Exploring Digital Twins as Policy Tools: An Analysis of Emerging Initiatives

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Abstract

Cities are among the largest and most complex artifacts created by humans. Yet the advancements in computing capabilities combined with ubiquitous data streams allow for complex socio-technical systems of cities to be abstracted and modeled.

This paper discusses the technology of Smart City Digital Twin as a policy tool. Following the ideas of flat ontology, the paper argues that intelligent machines exhibit their own agency, which has to be investigated through the behavioural lens. As making policy decisions based on counterfactual simulations is becoming more widespread, it is crucial not only to simulate how certain policy interventions will affect the life of a city, but also to investigate how such models and simulations are designed and behave.

Adding a social layer in the form of behavioural data of population will allow Smart City Digital Twins to be used for a wider spectrum of policy modelling purposes. Such behavioural data can be generated through task-based approach, where individuals will be asked to conduct certain activities in order to generate synthetic data for situations which require data that does not yet exist. This will not only allow to avoid certain privacy-related concerns, but also can be used as a tool for labor provision.

Keywords – Smart City; Digital Twin; Policy Tool; Behavioural Data

1 Introduction

The automation discourse today can be seen as a spectrum of ideas spanning from those who claim that "the boogeyman of automation consumes worrying capacity that should be saved for real problems" (Simon, 1966; Autor, 2016), through those who highlight the inevitable existential threats to humanity (Bostrom, 2017), to those on the far left urging people to embrace the opportunities that automation brings to build post-work society (Srnicek, 2015) and 'Fully Automated Luxury Communism" (Bastani, 2019). Being part of the wider discussion of what automation of different sectors of society could bring, digital solutions created by the governments are usually framed as automation of governmental operations, dismissing the fact that these platforms and algorithms reshape the social fabrics of our societies.

Most public services are being automated through the creation of governmental platforms, which seek to make bureaucratic processes faster and more efficient with the usage of digital tools. Rapid development of the technologies of Artificial Intelligence also allow the governments to work on the solutions that have agency to make decisions. In this paper, however, the main focus is on how governments can utilize visual interfaces of Smart City Digital Twins for running simulations of potential policy interventions, and how such technology can be transformed into a policy tool by adding a socio-behavioural layer to it.

The growing complexity of the world requires new analytical tools to be deployed for harnessing evidence-based policy. Smart City Digital Twins create enormous opportunities for city officials to embrace the notion of simulation governance and expand the reach of the contemporary planning techniques.

While having a great potential for providing visual representation of simulated activities in the city, Smart City Digital Twins are currently mainly used for the simulations of processes with regards to the built environment. Such approach brings certain unnecessary limitations to this technological solution, as the scope of its applications could be expanded to the simulation of socio-economic processes in the city. However, adding socio-behavioural data layer to the simulation can bring new challenges to the policymakers, as some of the simulations may require behavioural data of activities which have not yet happened and raise privacy concerns. A task-based approach to synthetic data generation is proposed as a potential way to solve this issue.

2 Rules as Objects

The process of digitization of governmental services through the creation of digital tools brings the notion of objects as mediums through which rules are exercised to the domain of policy inquiry.

While the 'politics' inherited by objects or artifacts (Winner, 1980) have been investigated within the domain of Science and Technology Studies (Latour, 2000), the knowledge about digital artifacts as frameworks for societal operations - rules - remains scarce.

The idea that technological artifacts exhibit properties that shape the domain of the social is a recurring theme in academic literature (Katzenbach, 2019). The idea that computer code is a new factor that regulates social behaviour - code is law - has been introduced in 1999 by Lawrence Lessig (1999), and since then has been further elaborated in the discussion of algorithmic regulation and governance.

The practices and effects of governance by algorithms are investigated in numerous disciplines, from computer science and media studies to economics and political science. Such an object of inquiry is usually investigated through two main frameworks. The first focuses on how smart systems for governance can be built based on the existing data - how certain aspects of social behaviour could be managed through quantification (Takikava, Nagayoshi, 2017). Another branch of research rather focuses on social implications of algorithmic governance technologies. Such research projects are "highlighting the economic, cultural, and political contexts that both shape the design of algorithms and their ordering effect in these specific contexts (Kaztenbach, 2019). Along the lines of such research some authors investigate how the practice of regulating by algorithms changes the fabric of the social relations and what legal and ethical challenges are faced by such practice (Yeung, 2018).

