The Citizen Twin

Designing the future of Public Service using Artificial Intelligence

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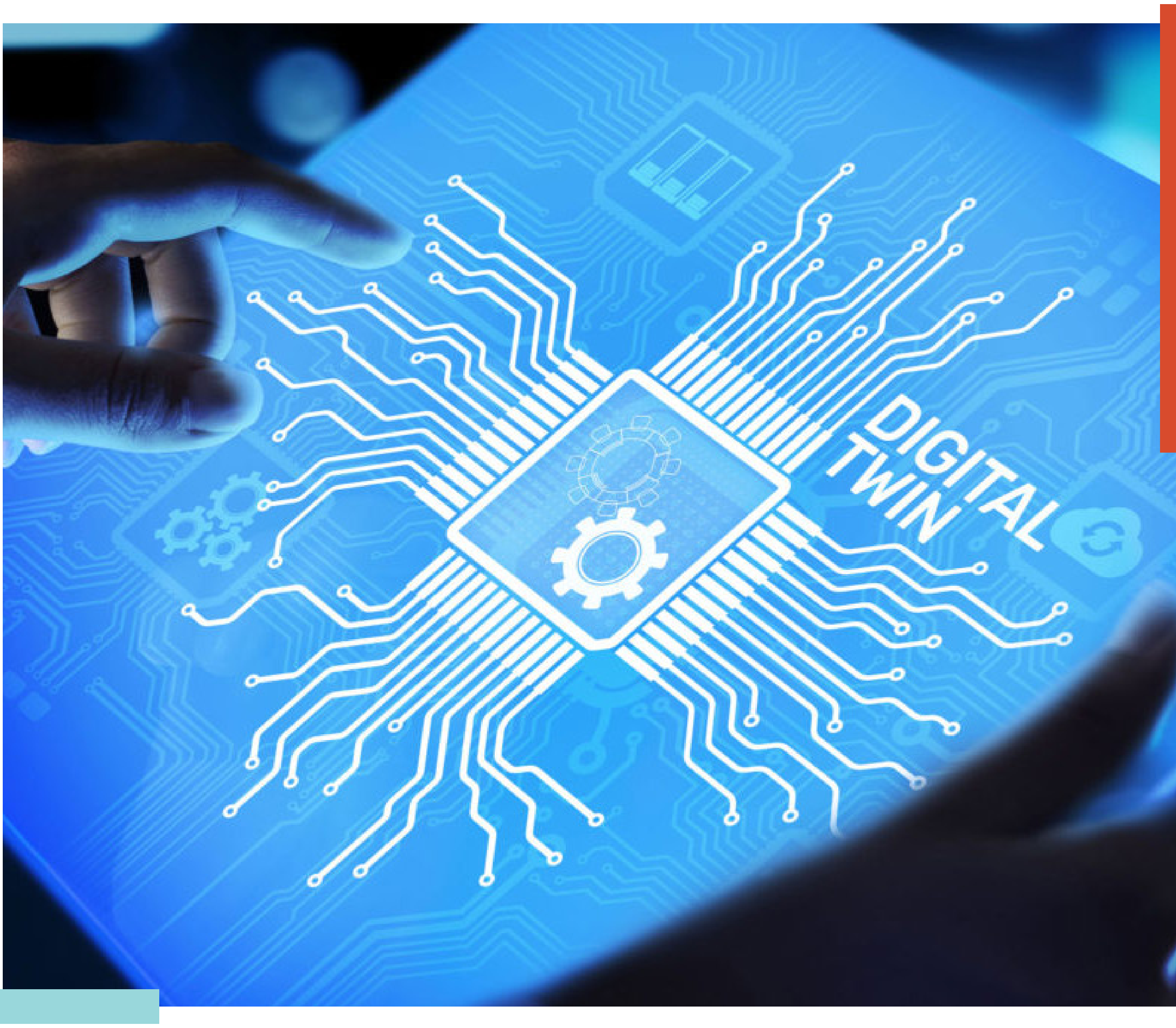


Introduction

Citizens are overwhelmed with the tsunami of data which engulfs them daily (Bawden and Robinson, 2009; Dingli and Seychell, 2015; Hemp, 2009).

The promises of the information society fizzled out (Halal, 2008), and many organisations struggle to go through with their digital transformation (Barmuta et al., 2020; Gregersen, 2018; Khitskov et al., 2017). The information overload problem people face daily is sowing further confusion while making cooperation between individuals more difficult. In fact, in many cases, rather than lead to constructive dialogue, it is merely polarising opposing views and fuelling further friction (O'Callaghan, 2020; Seargeant and Tagg, 2019; Williams et al., 2015). People today rely on algorithms to view the world, but many find it challenging to build a coherent picture of reality and digest all this information.

