolution into the future, and then repeat the cycle by blending the forecast atmospheric state with new data. In the same way, disease risk assessment also harnesses various types of available data to make an assessment about an individual's risk of exposure to or infection with disease, forecasts the spread of disease across a network of human contacts using an epidemiological model, and then repeats the cycle by blending the forecast with new data. Such assessments might use the results of an institution's surveillance testing, data from wearable sensors, self-reported symptoms and close contacts as recorded by smartphones, and municipalities' disease-reporting dashboards.

The research presented in *PLOS Computational Biology* is proof of concept. However, its end result would be a smart phone app that would provide an individual with a frequently updated numerical assessment (i.e., a percentage) that reflects their likelihood of having been exposed to or infected with a particular infectious disease agent, such as COVID-19.

Such an app would be similar to existing COVID-19 exposure notification apps but more sophisticated and effective in its use of data, Schneider and his colleagues say. Those apps provide a binary exposure assessment ("yes, you have been exposed," or, in the case of no exposure, radio silence); the new app described in the study would provide a more nuanced understanding of continually changing risks of exposure and infection as individuals come close to others and as data about infections is propagated across a continually evolving contact network.

The idea was born in the early days of the COVID-19 pandemic, when colleagues and partners Schneider and Chiara Daraio, the G. Bradford Jones Professor of Mechanical Engineering and Applied Physics and Heritage Medical Research Institute Investigator, abruptly found themselves isolating at home and wondering how to use their scientific and engineering expertise to help the world deal with this new threat.

One pre-pandemic focus of Daraio's research was the development of low-cost body temperature trackers. And that raised the question: Would the widespread use of such trackers allow for better tracking and understanding of COVID-19's spread?

"We were envisioning something like a weather forecasting app, harnessing information from sensors, infection data, and proximity tracking, which people could use to adjust their behavior to mitigate individual risks," says Daraio, co-author of the *PLOS Computational Biology* paper.

Schneider is a climate scientist who helms the Climate Modeling Alliance (CliMA), which is leveraging recent advances in the computational and data sciences to develop a wholly new climate model. He reached out to longtime acquaintance Jeffrey Shaman of Columbia University. Shaman's research on how climate change affects the spread of infectious diseases led Shaman to an interest in epidemiology and the adaptation of similar weather-forecasting methods for disease modeling on the community level.

"Over the last decade, the field of infectious-disease modeling, and forecasting in particular, has exploded. Many disease-forecasting approaches leverage ensemble and inference methods commonly used in weather prediction," says Shaman, co-author of the *PLOS Computational Biology* paper.

The team had two key challenges: adapting weather-prediction methods for this purpose and developing a realistic test bed to gauge how well it works.

"Conceptually it is a very appealing idea, as methods to forecast weather have been so effective in predicting the chaotic atmosphere, a famously challenging task," says Caltech research scientist Oliver Dunbar. "But there is no direct translation. An epidemic-forecasting app has very little data to work with and only on a partial population of users. We fortunately found success by coupling this sparse data with the latest smart-device technologies and a mathematical viral spreading model."

To test it, the team turned to Lucas Böttcher of the Frankfurt School of Finance and Management in Germany. Böttcher built a computer model of an imaginary city—a downscaled and idealized version of New York City—with 100,000 "nodes," or fictional people, and then studied how well the adapted weather-forecasting methods predicted the spread of a disease through the population.

The results were encouraging: In the simulations, the model identified up to twice as many potential exposures than would be caught by traditional contact tracing or exposure-notification apps when both use the same data.

"The methods developed in our study are relevant not only in the context of infectious disease management, but they also open up new ways of combining observation data with high-dimensional mechanistic models arising in computational biology," says Böttcher, co-author of the *PLOS Computational Biology* paper.

Despite these promising results, the implementation of this technology in the real world requires suitable levels of smart-device users, and effective testing campaigns to make the risk-assessment software work for managing and controlling epidemics. If approximately 75 percent of a given population provide relevant information (for example, whether they have tested positive for a disease) and self-isolate when they may have been exposed, the risk-assessment software is accurate enough to manage and control the COVID epidemic through the entire population. And yet, as is evident by COVID-19 vaccination rates, buy-in by such a large fraction of the population is difficult to achieve.

Nevertheless, a promising scenario is deployment by smaller community user bases—for example, the population of a college campus—that can readily provide the software with more than enough data to provide accurate risk assessments that will locally reduce the spread of disease.

"The challenge in making this system a reality is managing privacy concerns, for example, about transferring data about close contacts to a central data-processing facility," Schneider says. "That being said, only anonymized information is needed. Location information is already routinely collected for commercial use, and we envision ways to harden the system against exploitation by bad actors."

More information: Tapio Schneider et al, Epidemic management and control through risk-dependent individual contact interventions, *PLOS Computational Biology* (2022). DOI: 10.1371/journal.pcbi.1010171

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