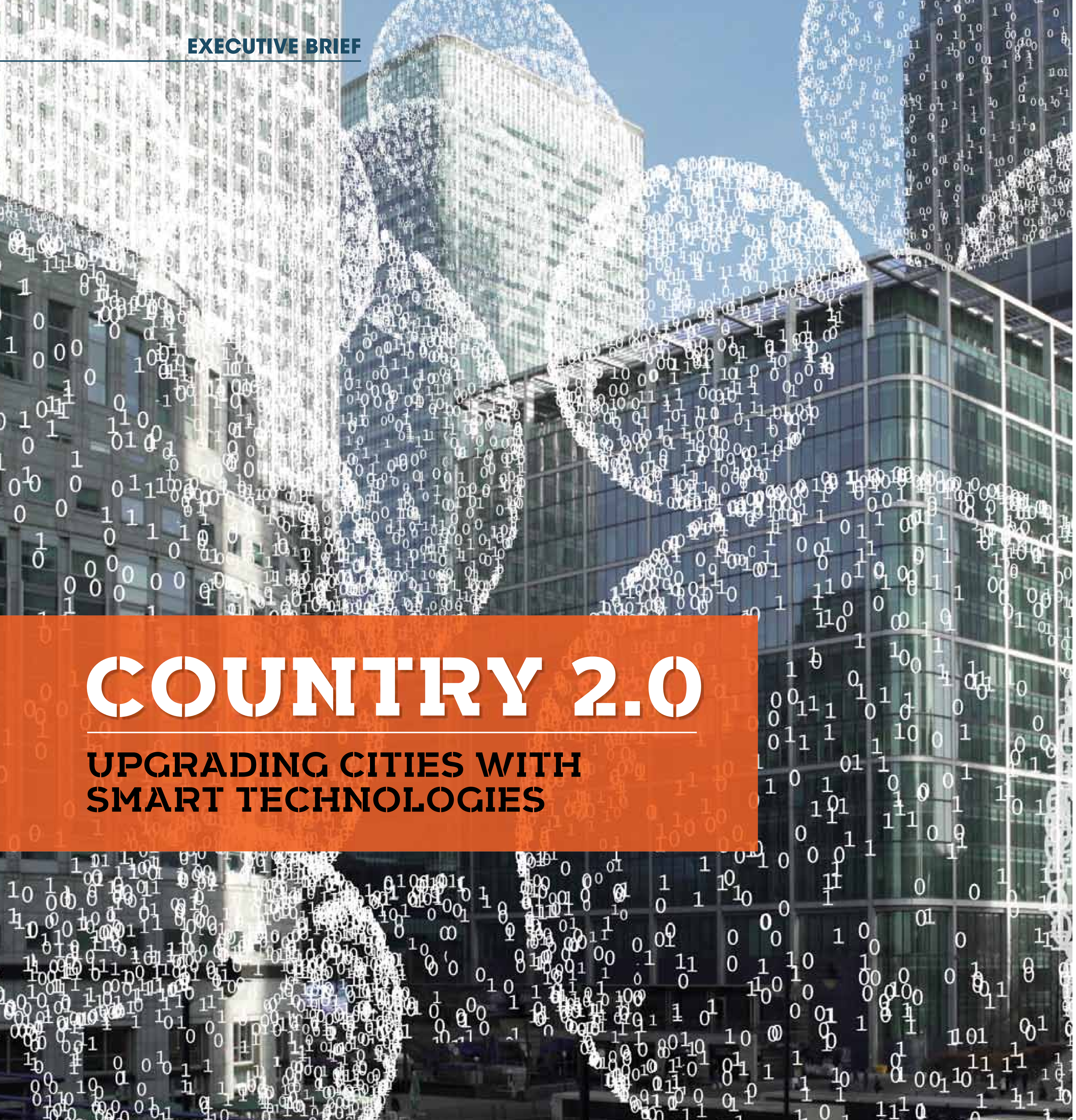


COUNTRY 2.0

UPGRADING CITIES WITH SMART TECHNOLOGIES

Advancements in technology are being used to transform our cities into smart cities, but the process is not without its risks.

By Steven Miller

The ability to collect, process and use information well–enabled by the necessary infrastructure of hardware, sensors, networks, data management and software applications–is what makes a smart city. Recently, I moderated a panel discussion at Singapore Management University with three recipients of the Turing Award (the Computer Science equivalent of the Nobel Prize): Vinton Gray Cerf, Google's Chief Internet Evangelist; Butler Lampson, a senior scientist at Microsoft Research and an Adjunct Professor at MIT; and Richard Karp, professor at the University of California, Berkeley. The fourth panellist was Tan Kok Yam, head of Singapore's Smart Nation Programme Office.