The Twins

The need arises to reinvent how Public Service interacts with its clients. The solution to this is in the setting up of a Digital Twin (DT) for people, generally referred to as a Citizen Twin (CT). Let us start by understanding what a DT is.

Digital Twins

A DT is simply a virtual replica of a real system (Fuller et al., 2020). It enables the monitoring (via sensors) and remote control of that entity. Data about the DT is obtained and visualised in real-time. As defined by Boschert and Rosen (2016) a simulation of the various processes within that system is then run to decide which actions will give the best results. Furthermore, that information is also essential to make future predictions about the state of the system. By utilising historical data, trends and patterns are extracted and applied to real-time data, allowing the DT to forecast what will happen in the future with a certain degree of accuracy. With this information in hand, the DT can orchestrate (Borodulin et al., 2017) the right processes and execute the correct actions to reach the desired results. Because of this, Datta (2017) deems DTs as being the holy grail of digital transformation.

Even though there's ample literature about DTs, as can be seen in (Dingli et al., 2021; Farsi et al., 2020; Tao et al., 2019) the concept is still in its infancy. Very few applications transitioned from the drawing board to the real world, the bulk of which concealed to manufacturing industries. These implementations within industry come as no surprise since manufacturing plants rely heavily on automation; thus, their data is already available. All they do is get a stream of that data and feed it into the DT for further processing. The DT will then mirror the real device's processing and present it back to the users by using visual means. Such systems typically rely on animations produced using augmented or virtual reality headsets as specified in Dingli and Haddod (2019), thus offering the user a comprehensive overview of what is happening inside the machine. In other industries, gathering the data necessary for a DT is somewhat more complicated. But a DT goes beyond the possibility of just receiving data from the real object. It needs to have, the option to send data back to the physical machine. If the communication back with the device is not available, it would be presumptuous to call it a DT model. At most, it would be a Digital Shadow as mentioned in Kritzinger et al. (2018) that would still process the data but cannot influence the real-object autonomously. Any interaction between the virtual-object with the real-object would happen with manual intervention. Such an approach defies the scope of having a DT since human mediation tends to be slow and error-prone.

A common issue which arises when dealing with DTs is the amount of data which is required (Liu et al., 2018). As mentioned earlier, the world is facing an information overload epidemic. Computers can handle much more data than humans; however, one cannot pump large volumes of data and expect the DT to manage it. The transfer of information between different systems is still a significant bottleneck even though clouds or data-lake infrastructures (Małysiak-Mrozek et al., 2018) handle the storage. Furthermore, more data is not always better, and in some cases, it merely adds noise, thus causing more problems than it solves. Therefore, when dealing with a DT system, it is recommended that processes only store the required information or that which might be useful in future applications.

To summarise, a DT is nothing more than a virtual mirror of an actual physical process that uses the data generated by the process, analyse it, and sends back instructions. This approach enables much more efficient and effective use of the underlying data, which encourages further automation. Ultimately, such systems aim to automate the management part to optimise these processes.

Citizen Twins

A CT is a DT which is mirroring a real person rather than a machine as defined by Gartner (2020).

Its fundamental component is a repository that holds all the public data (stored by the government) about an individual throughout their lifetime. This approach is a significant shift in mentality to what is currently in use. Today's most popular strategy involves having public entities, each with a separate database (or group of databases) distinct from others (Aaker, 2008; Rasmussen Pennington and Cagnazzo, 2019). With such a system, different entities hold fragments of the personal data of an individual. Governments have been trying to get these entities to share their data for decades. The latest push sees the implementation of the "once-only principle" (Kalvet et al., 2018; Krimmer et al., 2017; Wimmer et al., 2017) which is an e-government concept to get citizens and companies to provide standard information to the government only once. Of course, it is easier said than done. Legacy systems rely on different databases, using various formats and following conflicting conventions. The biggest problem with such systems is that since the databases contain data collected during different periods, there might be inconsistencies amongst the repositories (Eiter et al., 2014). Furthermore, it is probably difficult for the government to get a comprehensive yet coherent picture of each client since many of these systems do not communicate with each other, and there is nothing that aggregates the information.