What is missing from these studies, however, is the investigation of the actual behavioural patterns of the machines. "The scientific study of intelligent machines, not as engineering artifacts, but as a class of actors with particular behavioural patterns and ecology" (Rahwan et al., 2019) is required for furthering the understanding of the agency that is possessed by digital objects. This argument comes along the lines of 'the sciences of the artificial' proposed by Herbert Simon (2019) - a scientific inquiry into the world of non-living objects.

Similar questions are currently being discussed within the discipline of philosophy, where the arguments about treating subjects and objects on equal terms is rising in prominence. Object-Oriented Ontology (OOO) is a philosophical school, which promotes the idea of flat ontology - a theory of reality in which humans and non-human objects (such as trees, dogs, governments, etc.) should be given the same ontological status (Harman, 2013). Following this stance, the school is arguing against the idea of looking at non-human objects only through the prism of their interaction with humans - thus proclaiming its positioning against the correlationism and network effects.

As Graham Harman puts it "in every field, the object-oriented method reminds us that an object is more than its constituent pieces, more than its relations, more than its qualities, and more than the events in which it happens to participate so far" (Harman, 2013). In light of the growing importance that smart digital objects are playing in the contemporary world, the idea of treating material objects as entities that possess their own agency seems very relevant (Robb, 2019).

3 Digital Twin

Digital Twin is a virtual representation of characteristics and behaviours of a physical object. The purpose of the creation of a Digital Twin is to model and predict the lifecycle of a system (Jones et al., 2020).

The concept of Digital Twin originated in the works of Michael Grieves and John Vicker at NASA in 2003 (Grieves, 2017). Initially introduced as a virtual representation of a physical object, the concept has been further elaborated to include "a physical product, a virtual representation of that product, and the bi-directional data connections that feed data from the physical to the virtual representation, and information and processes from the virtual representation to the physical" (Jones et al., 2020).

According to Grieves and Vickers (2017), if applying the model of Digital Twins, then the creation of a physical object starts in the virtual space through the creation of a Digital Twin prototype. Once the modelling and simulations of a system are conducted and potential obstacles are understood, the physical object (Digital Twin Instance) is being built, and the data connections between the virtual and the physical domains are established.

4 Smart City Digital Twin

The growth of computing capabilities, ubiquitous data flows and general interest in the application of Digital Twins has allowed us to use this methodology for modeling not only physical objects, but also complex socio-technical systems. As this approach has gained in prominence, digital twins of smart cities started to be created in order to analyse the data about urban complexities across time and scale (Francisco et al., 2020).

The concept of Smart City Digital Twins is widely discussed in academia, with research projects spanning from general overviews (Mohammadi, Taylor, 2017), applications to urban energy systems (Francisco et al., 2020), disaster management (Fan et al., 2019), city as a platform (Ruohomaki et al., 2018), multimedia (El Saddik, 2018), and various applications of machine learning (Austin et al., 2020) and game theory (Mohammadi, Taylor, 2019) techniques for the creation of Digital Twins. However the modelling of the social layer of the city has not been covered extensively, especially in the light of its policy relevance.

Pilot projects of Smart City Digital Twins are being developed in numerous cities across the globe, including Singapore, Glasgow, Helsinki, and Boston (Minsky, 2020), with Helsinki expanding this notion to provide virtual tourism services with the usage of Virtual Reality technologies (virtualhelsinki.fi). The approach introduced by Grieves and Vickers (2017) is being utilized in a newly built Indian city Amaravati, which is the first attempt to build a city starting from building its Digital Twin - thus allowing everything to be modelled and simulated before embarking on building it (SmartCitiesWorld, 2018).

In the UK, the concept of Smart City Digital Twin has been taken further with Cambridge University's Centre for the Digital Built Britain launching National Digital Twin Program with an aim to create an ecosystem of connected Digital Twins of different cities in the country. This project is not seeking to establish a singular Digital Twin of the whole built environment of the country, rather it pursues the idea of creating a federation of connected Digital Twins via secured data streams - only in the cases where such connections will bring valuable insights. These Digital Twins will differ from one another by four distinctive sets of characteristics: purposes, spatial scales, temporal scales, and approaches to modelling.