All four speakers shared their vision and views on how 'smart systems' can be used to enable more liveable cities now and in the future. They elaborated on what they meant by smart systems in the context of urban liveability and smart cities, and how smart systems should (or should not) be used to meet the challenges of making cities more liveable. As Karp explained, "The fundamental organisational structure of a smart city will involve advances in data management, communications, as well as the development of the Internet of Things and a large range of physical systems, such as sensors and other monitoring devices that allow more intelligent management of processes in the city."

The role of the government in delivering such infrastructure cannot be underestimated; and it must play an active role in smart city planning, implementation and operations. Tan discussed the need for more integrated data management systems for the civil service, and commented on Singapore's Smart Nation effort in working on ways to enable government units to share information and coordinate with one another with more speed and flexibility.

Risk factors

IMPLEMENTATION CHALLENGES

Smart systems technology for smart cities will face many practical issues in implementation. Cerf elaborated on these issues using an example that is close to home. "Consider a smart thermostat that learns. It will always infer a pattern from the data it collects, but only a subset of these patterns are the ones we want it to remember and learn from. So without deep understanding of context and user needs, the thermostat can easily end up learning the wrong things. How do we get the thermostat and the surrounding home environment to be smart enough to know which patterns are the useful ones versus those that are just noise?”

“For example, the thermostat knows it is not supposed to heat or cool the house when nobody’s home. But it is more complicated than you might realise to know if there are people in the house. One of the new brands of smart thermostat comes packaged with two sensors to detect the presence of people at home, but even this has a limited range of detection. In a bigger house with multiple rooms, the thermostat would think there are no people in the house when the inhabitants are spending extended periods of time in the other rooms, and would automatically shut off the cooling or heating.”

Even this simple example of using an ‘intelligent thermostat’ in a multi-room house illustrates that it is not so straightforward for the smart system to have the full understanding required to make the right decisions for a specific situation. The smart thermostat would need to be integrated with sensors in other parts of the house. Also, the thermostat needs ways to learn which patterns it observes are the ones to be incorporated into its updated knowledge base versus those that are special situations and should not be used for updating decision-making rules. Not all of the activity data observed by the thermostat is equally important, and the thermostat has to be smart enough to know this.

In just one smart home, detection issues can be easily resolved by installing more sensors, and the range of different types of human activities that need to be understood and learnt is limited. On a city-wide scale, however, it becomes a much bigger challenge to provide the smart systems with the necessary deep understanding of the context they need in order to know how to make the right decisions in specific situations. It is a logistical and operational challenge to have sensors deployed across an entire city, although technological developments are making it increasingly possible and economical to do this. It is a much harder challenge to know how to evaluate the vastly expanded range of human activities and behaviours, as well as infrastructure and other physical data that would be observed and needed for monitoring, situation assessment and decision-making.

While progress has been steady and impressive, it will still take five to ten years, and perhaps even longer, to fine-tune the performance of these types of smart systems for supporting infrastructure maintenance that are now being deeply interwoven into the smart nation infrastructure.

MANAGING DATA PRIVACY

The potential for the loss of personal privacy when collecting data poses a wide range of complex challenges. Lampson explained that residents must be willing to share information in order for artificial intelligence (AI) to achieve results: “If you want more privacy, then it’s bound to put constraints on how you can use the data.”

As more information becomes available, people will face a trade-off between privacy protection and the benefits that can result from wider ranges of data usage. There will always be groups of people on both sides of this issue: those opposed to any trade-offs that result in less data privacy, and those opposed to trade-offs that restrict data usage or constrain possibilities for innovation. The government needs to be closely engaged with civil society groups and the business community to thoughtfully navigate these trade-offs.

COUNTERBALANCING ACCELERATED LEARNING AND CYBERSECURITY

Smart systems benefit from accumulated experience (lessons learned) to improve their contextual understanding and overall system performance. State-of-the-art software systems are increasingly enhancing their ability to automatically learn as a result of taking in more data and analysing more examples. Even so, there will still be many situations where software designers (let’s assume it is mostly humans serving in the designer role) realise that they can further improve the capabilities of the smart system by making a change in programme design and implementing it via a software update. There will also be situations where system designers of one type of smart system in one location figure out a way to improve the software programme design, and want to share that performance-improving software change with similar types of smart systems in other geographic locations through software upgrades.