With a CT, the government would have a single repository for every individual. This approach automatically eliminates issues of inconsistencies amongst databases. It will also solve any incompatibilities since the CT will act as the *lingua franca* of government. Legacy databases will be a thing of the past and the headaches associated with maintaining them and ensuring that the right expertise is available would diminish. Let's not forget that the world already passed through such an issue a few years before the end of the last Millenium. At the time, experts predicted that the world's legacy systems were prone to the Millenium or Y2K (the Year 2000) bug (Kratofil and Burbank, 1999). The bug has its origins soon after the Second World War when computer memory was scarce and expensive. To be economical, computer programmers started writing a date using two digits to represent the year. Of course, this would create havoc at the turn of the century since a record entered on 1st January 2000 would appear before one inserted on the 31st December 1999. Luckily, careful planning averted the global disaster. However, the search for COBOL programmers to fix the legacy systems was a real feat. Hence why governments should do their utmost to move away from such legacy systems.

Once the CT is in place, different entities will have different data viewpoints on a need-to-know basis. For instance the tax department will see different aspects of the CT than the, say, licensing department (which would also fall under separate ministries). However, if the compliance department wants to check whether the licensed individual is paying their taxes according to predefined analytics, the compliance department would view the data accessed by both the tax and licensing departments.

But a CT is much more than a glorified database. The data warehouse is just one of the foundation stones to create such a system. Let's not forget that a significant challenge with data is the quantity. According to Margetts and Dorobantu (2019) people generate massive amounts of information daily through their mobile devices (computer, laptop, tablet or smartwatch, to name a few). We estimate it amounts to around 2.5 quintillion bytes data per day. Thus it is not surprising that in the past two years, we created 90% of all the data in the world. When one considers that governments are placing the Internet of Things (IoT) sensors everywhere (AlEnezi et al., 2018; Kankanhalli et al., 2019) (such as access cards, smart lamps or cameras), this number will increase drastically. A robust data warehouse needs to handle all this data volume and connect the different data snippets almost in real-time.

Since one of the CT's goals is to help every person lead an enjoyable life, it will also change how we communicate with the government. The system acts

as a mediator between the virtual world and the physical space. People should not access digital services just through their digital window (such as a mobile phone, tablet or computer screen) but through the introduction of more natural interfaces (such as speech (Wijeratne et al., 2019). Sensors, located nationwide, will become their extended feelers which will feed information into a network of distributed databases. The big data collected is then analysed using advanced AI algorithms and fed back to people in various forms. Whereas before, most of the connections were physical, now everything is shifting online. Thanks to the IoT, there is little distinction between physical or virtual objects. It provides AI with an extended view, beyond the online world and encroaching into the physical world. If a person is waiting at a bus stop, the CT will automatically communicate with his mobile device and push real-time bus scheduling information. The physical context becomes a trigger to the data which the individual needs. In so doing, AI can then assist the people in their daily lives. Thus, this process brings new value to society in ways not previously possible.

> **...now everything is shifting online.**

This reality comes at-a-time when life is becoming prosperous (Kohli and Agarwala, 2017), so the demand for food and energy is rising, lifespan is increasing, and society is advancing. Apart from this, international competition is becoming fierce thanks to globalisation (O'Sullivan, 2019). As a result of this fast-moving world, inequalities are multiplying, generating more social problems (Bauman, 2011) Countries are also facing new challenges such as reducing greenhouse gases, increasing food production to satisfy demand, redistribution of wealth, promoting the circular economy and managing the ageing society to name a few. Nations can only tackle these challenges with AI and a combination of advanced technologies such as IoT, Robotics, 5G and Big Data.

The need for such a system became evident during the pandemic when governments launched apps (Trang et al., 2020) to help people sustain social distance and facilitate contact tracing. The next stage in the evolution of these systems is creating health passports (Brown et al., 2020) intended to keep a record of who was vaccinated and provide access to public places (such as restaurants, shops and public transport to name a few).

But the idea of CT goes much further. The data is harvested from different data sources and amalgamated to create digital personas. When dealing with personal data, privacy can be a big issue. Thus, all the data is stored either in their device or on their cloud account. The AI algorithms will then use federated learning techniques (Li et al., 2020) that access the device, learn the trends, and upload only anonymised data to the central server. Users can also opt not to allow the federated learning algorithms to access their data. Such a system will ensure that data usage is both ethical and secure.

The CT can hold information about anything, from interactions with government agencies, work-related information, health diagnostics from wearable devices, and even shopping patterns. The system will also ensure that the profiles are up to date in real-time. This data fusion will eventually open new opportunities for both public, and private organisations.