The Centre for the Digital Built Britain has further proposed nine principles, which should be pursued by those who are developing Digital Twins: Purpose - public good, value creation, and insight; Trust - security, openness, and quality; Function - federation, curation, and evolution (Bolton et al., 2018).

5 Simulation Governance

Smart City Digital Twins should not only be treated as interactive representations of the city, but rather should be seen as policy tools - "techniques through which governments generate, evaluate, and implement policy options" (Capano, Howlett, 2020). Advanced computing capabilities of the current age allow for modelling of sophisticated computer simulations of societal processes. As has been seen during the Covid-19 pandemic, "governments across the world are relying on mathematical

projections to help guide decisions" (Adam, 2020). Thus making policy decisions based on machine-generated futures as shown to them by the abstracted representations of reality.

If real policies are to be implemented in the physical environment based on the results of the simulations in a virtual environment, then "it is crucial to know how they (simulations) are made and the assumptions on which they are built" (Adam, 2020). In the era of intelligent machines, the investigation of behavioural patterns of the machines (Rahwan et al., 2019) is as important as driving insights from the behaviour of the people. Thus, by providing infrastructure for 'what if' modelling, the virtual objects (digital twins) are becoming avatars of the policies that they simulate, bringing us back to the ideas of Object Oriented Ontology - a discussion of the agency possessed by non-human objects.

6 Virtual Singapore

Virtual Singapore is one of the most advanced project in this field. The project was granted with $73 million by the National Research Foundation of Singapore in order to create a dynamic 3D model of the whole city of Singapore as well as to create necessary technical infrastructure to turn it into a collaborative data platform.

The data ecosystem of Virtual Singapore includes data from government agencies, 3D maps, information from the internet, and the data from the Internet of Things ecosystem of the city. The project strives to "enable users from different sectors to develop sophisticated tools and applications for test-bedding concepts and services, planning and decision-making, and research on technologies to solve emerging and complex challenges for Singapore" (National Research Foundation, 2018).

The capabilities of the project include:

1) Virtual Experimentation - stakeholders will be able to experiment with different technological solutions in the virtual environment of the city. For example, one can conduct the visualisation of mobile internet coverage areas in order to determine its weak points for potential improvement.
2) Virtual Test Bedding - the platform will allow to run simulations of systems and agents' behaviour in the city. For example, run simulations on crowd dispersion during emergency situations.
3) Planning and Decision Making - being a data-rich platform, Virtual Singapore provides plenty of resources for the development of analytical applications for the improvement of city services.
4) Research and Development - researchers and innovators can benefit from the data-rich environment in order to test their hypothesis in a virtual setting.

The project realizes the value it can bring to different stakeholders, including the government, citizens, businesses, and research community, by giving access to city-level experimentation. Potential use cases of the project are divided into five thematic blocks. Collaboration and Decision-making will allow city planners to visualise the potential interventions in the city landscape in order to simulate and predict how it will affect traffic and pedestrian flows. Communication and Visualization can allow city officials to visually represent their initiatives in order to understand its value - for example, create a visual representation of the potential benefit of solar panel installation on the roofs. Improved Accessibility domain allows to model travel routes in 3D - showing the potential barrier-free routes for disabled and elderly people. In Urban Planning domain, this Digital Twin grants insights into how a new building might affect light intensity and temperature in the estate. Based on 3D models of the city, urban planners can draw insights into the Potential for Solar Energy Production (National Research Foundation, 2018).

7 Human Digital Twin

The initiatives such as Smart City Digital Twins are expected to accelerate this trend of making policy decisions based on quantified predictions. Without going into dystopian vision of surveillance capitalism futures (Zuboff, 2019), such visual interfaces have the potential to step beyond futurecasting policies aimed at building an environment to a wider array of social simulations.

Though some researchers argue that "for some urban challenges, such as social inequality and housing

crisis, the digital twin tends to be less effective" because "it can not address the underlying socio-political causes" (Wan et al, 2019), wider inclusion of behavioural data can change this problem.

As cities consist not only of built environments, but also of its inhabitants, modelling of adequate city interventions requires modelling of social activities. While most Digital Twin projects replicate physical environments and systems, there are projects that are trying to replicate human cognitive processes in urban environments (Du et al., 2020). As the human behaviour can not be measured via IoT sensors, "the property and behaviour of a human digital twin need to be based on user feedback and recorded patterns instead of actual measured data" (Graessler, Poehler, 2017).

