A BREATH OF FRESH AIR FOR PUBLIC HEALTH MESSAGING

SUPERCOMPUTER-ASSISTED RESEARCH to control the spread of COVID-19 could lead to lasting benefits in our battles against flu and other airborne pathogens.

Preschools and nursing homes were significant sites for COVID-19 infection clusters, and have historically been hotspots for other potentially fatal respiratory viruses, including seasonal waves of influenza.

In Japan, the intense research effort to understand and control the spread of COVID-19, enabled in part by the supercomputer Fugaku at the RIKEN Center for Computational Science in Kobe, played a key role in minimizing transmission.

The lessons learned from this work, especially regarding building ventilation, are expected to have a lasting benefit in protecting vulnerable people. As well as enhancing future pandemic preparedness, the work could help to minimize the seasonal spread and fatality rate of flu and other airborne viruses.

A PROMISING PIVOT

When COVID-19 hit, Makoto Tsubokura, a professor of computational fluid dynamics at Kobe University, and a team leader at the RIKEN Center for Computational Science, had been using Fugaku in collaborative research with car companies to simulate the behaviour of fuel droplets in internal combustion engines, as a tool for improved engine design.

"After the pandemic started, our staff went into lockdown," Tsubokura says. "Our team discussed how we could contribute to the pandemic response. One of our youngest researchers suggested that we modify our engine simulation software for simulations of aerosol droplet dispersion."

Virus-carrying aerosol droplets exhaled by infected people were already a well-established potential route of respiratory infection spread, and over the course of the pandemic, aerosols were proven to be a key mode of COVID-19 transmission.

Within a month of starting the project in April 2020, Tsubokura and his team had adapted their fuel-dispersion simulation software to model and generate visual representations of aerosol spread. "The dispersion of aerosols and fuels are actually very similar in terms of the physics," Tsubokura explains.

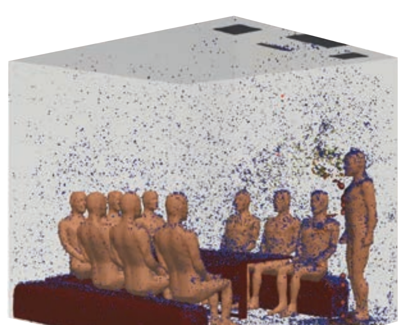
The group's efforts formed a key part of the Japanese government's COVID-19 AI & Simulation Project, a programme that brought research teams from different disciplines together to quickly provide scientific evidence in response to the unfolding pandemic.

In 2020, Fugaku was the world's the fastest supercomputer, and by using it to simulate aerosol spread in different enclosed environments, the team established the value and importance of infection reduction measures such as face masks, room partitions and building ventilation. The team simulated more than 1,500 different cases in more than 70 social situations, including in commuter trains, karaoke rooms, nursery schools and facilities for the elderly.

"Fugaku's enormous computational power allowed us to perform risk assessments for various infection scenes within the urgent timescales needed," Tsubokura says.

Crucially, the team could generate vivid visual representations of aerosol spread, which were made readily available to the media and shared widely with the public.[1] "Visualizing the dispersion of aerosols is helpful to understand infection spread," Tsubokura says. "Our main contribution to the pandemic effort was to grow societal awareness and understanding."

This powerful public health messaging contributed to the suppression of the spread of infection, especially in the early stages of the pandemic in Japan. In November 2021, the team received the Association for Computing Machinery's Gordon Bell Special Prize for High Performance Computing Based COVID-19 Research, for the simulation's capacity to rapidly simulate aerosol behaviour at high resolution and scale.



▲ Visualizations of aerosol spread produced using RIKEN's Fugaku supercomputer were released directly to the public during the pandemic.

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▲ Fugaku (pictured) was the world's fastest supercomputer in 2020.

REAL WORLD RESULTS

Since establishing the aerosol simulation methodology at the start of the pandemic, Tsubokura's work in the area has continued to expand. "We are not specialists in aerosol or indoor environment research, so we asked other researchers to join this project to support our simulations," he says.

A key collaboration was forged with Motoya Hayashi from Hokkaido University, an expert in the indoor environment and its influence on human health.[2] "I organized a team to assess and measure ventilation performance in real buildings," Hayashi explains. "We confirmed poor ventilation in buildings where infection clusters occurred, demonstrating the importance of ventilation measures against aerosol infections," he says.

Opening windows for natural airflow is deeply rooted in Japanese culture, and reflected in the country's architecture, but this alone may not achieve sufficient airflow to sweep away virus-carrying aerosols and droplets, Hayashi showed.

"We focused on nursery schools where many clusters occurred, and care facilities for the elderly," he says. In a representative range of such buildings, ventilation performance was measured, improvements were planned and implemented, and the effect of the changes were measured. Following the team's analysis, a series of building ventilation case studies were released. "Our aim is to make the importance of ventilation understood by the public," Hayashi says.

As well as opening windows for natural ventilation, the use of well-maintained mechanical ventilation, adjusted to increase the intake of outdoor air, was recommended.

Throwing open the windows is not necessarily good advice in mid-summer or mid-winter, Hayashi notes.[3] During these periods, good mechanical ventilation combined with air conditioning or heating is required to simultaneously achieve high air exchange while maintaining a healthy indoor temperature and humidity.

The vital importance of ventilation system upkeep in healthcare settings was also highlighted. "In hospitals, ventilation facilities are often poorly maintained, which increases the risk of infection," Hayashi says. "In the wake of investigation on infection clusters, researchers have begun to review building ventilation design and maintenance."

Collaborating with Hayashi's group has been mutually beneficial, Tsubokura notes. "Their experimental measurement of actual facilities enabled us to improve the accuracy of the simulation," he says. "In addition, by performing simulations that would be difficult to measure experimentally, and sharing the results, the Hayashi group could develop more effective ventilation recommendations," he adds.

Although the COVID-19 global public health emergency has been declared over by the World Health Organization, current and future respiratory infections remain a significant health threat, and the team's work continues. "We are now working with Hayashi's group to quantify of the effectiveness of infection countermeasures in kindergartens," Tsubokura says.

During the pandemic, groups from disparate research areas, including infectious diseases, public health, architecture, information and biosensor technology, came together to collaborate toward the shared goal of healthier indoor air, Hayashi notes. "Such collaboration must continue." ■

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