Cerf helped the audience to understand the power of this capability of smart systems to enhance learning and performance through this example. “The new generation of autonomous (without human drivers) vehicle fleets learn to improve performance much more quickly than our current cars with drivers. Once errors in understanding and decision-making are corrected and thoroughly tested based on the experience of one autonomous car or a small set of autonomous cars, these lessons learned can be distributed to all autonomous cars made by that same manufacturer via software updates on a regular basis. This type of phenomenon is expected to

be widespread, and true of a large range of physical systems, called the Internet of Things," noted Cerf.

We are all familiar with the benefits of software upgrades. Essentially, this is what happens every time we update our computer's cybersecurity software used to protect our machines from malware and viruses. Cerf asked the audience to think about a cybersecurity challenge that will become even more prevalent than it already is. Suppose the software update from the creator/manufacturer of the system is somehow 'infected' by cybercriminals, and the supposedly trusted update itself becomes the carrier of malicious software. As widespread and problematic as malicious software and hacking already is in our current world, the new generation of smart systems makes the challenges of new cybersecurity threats even greater. Cerf warns that the global community needs an ever greater effort to ensure that software updates, especially to smart systems that can result in life or death outcomes, have the strongest forms of authentication and absolute validation to ensure that the software has not been inappropriately altered from its original state.

PREPARING FOR THE UNKNOWN

Smart city improvements will also require preparing for unknown situations. Lampson raised the point when he questioned how, and to what extent, will the demand for existing modes of public transport be influenced by the increasing usage of autonomous cars? His question points us to related questions, such as what would happen if some of the buses were also to become 'driverless', giving us the option of mass transit autonomous vehicles? In addition to the positive benefits, there may be unforeseen negative consequences as well. Lampson cautioned that these are extremely complex situations. With so many unknowns, and so many possibilities for unanticipated interactions, it is inherently difficult to predict the impact of these types of profound technological changes and the accompanying socio-technical interactions.

In the past five years, deep learning systems have been commercially deployed across a broad range of applications, including image recognition, speech recognition, natural language processing, e-commerce recommendation systems and drug discovery. Deep learning technology has tremendously accelerated the deployment of machine learning systems in a number of specific real-world settings, including smart cities.

With deep learning systems in particular, some of the 'black-box' aspects of how they function may add further complexities to understanding and managing future impacts. Deep learning algorithms are often expressed in the form of neural network structures. While we may know the number of neural network layers, the number of artificial neural nodes at each layer, and the weighting of the nodes at each layer, the exact decision-making model used by the deep learning system to make decisions is not visible to the humans who create, train and support the system. No one really knows the exact steps being followed by the machine, although we know the structure and properties of the artificial neural network being used to convert the input data to output judgements.

"For example," said Cerf, "at Google, we trained our tensor processing units, which are application-specific integrated circuits tuned to improve machine learning performance, to control the cooling system for our data centre. We used to do this manually, but by training our deep learning system to figure out how to optimise the use of power for cooling purposes, we have cut the cooling power requirements by 40 percent. While deep learning has worked very well here, we do not really understand exactly how it works–and philosophically, I get nervous when I don't fully understand why things work. More generally, my view is if you don't fully understand why a deep learning AI system has been working so well, you will not be able to understand what happened when it does not work."

To minimise these risks, we need a careful and cautious approach to how we test, deploy, monitor and supervise our smart systems for our smart cities, especially as we create systems that have increasing degrees of autonomy.

