Singapore is taking the lead with smart city technology.

INTELLIGENT MODELS FOR A SUSTAINABLE SINGAPORE

HIGH-PERFORMANCE COMPUTING AND AI will play a crucial role in planning the efficient and sustainable growth of cities such as Singapore.

Most cities have grown in a haphazard fashion, with little thought given to the impact of changing conditions. Now, with burgeoning populations and a warming climate, city planners may take into account scientific evidence, and leverage new technologies to ensure that new developments have minimal environmental impact and prove robust in the face of future challenges.

From a research perspective, a city is an intricate system that can only be modelled using complex algorithms, ranging from physics to human behaviour.

Researchers at the Institute of High Performance Computing (IHPC), a research institute in Singapore's Agency for Science, Technology and Research (A*STAR), are developing advanced models of such intricate systems in order to help urban planners keep neighbourhoods cool, identify the best sites to charge electric vehicles and even improve the efficiency of shipping operations. Their efforts to turn Singapore into a truly 'smart city' are aimed at ensuring a new and improved path to future development.

City life can be hot, noisy and hectic. Areas with dense buildings, high traffic and exposed concrete can trap hot air, creating unbearable microclimates, something known as the 'Urban Heat Island' effect. In response, a team led by IHPC senior scientist and built environment specialist, Poh Hee Joo, has worked with the Housing and Development Board (HDB) to jointly develop a tool called the Integrated Environmental Modeller (IEM), a project supported by the Ministry of National Development (MND) and National Research Foundation Singapore (NRF).

TOO HOT TO HANDLE

"The IEM utilizes high-resolution 3D city maps coupled to urban physics models, to simulate the combined impacts of wind, sun and noise on urban planning and design," says Poh. "It helps urban planners design buildings that better harness wind flow and have a reduced solar irradiance. This allows new estates to achieve greater sustainability and liveability."

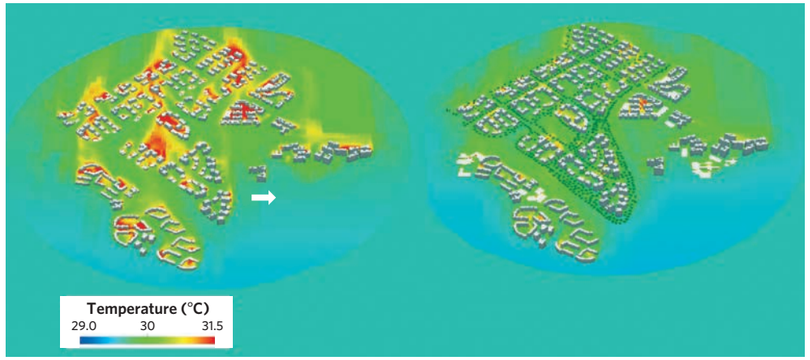
The IEM requires many input variables — such as information on tree coverage, topography, architectural plans, wind speed and direction, temperature and solar irradiance — from a network of 43 sensors, as well as data from Singapore's Housing and Development Board (HDB) and Meteorological Service Singapore (MSS). The resulting model and its impressive visualizations are reminiscent of city simulation games, and require powerful supercomputers to generate it.

"Simulating a town of just 300 buildings takes 3—4 days on a high-end workstation," says Poh. "For a much bigger city scale, we ran 3D air-flow simulations at a 10-metre horizontal resolution, including all the buildings in Singapore. This huge task took more than five days with 6,000 processors at the National Supercomputing Centre (NSCC) Singapore."

The IEM was adopted to aid the design of Tengah Town, a 700-hectare neighbourhood that will feature a large forest corridor and car-free centre. The model determined the ideal placement of buildings to improve wind flow, and identified areas likely to receive more solar heat, so that greenery could be strategically introduced to reduce temperatures.

At a larger scale, Poh and his co-workers are furthering IEM as a further enhanced tool to carry out Urban Environmental Modelling works and grow an ecosystem for environmental study focusing on many aspects of microclimate modelling.