The notion of Human Digital Twins is mainly discussed in the healthcare literature (Liu, et. al., 2019), where Human Digital Twins are understood as "representations of an individual that dynamically reflect molecular status, psychological status, and life style over time" (Bruynseels, et. al, 2018). Some pilot projects have focused on creating Human Digital Twins with the usage of wearable fitness bracelets SmartFit, through which the behavioural data about activities, food consumption, and mood has been aggregated (Barricelli et al., 2020). Other work has focused on employing Human Digital Twins in industrial settings (Sparrow et al., 2019; Amenyo, 2019).

Such approaches to modelling human behaviour can be of great use if combined with Smart City Digital Twins. Similar to the approach of creating behavioural simulations of human activities introduced by PWC (Lombardi, 2014), behavioural data of city inhabitants can be used for more accurate simulations of the potential social effects of an intended policy.

Populating Smart City Digital Twins with Human Digital Twins can expand the reach of the novel tool in the hands of policymakers. However, such proposition may raise numerous ethical concerns with regards to the privacy issues and intervention into personal lives.

One way of solving this issue can be found in generating synthetic data. In broad understanding, synthetic data are artificial data, which have characteristics similar to real data. Mainly used in the cases where the real data are sensitive, it can also be used for replacing missing data, and augmentation of artificial data with real data (Kaloskampis, 2019). While the potential of this methodology is vast, currently this "method allows us to put an end to the deidentification-reidentification arms race and focus on what matters: useful, private data" (Bellovin et al., 2019).

However the scope of such an approach exceeds pure privacy concerns, as it can also be turned into a tool for generating data about a phenomenon or a product which does not yet exist (AIMultiple, 2020). This fact can be especially relevant to policymakers working with Smart City Digital Twins, as data may simply not yet exist for some of the policy proposals that they want to test in a virtual urban environment. Creating artificial behavioural models of human behaviours in the city can be an important next step in the utilization of this technology, allowing policymakers to avoid falling in the trap of assuming that people will react to new initiatives similarly to how they reacted in the past (Levina, Duerk, 2018).

One step further in creating and utilizing Human Digital Twins for counterfactual simulations of policy scenarios can be taken by applying the methodology of Data Labelling labor (Murgia, 2019) exercised by technological corporations. Such services ask employees to conduct simple tasks, which can not be executed by computers, for creation of data on which machine learning models will be trained. The services include comparison of two images, search results, and interface designs; representativeness of search query with the search results; search of information on the Internet; and field tasks, such as checking if the business is still in operation or secretly buying a product from a store and writing a review.

Such task-based methodology can be further taken outside of web-service optimization to the domain of public policy data generation. This will allow the governments to save resources by conducting a field experiment in a virtual environment, instead of a physical environment, in order to obtain findings about the behaviour of the population for the purpose of policy making. Counterfactual simulations of future policy decisions will require tailor-made data responses to such decisions. Asking people to conduct certain activities for data creation purposes can allow governments to have more accurate data for 'what if' simulations, while at the same time not violate privacy rules, as the data generated through such a task-based approach is not representative of

a real-life behaviour of an individual. Not only such 'Data Trainers' can create valuable insights for counterfactual policy modelling, but also be a means for supporting lower income individuals through labor provision.

8 Conclusion

This paper discusses the application of Smart City Digital Twin technologies to urban policymaking. Following the ideas of flat ontology, the paper argues that intelligent machines exhibit their own agency, which has to be investigated through the behavioural lens. As making policy decisions based on counterfactual simulations is becoming more widespread, it is crucial not only to simulate how certain policy interventions will affect the life of a city, but also to investigate how such models and simulations are designed and behave.

In order to maximize the potential of Smart City Digital Twin technology for becoming a policy tool, it is crucial to include social behavioural level to the simulations of urban processes. Certain methodological insights for the creation of the synthetic population of Smart City Digital Twins can be found in the domains of synthetic data generation and data labelling practices. As simulations of policy interventions may require data for the activities that have not yet happened, a task-based approach to synthetic behavioural data generation is proposed which will allow the governments to make evidence-based decision with the usage of semi-personal data without violating privacy restrictions.

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