Case Studies

There are many things which a CT can do, but it can focus on two aspects: first of all, it will ensure that all citizens get the most out of the government services available. Second, it will predict which services will be needed in the future, thus allowing the government to plan and offer those services to the individual when needed. The following are some examples:

Remote Monitoring

The ageing population is rising every year (He et al., 2016), and most governments are under pressure to provide more institutional care. But such care is very costly (Kitchener, 2006), and most of the time, the demand is much bigger than the supply, thus leaving vulnerable people without adequate supervision. Furthermore according to Challis et al., (2001), it is a known fact that people prefer to keep on living in their community rather than being uprooted and placed in an alien environment.

To solve this issue, a CT is used to provide Ambient Assisted Living (AAL) services (Marques, 2019) in their own homes. AAL makes use of technology in a person's daily life to help them live independently. Several AAL devices have been designed and developed, based on sensors, microphones and vision systems with quite promising results. However, for the field to reach maturity, many challenges need to be tackled, including developing robust processes in the real-world that are easy to use and accepted by the society, users and carers. Various AAL products are available on the market, and these provide elderly and vulnerable people with a better lifestyle and a secure environment. As outlined by the EU Commission (Van Grootven and van Achterberg, 2019) we can define stakeholders' needs in the following categories; AAL for persons (home and mobile), AAL in community and AAL at work. The technologies on which the applications and functionalities rely on are;

- Sensing – exist in almost all AAL applications from wearable products to sensors built in the environment (such as home, vehicles and public areas).
- Reasoning – knowledge about the user's daily activities or an abnormal activity such as an emergency.
- Acting – can be considered as the services that proactively act to monitor the assisted environment.
- Interacting – Intelligent interfaces supported by networks and computers that will be surrounding humans or machines.
- Communicating – AAL systems can also communicate with each other using centralised services.

AAL technologies include a wide range of devices (Benetazzo et al., 2015) such as home embedded sensors and networks, body-worn sensors, robots and implants.

The industry recently showed a growing interest in computer vision-based solutions (such as Dingli et al., 2012; Dingli et al., 2013; Dingli and Seychell, 2014) because these products are offering much more affordable solutions. A significant risk faced by older people is accidental falls. According to Zecevic et al. (2006), a suitable definition of a fall is "Unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in stroke or an epileptic seizure". Walker and Howland (1991) estimate that about one-third of the elderly living in the community experience at least one fall yearly and this goes up to 30% for people aged 65 or older.

Loss of consciousness before or as a result of a fall can lead to difficulty where a person remains lying down until someone notices the accident or until the person regains consciousness. This situation could lead to problems if the person involved suffered injuries and cannot move. Calling for help or trying to get up can be critical. Non-intrusive sensors that monitor the person's movement and actions can avoid such situations. Standard camera feeds monitored by an AI system like that developed by Gatt et al. (2019) can follow a person throughout their home. They can perform skeletal detection[1] and through it, infer what the person is doing. Thus, if the system detects a person lying on the floor during the night, it will first try to interact with him via voice. If the person does not answer back, it will then raise the alarm to his next-of-kin or the relevant authorities. The entire process is performed automatically by an AI, and there are no humans involved, thus guaranteeing the individual's privacy. Apart from emergency issues, the CT can also handle mundane things like prompting the person to take their pills (Yugandhar and Jayanthi, 2020) or even create geofences (Wan et al., 2015)in cases where the illness requires them to stay home.

"...elderly living in the community experience at least one fall yearly...

[1] Skeletal detection is a digital estimation of the person's skeleton.