"With the IEM tool scaled up for the whole island of Singapore, users can zoom into new developments and study their environmental conditions," says Poh. He suggests that climate scientists could even use the IEM to study the localized effects of future global warming and encourage cities to adopt mitigation plans.



▲ A map of Tengah Town that demonstrates the effect of urban greenery in lowering air temperature.

LEADING THE CHARGE

Another challenge facing cities is how to manage the rapid transition to electric vehicles (EVs). Singapore currently has around 2,500 charge points for more than 3,600 EVs. But the government has ambitious plans to increase this to 60,000 charge points by 2030.

Qin Zheng, director of the IHPC's Systems Science Department, is leading research on how Singapore can optimize the rollout of charging infrastructure needed to support nationwide EV adoption. The Singapore Integrated Transport & Energy Model (SITEM) his team is working on, simulates island-wide vehicle movements and analyses patterns of charging demand and their impact on the electricity grid. The project — commissioned by the Science and Technology Policy and Plans Office (S&TPPO) of the Singapore Prime Minister's Office — aims to advance the nation's capabilities in integrated modelling and simulation to enhance policy decisions.

"Our objective is to make sure that most of the time, EV drivers would be able to find available chargers when they need to top up," says Qin. "However, we want to try and optimize the distribution of chargers, so as to not overload the grid, while ensuring that demand is readily met."

An important aspect of SITEM is the ability to model the behaviour of drivers with respect to EV charging. To this end, Qin's team collated an extensive data repository from the public domains and collaborating government agencies, and adapted empirical findings on charging behaviour of drivers from overseas cities with similar infrastructure to the Singapore context. This allowed the team to develop charging behaviour models for drivers of private cars, taxis and private-hire cars. These models are then incorporated into an integrated system of different vehicle types to simulate their movement and charging demand in the electrical grid. The simulation output is used to evaluate different scenarios of charger placement and energy management for maximum utility.

"Charging demands vary greatly, from public buses and two-shift taxis needing very rapid charging for all-day usage, to private EVs that can be charged slowly over night," says Qin.

The multidisciplinary team comprises data scientists, simulation modellers, software engineers and behavioural scientists — and this variety of expertise allowed them to model all modes of transport.

"Our simulation findings have enabled agencies to validate and refine planning assumptions resulting in significant cost avoidance in planned infrastructure upgrading," says Qin.

MARITIME AI

Land transport is not the only domain that can benefit from smart modelling solutions to manage growth. Fu Xiuju, a senior scientist and group manager at IHPC, leads a team dedicated to modelling maritime traffic and improving the efficiency of ports.

"Maritime transport forms the skeleton of the global supply chain," says Fu. "Some ports are trying to use modern algorithms to improve shipping, but generally sea transport has lagged behind land and air transport in these efforts."

To fill this gap, Fu and her co-workers are developing artificial intelligence systems that can improve management of ships, fleets, terminals and ports. IHPC is aiming to develop a national maritime AI programme in Singapore, with the goal to be a central node for maritime AI research and drive translation to maritime industry. It aims to develop maritime AI techniques and promote AI applications in maritime domain. For example, it will use AI to improve marine traffic safety by avoiding collisions and reducing near misses, predict when maintenance is required, reduce fuel consumption and emissions, and save money through more efficient logistics.

The AI models require detailed spatial and temporal data about marine traffic, as well as onboard sensing, so that they can assist real-time decision making.

"Singapore is a busy port," says Fu. "Autonomous shipping is being developed, but there are many concerns about its reliability. We're developing and testing our AI-based model with live data from the port authority and shipping companies, and it is showing great potential as a maritime intelligence management system."

Aside from helping to make maritime shipping operate more efficiently, the AI can reduce fuel consumption by optimising the speeds and navigation of vessels. Future models will use sensor data on engine noise and vibrations to predict when maintenance is required.

"Our research team is working towards clever technologies that better connect transport, moderate the climate of neighbourhoods, optimize the charging of vehicles and make the city 'smart'," Fu adds. ■

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