Next-generation transport is now well on the road

A decade of research has brought future mobility closer to the present
by Jinhua Zhao and Daniela Rus

The need to plan, design and operate new transport systems is critical for Singapore's development and growth, especially in the context of the limited space available and its growing demand for mobility.

The constant challenge researchers face is developing mobility systems that are environmentally sustainable while also enhancing the wellbeing of the travelling public both here and in cities around the world.

As Singapore's economy and population grow, so too does the need to deal with mounting congestion. To mitigate this, the country has taken sophisticated approaches to its transport system, with a system that requires drivers to pay for a licence to own their cars and monitors and charges for usage of congested roads at peak hours, also known as the ERP or electronic road pricing. In 2023, Singapore will switch to a satellite-based ERP system. At the same time, the government is also encouraging commuters to take public transport more often.

Although Singapore's transport network is world-class, it must be enduringly reliable and efficient even as the buses and taxis are forced to share the roads with ever more cars and commercial vehicles.

Leading research and innovation

At Future Urban Mobility (FM) research group under the Singapore-MIT Alliance for Research and Technology (SMART), MIT's research enterprise in Singapore, we focus on developing new ways to improve transport systems and introduce new ones.

Over the last decade, we have carried out interdisciplinary research projects and developed technologies, models and algorithms that allow for real value creation and provide innovation in next-generation urban mobility.

By integrating behavioural science and transportation technology, we have been able to design systems that tap into human needs and ultimately recommend effective reform policies. This combination of human instincts and computation also enhances our understanding of predictive, individualised experimentation and multimodal integration trends in the mobility industry.

Among our projects to mitigate mounting congestion was the development of a next-generation control system that is capable of scheduling traffic, routing it and controlling vehicle flow in a way that will allow the most vehicles on the roads while still keeping congestion to a minimum.

Alongside this, we have developed a system to operate public transport so that the speed and frequency of bus services are at their most efficient.

A number of our developments have evolved into spin-off companies. Among these, SMART FM's autonomous driving spin-off became Motional, evolving to a US$4 billion joint venture between Hyundai and Irish auto parts manufacturer Aptiv. The startup Fuente which promotes data-driven decision-making in cities is using Flocktracker, an urban data collection platform that resulted from one of our research projects with the MIT Department of Urban Studies and Planning.

Our research into the relationship between ride-hailing and public transport found that car-sharing services both complement and provide a substitute for buses and trains. This finding provides public transport agencies with crucial data to encourage them to collaborate among themselves and with other carriers to improve efficiency. It also highlighted the need for agencies to enhance how they integrate infrastructure, information and fares to encourage people to use public transport alongside ride-sharing platforms.

Pioneering autonomous vehicles

Because it is a struggle to meet the needs of the public while also protecting our planet, we have responded by developing autonomous vehicle (AV) systems to make the car-sharing economy a cheaper and more ecologically viable alternative to private vehicles.

SMART FM has set out to make Singapore one of the leading AV technology players in the world. In 2014, one of the first ever public AV trials took place in Singapore's Chinese Garden, during which members of the public were invited to experience autonomous driving for themselves. Further research has enabled the continued advancement in AV development by overcoming a number of longstanding challenges involving data availability, quality and interpretation.

One of the special challenges for the use of self-driving vehicles is the torrential rain all of us are used to in Singapore. Difficult environments, especially rain, degrade the performance of AV systems by reducing the quality of data collected by sensors and messing with the algorithms used to interpret these data. To counter these drawbacks,

we have developed a novel method called LIDAR Degradation Quantification, which enables the necessary adjustments to be made to the AV control systems by assessing the level of degradation caused by rain.

We have also drawn inspiration from the humble earthworm, with its extremely basic neural structure. Somehow, with just 300 neurons—compared to the hundreds of thousands we would use to steer AVs—a worm can find food, find a mate and live a good life.

This led us to develop a new type of neural network that allows us to compress all our former neural networks into just 19 nodes that still provide the same level of computing power. Through this approach, we can be much more efficient and broader in our capabilities.

The development of AV took a further step in the right direction when Singapore's Land Transport Authority approved the use of more than 1,000 kilometers of public roads in the west of the country for testing self-driving vehicles.

In a collaboration with National University of Singapore, we have been testing our AVs on the university's campus and at the One-North business park in Queenstown. This added access to public roads has provided us with a platform to further research while raising public awareness of AV at the same time.

Notwithstanding all this progress, fully autonomous driving still has quite a distance to go before even its development stages are complete. Yet our pioneering research has set the stage for future work in Singapore and elsewhere.

After a decade during which our MIT scholars have had the opportunity to view their research from a wholly different and complementary perspective in Singapore, helped by the facilities and support that have been given, SMART FM can look back on a body of knowledge enhanced by the 282 journal papers and 466 conference papers we have published throughout our time here.

Over the years, this knowledge and expertise have been transferred to society as our alumni took up academic roles at institutions and leadership positions at companies such as Baidu and IBM. Together, our staff have brought about fundamental changes in the long-term trajectory of sustainable mobility development.

The Singapore-Massachusetts Institute of Technology collaboration has been in many ways at the forefront of innovation in mobility--a field that has seen significant changes

in the decade since the project began. MIT has since made mobility one of its priorities, as evidenced in the recently established Mobility Initiative, and will be driving much of the research begun as part of the partnership forward in the coming years.

It has also been a two-way street both for us and for the people and organisations we have worked alongside, in that each party has had much to offer the other. Our work has taken us further, and we have reached our goals faster, within this novel environment. Our time in Singapore has been of great benefit to our research mission. And we hope to demonstrate this to the world with exciting new and improved transport systems well into the future.
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