Optimisation

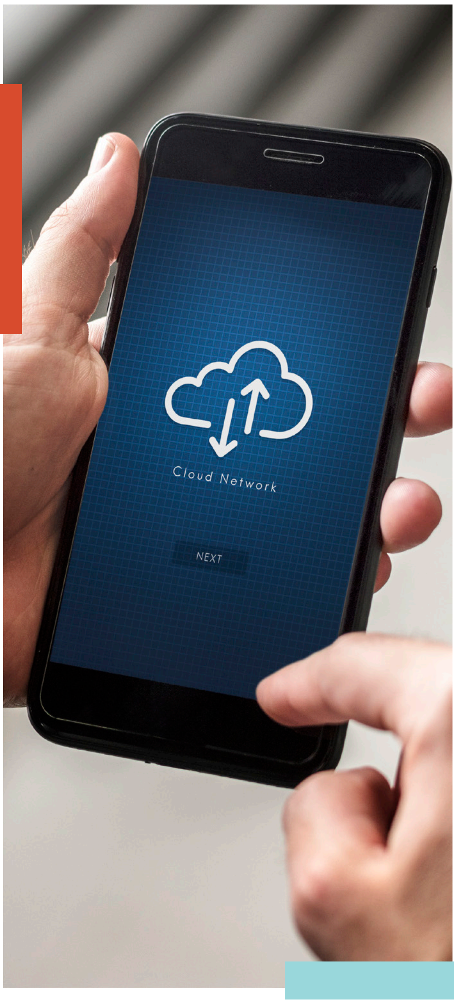
Governments are continually coming up with initiatives to help their citizens. They do so with the best intentions, but the schemes are not always successful (Cerqua and Pellegrini, 2018). The reasons are varied; it might be that the targeted audience is not interested. Maybe the burden to apply is too complicated. It could also be that the people are interested, but their current situation impedes them from considering it. The reasons are various, and it is not always easy to understand them in advance.

A CT would help in such a situation because it can calculate uptake and account for the entire population. An analysis of previous schemes will help the CT determine what works and what doesn't with different cohorts. It will then direct policymakers towards learning from past mistakes and help them develop successful initiatives.

The CT even goes further by proposing new initiatives. It combines data from different departments and uses it during the different phases of the product life cycle. In this way, simulations are run at all stages to achieve an optimum approach. The basic architecture analyses historical and real-time data using algorithms. When new data streams become available, they are inserted into the system, and the CT uses them. We can consider this approach as being a constant evolution of the processes. It not only helps in the creation of better initiatives but also cuts the time involved. Of the extensive repositories of data available, only those considered essential are used. Thus, the CT is a lean model which increases the overall efficiency of the entire process.

Future Predictions

CTs are data-hungry, and if they have enough information, they can manage to elicit patterns and make accurate predictions.



These predictions are critical not just for the individual but also for the state. Let's have a look at the following examples:

- If we look at screening programmes currently in use, most of them utilise statistical analysis. Take breast cancer (Dilaveri et al., 2019); screening involves all women after the age of 40. But a CT can be much more precise than that (McKinney et al, 2020); it can record if the person is physically active, overweight, drink alcohol, their reproduction history, and so much more. If these factors are combined, the CT can predict whether that person is more prone to develop breast cancer and, in that case, refer it for testing.
- A CT can easily combine data analytics, machine learning and AI (such as that developed by de Roux et al. (2018)) to predict payment irregularities and tax fraud before they happen. The state can quickly identify which person risks a tax payment default and launch assistance programmes ahead of time. These programmes will then help people with their fiscal responsibility while predicting an accurate income estimate for the state.
- Some countries tag their offenders under house arrest with electronic bracelets such as those mentioned in Díaz et al. (2019). These people are not expected to stay home but have minimal mobility and well-defined time windows. The CT creates a geofence for them and raises an alert if they venture beyond their restricted zone. However, it can do much more; it can calculate the probability of meeting a past victim. If a person accused of domestic violence walks close to his partner's house, then the likelihood of relapsing increases. To avoid such situations, the CT will direct the person towards choosing an alternate route, thus helping him throughout his reformation process.

Jigsaw Puzzle

A problem with today's approach is that due to various constraints, adequate planning is sometimes given less importance. Unfortunately, some administrations tend to go for quick fixes while missing long term solutions. We can easily experience it in urban planning (Johnson, 2001; Kaker et al., 2020), whereby districts or entire cities emerge from the expansion of previous settlements. Of course, once they grow, it is diffcult to solve some of the issues that arise due to their development. A CT can be of immense help in this process. First, it will provide valuable information about the citizens within a particular locality. It can determine how people commute throughout the day, from where they buy their daily needs and where they go enjoy themselves. Second, it will use AI to propose potential solutions tested using simulations. AI might suggest some of the following:

- Some roads might change direction during certain hours.
- Localities can consider installing tidal lanes to ease traffic during rush hours.
- The switching of traffic lights might change during the day to reduce traffic.
- Municipalities might construct new parks or commercial entities to attract traffic towards other parts of the city.
- They can discourage the construction of residential zones in one area while promoting them in others.

Finally, policymakers can change bits and pieces of the proposed solution as if they're constructing a complex jigsaw puzzle under the guidance of the CT while keeping in mind the city's long-term objectives.