Possible solutions

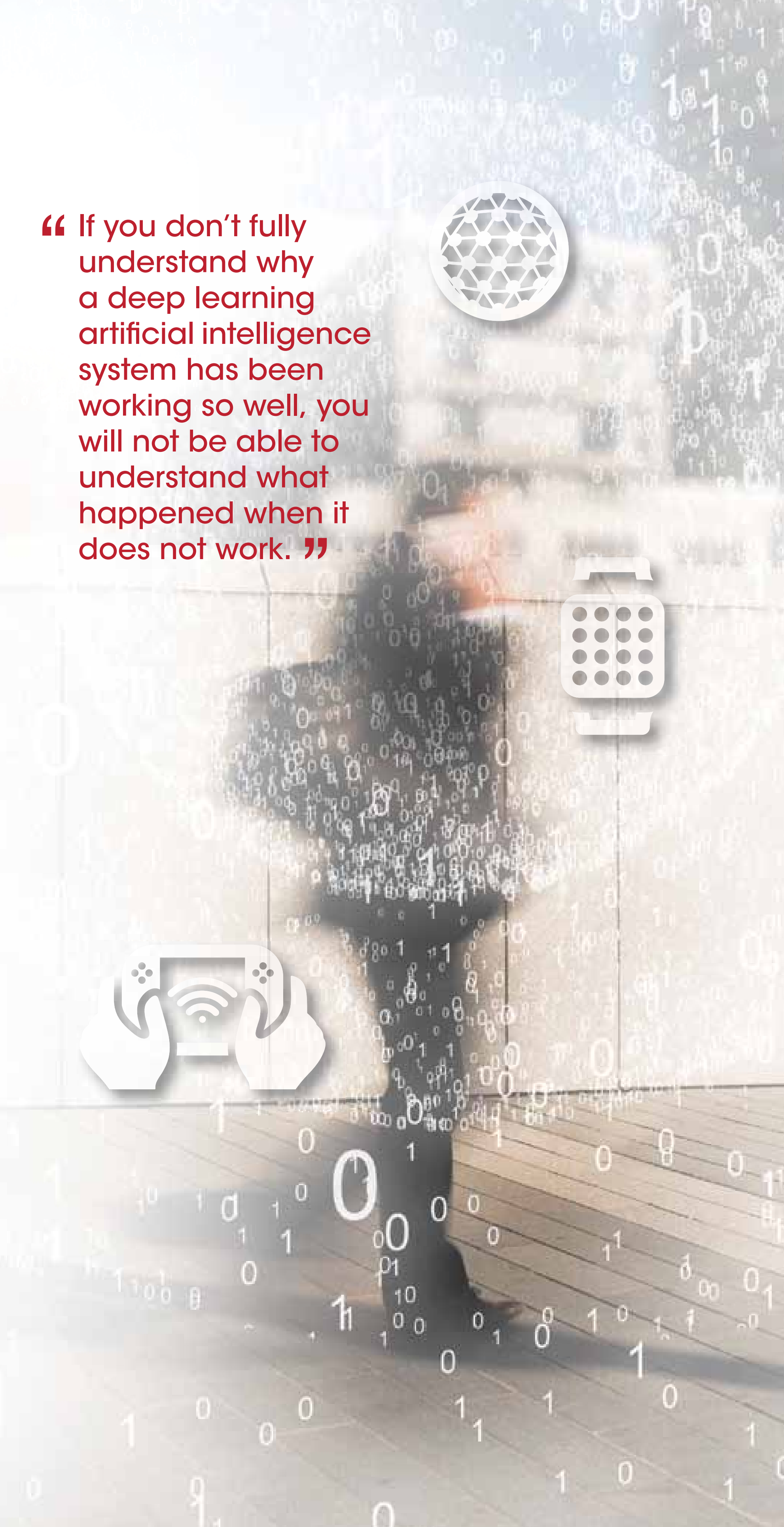
The transition from where we are now to a truly smart city will be an ongoing and gradual process. The government has to pace the rate of change in a way that balances the need to move quickly in order to maintain and advance the city's economic competitiveness, versus the need for transition time that allows for more engagement with residents and that gains greater acceptance. Government planners must also factor in the time needed to ensure the smart systems being deployed are carefully tested and validated. This includes making sure that those responsible for implementing these smart systems have the organisational capacity to monitor and supervise how this is all working out, and that they can prudently manage the risks associated with using smart systems. Another important consideration is to strike a balance between the protection of personal data and pooling individual level data (which can be anonymised) into population-wide data sets that can be used to arrive at more well-informed decisions for the benefit of communities, and overall society and economy.

DECENTRALISATION

Some level of decentralisation can also enable the transition to a smart nation. Cerf explained, "Signboards for how many parking spots are available is a simple convenience made possible by smart systems. In this case, only local communication is necessary. This is a good example of the following principle: if the information that's required to make something usable or liveable is very local and does not need to be centralised in order to make it work, you don't necessarily need to centralise that." This type of approach, where applicable, could help reduce the complexity of the smart systems being implemented.