Of course, this is just considering normal circumstances. If the city won the right to host a major event, a multi-year project to build all the facilities would be underway. Using machine learning models, urban planners can investigate the future and understand how the city will evolve. The CT will not only show the current data, but it will make predictions about its citizens:

- The number of children born in the future and the services they would need.
- The people who will migrate to and from the city while mapping the changing demographics of the zones.
- The increase in the ageing population and the services they would require.
- Many other scenarios.

By looking at these predictions, the CT can understand the change in traffic, how to manage new traffic flows by designing new routes leading to and from mass venues and where to boost public transportation amongst others.

Asset Management

Any government is asset rich and managing all of the items is a big headache, especially in large dispersed areas (Misnan et al., 2012; Musa, 2015) Some of them are huge (like buildings), others reside in them (such as computers or furniture) while many of them are located outside (like street furniture, vehicles or sensors). It is impossible to manage them all coherently!

Thus, predictions become even more valuable, especially when managing parts for defective components or planning future initiatives. AI can be used to sift through online stores, estimate the cost of parts (while considering delivery dates plus other variables) and predict the total cost of ownership.

A unique identifier is inserted in most components for tracking purpose. Some of them will be tagged using technologies (such as Radio Frequency IDs (Shamsi et al., 2015)), which seamlessly provide information to the central system regarding objects' movement in the real world. Thus, with the click-of-a-button, the person managing the system will have an up-to-date overview of all the physical assets available at any one point in time. It will also provide additional details about the products on order or those in transit. Furthermore, if the tracking module uses a blockchain system, one can ensure full traceability for any product (Xu et al., 2019); starting from the raw materials that make up the product, up to the end of the product's lifecycle, the recycling stage.

All of this is important to provide a safe environment for our CTs. People interact with all sorts of government possessions. They use roads, walk on pavements, interact with automated kiosks and use public transport, to name but a few. However, their connection with the central government is set to increase in the coming years. If we take self-driving vehicles as an example, these must read road signage (Fathy et al., 2020). Thus, it is no longer acceptable to have a sign hidden by a tree or a road marking which has faded. The general infrastructure of the country must be impeccable if we want to make this new leap.

"A unique identifier is inserted in most components tracking purpose.

Decision-Making

The CT system assists policymakers in providing timely information, in the sifting through the sea of data and in the creation of summarised viewpoints over the various processes. Without doubt, they will become the personal assistants of ministers and departmental heads (Chin, 2016) capable of giving accurate snapshots and highlighting areas of concern in real-time.

Furthermore, the time will come when part of the administration will be entirely entrusted in the AI system's hands, thus automating run-of-the-mill decision-making processes. The CT will take decisions at the lightning speed, and it will dispatch corrective actions as soon as they are needed.

Let's consider the case where there's an emergency, such as a traffic accident. The CT is already aware that the accident happened through the road network camera system, which is in place. Modern cars will have an internal diagnostics system that automatically determines the extent of the damage suffered and the passengers' situation. Since they are connected vehicles , they relay the accident report to the centralised Intelligent Transportation System (ITS). The ITS would have already created a hypothesis of what happened and validates it with the cars' statement. It then summons one or more ambulances to the scene. Considering that the passengers' identity is known, it can inform the paramedics about the people involved and highlights relevant aspects of their medical history. The ambulance receives the directions consisting of the timeliest route (which avoids traffic). Since time is critical, the ITS will guide all the connected vehicles along the way (or those that will cross path with the ambulance at a future time) towards an alternative route. The system then sends several instructions to tackle the remaining situation; a tow truck clears the cars from the road, the local authorities remove any debris, and the police maintain public order. The final task is to send the relevant information to the insurance companies and the accident report to the AI judge for evaluation. All this coordination is done in less than a minute.

As evident in the previous example, administrators will be relieved from day-to-day micromanagement; they can look at their operations from the macro perspective and spend more time planning future improvements.

Conclusion

There is no doubt that CTs are the future of Public Service. Of course, there are still various issues to consider. One of these is without doubt, privacy. However, the individual's data does not need to leave the person's device, but it can still contribute to the centralised system.

The only requirement of such a system is that people install an app on their mobile device. Traditional services like localisation, social media, chats, e-wallets and others will all be available. However, rather than having a centralised server as it is the case today, the user's phone stores all the personal information. The user will have full access to the data, and they can choose to retain or delete it. Furthermore, the system will use two AI components, one located remotely and the other on the device itself.