PUBLIC ENGAGEMENT

Tan commented on the importance of educating the public to get them familiar with changes that will come about as a result of the smart nation effort. He also highlighted the need to get the general public to better understand both the direct and indirect ways in which smart nation efforts are related to the ongoing changes they see around them. For instance, when people see an autonomous vehicle on our roads, they easily associate it with Singapore's Smart Nation effort. However, when they see a new pedestrian bridge that makes it easier for people, especially the elderly, to cross a street, most members of the general public view this as just another construction project, unrelated to Singapore's Smart Nation effort. They do not



> "If you don't fully understand why a deep learning artificial intelligence system has been working so well, you will not be able to understand what happened when it does not work."

realise that there may have been a smart nation element that was an important input into why and how this pedestrian bridge construction project was done. But this is increasingly the case, as Tan explained. “Data analytics and geographical information are used to ascertain where our elderly people are living, their visits to the neighbourhood market, and their other frequently used walking pathways. We use the results of this type of analytics to decide the most useful place to locate the new pedestrian bridge to meet the needs of the elderly.”

Increasing opportunities for public feedback and improving the ability of various government units to analyse and make use of that feedback is a natural application area for smart nation efforts. In fact, Karp observed that it is something the government must do out of necessity, and commented, “The design of the smart city will have to account for the interests of the many subcommunities. Interest groups must have avenues to make their needs known.”

While smart nation initiatives will be deployed to improve lives, and in some cases even to save lives, there will be specific subgroups of people who will be adversely impacted. For example, while Singapore’s capacity for ‘personal transportation-on-demand’ has increased substantially as a result of Grab and Uber introducing their shared-economy transportation services and mobile apps, some drivers working for pre-existing taxi fleets are making less revenue due to the increased competition. As these types of technology-enabled disruptions continue, specific subcommunities and groups will be disproportionately impacted in adverse ways. The government will have to further strengthen its already existing network of feedback mechanisms to know what is happening on the ground, and use this social sensing insight to address the special circumstances of those whose livelihoods are upended in the name of progress towards a smart nation and global economic competitiveness.

ENSURING SAFETY AND RELIABILITY OF SMART SYSTEMS

Cerf also pointed out the need to have software engineering competency standards, especially for systems that could result in loss of life if there were malfunctions. “There are some types of programming that ought not to be done except by programmers who have demonstrated a high degree of professional competency, which essentially means professional licensing,” noted Cerf. “In any society, we should not be releasing software that we don’t have reasonable confidence is safe for people to use. The most important thing to be able to promise the consumer is that the device is safe to use.”

Lampson had a clever idea of using software itself as a means of making complex smart systems safer and more reliable to use. Drawing on his own experience as a system designer and software developer of complex distributed systems, he observed that inserting new safety commands into a very large code base is complicated and takes a lot of time for the required testing. He suggested that the large complex system be surrounded by a very simple software system that is dedicated to monitoring safety mechanisms and enforcing a small number of basic safety conditions that would always make sure the full system was guaranteed to be working within acceptable bounds.

For instance, in a traffic light control system, he suggested, “Give the traffic light this type of ‘executive monitor’ that has to guarantee the enforcement of two simple rules: at least one direction of the traffic light is always red, and when the traffic light turns yellow in one direction, it stays yellow for at least three seconds. Also, give this executive monitor veto power over the 20 million lines of code of the full system with all the real time inputs and the smart decision-making algorithms.” In short, Lampson highlighted the possibility of designing very simple and provably correct software systems to work in tandem with the full and highly complex smart system as a means of helping the people and organisations responsible for the smart system to monitor its behaviour and performance.

While this is just a hypothetical example, it illustrates that there may well be clever ways to manage the safety and reliability of this new generation of smart systems for smart cities. While this is a very promising strategy for monitoring and managing the decision outputs of smart systems, adding an additional ‘part’ to the overall system (the smart system plus the executive monitor) increases the possible pathways of interaction, which means increased complexity. So even with Lampson’s approach, we have to exercise great caution.

From smart cities to smart nations

There is great potential in realising the vision of being a smart nation. For Singapore, successfully implementing and realising the Smart Nation vision is more of a necessity than just a possible option to consider, as this vision is a critical part of the transition to the future economy. While there are formidable challenges and obstacles, both technologically as well as socially, these challenges can be addressed. With a smart approach to designing, implementing, testing, supervising and managing our smart systems for a Smart Nation in Singapore, these challenges can be overcome. In summary, I believe these challenges are surmountable in Singapore and in many other smart cities in other locations, if we go about the learning and transition process in smart ways.

A truly smart city needs to be more liveable for everyone–and we can make Singapore into a more liveable smart city as technology improves and as our government and inhabitants continue to engage in ways that enable them to co-create the way forward.

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Quoted comments have been edited for clarity and to meet the needs of a written article versus a panel discussion.

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