If we consider an e-Wallet, the first advantage is that payments occur using contactless virtual cards and without exchanging real money, thus moving towards a cashless society. The e-wallet also includes information about shops visited together with the purchases. The system stores the location of the shop and logs the time in the user's device. From the purchases, the local AI can gather information regarding the wellbeing of the individual. It can easily infer that if certain items (such as medicines) are purchased, then the person or someone close to them is most probably ill. The local AI can also start a chat with the user, inquire about this, and inform the user if a particular medicine falls within a government scheme for which they're eligible. The important thing is that the choice remains in the users' hands, and no information gets shared with any department. Such an AI system is possible because today, we have AI engines that efficiently work on a mobile device without communicating with a server such as those developed by Shuan-feng (2020) or Warden and

Situnayake (2019). If the user requires specific medical assistance, it can connect them directly with the appropriate health provider, thus solving the various queries which the person might have. There are also some countries where they're using an app to perform Emergency Triage on their mobile phone (Wiktor et al., 2018) thus managing patients effectively.

The localisation module provides precise information regarding the person's whereabouts (within an error of a few meters). Of course, this information is only stored on the device and not shared with anyone. Systems can use this information without revealing the user's identity through a novel AI approach called federated learning (Li et al., 2020). The system works as follows; the device downloads the AI model from the server and enhances it locally by learning from the phone's data. A summary of the new model is created and uploaded to the cloud. No personal information ever leaves the device, and it is impossible to extract any information from the update sent because it is just an aggregate. With the AI model on the device, the system knows the city's visited areas, thus calculating important analytics on traffic flows amongst others. In the case of a pandemic, if the user comes in close contact to a location which had someone infected with a virus, the AI alerts them immediately and gets them to avoid that area. Through this approach, when a user gets infected, they can easily send a warning message to their friends' social circle without revealing their identity and alert them to take the necessary precautions.

As can be seen from these examples, today's approaches allow people to contribute to society without necessarily sacrificing their privacy. Thus, CT system will take care of the individuals and propose adequate actions based upon their personal needs. The government will benefit because it will ensure that citizens take the best service possible, especially those opportunities they're not aware of or which they will need in the future. By suggesting that people undergo direct interventions, it is also promoting healthy living based on statistical analysis and according to that individual's lifestyle. The system will also be capable of analysing the data and make informed decisions. It might predict that an individual can no longer live independently and might need an ambient assisted living solution. It would keep the elderly in the community, save institutionalisation costs and monitor their wellbeing. The system might analyse the occurrence of nationwide emergencies (such as health, fire or flooding) and predict rapid deployment of emergency vehicles.

There's a lot that can be done, and with the deployment of a CT system, the government is not only closer to the people, but it will ensure that no-one falls through the social network. It will effectively monitor the individuals and guarantee their utmost wellbeing.

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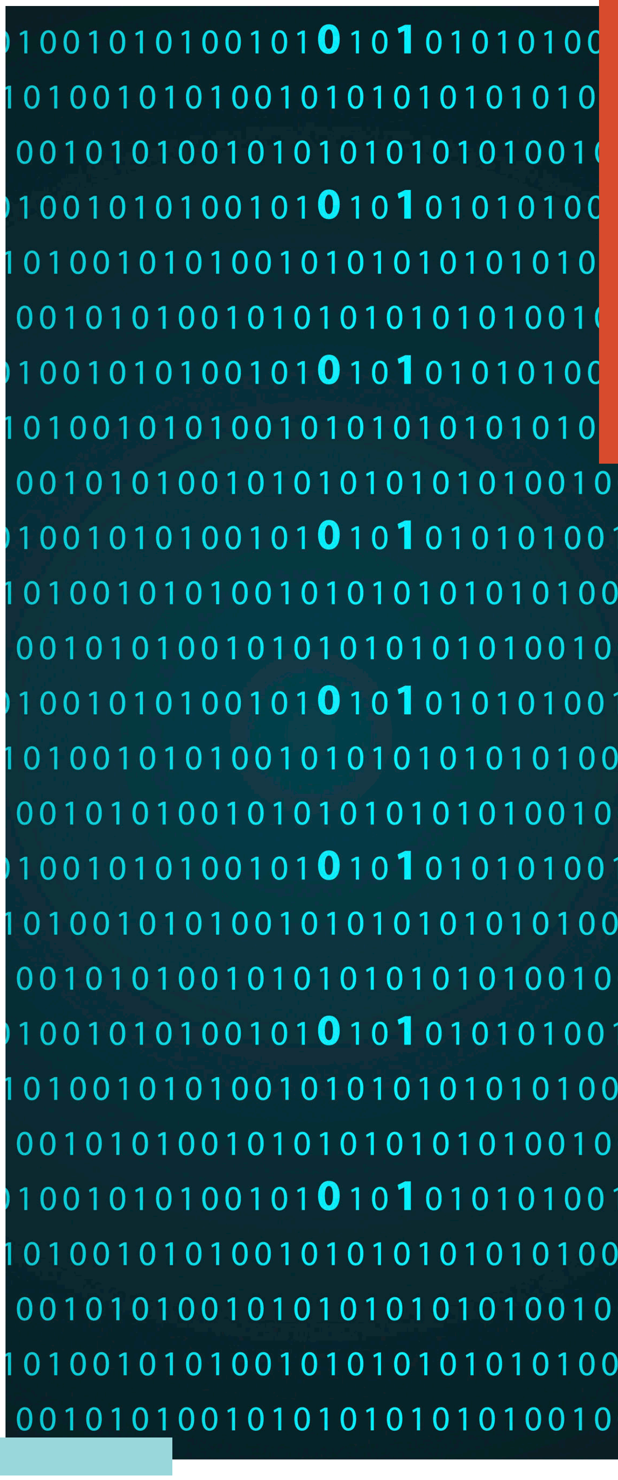

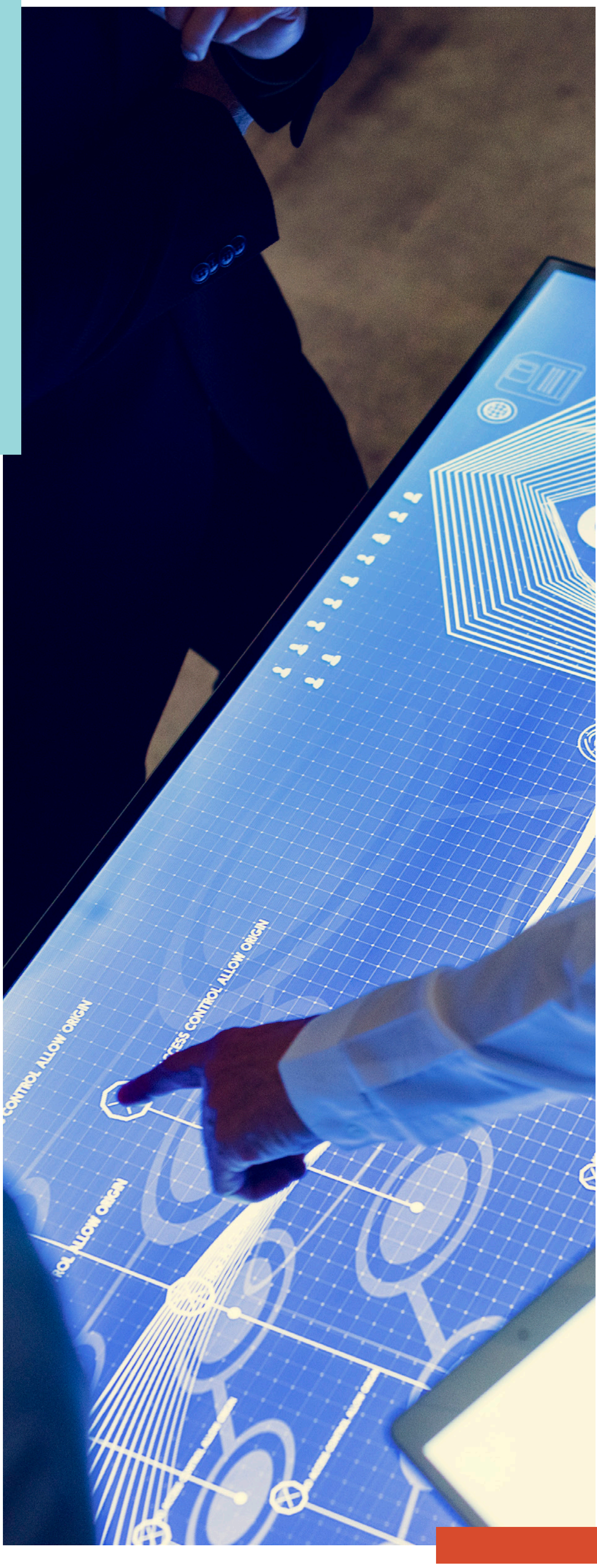

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