A Digital Soul is all you need

by Antonio Lalaguna

1. Context and motivation

Smart technologies like cloud/edge computing, the Internet of Things (IoT)[1], and even Artificial Intelligence of thins (AIoT)[2] have become widely used in many industries and domains due to the recent advancements in wireless communication technology. However, in other domains lie smart city, development varies among different countries and cities, and for those just starting, their lack of quality data limits the possibilities for developing advanced digital services. To overcome this, current smart city practitioners must first accomplish the first phase: build large-scale platforms to collect and integrate data before implementing specific services. Once the first phase is reached, the next step is about creating those new data-driven services, while maintaining, improving and inter-connecting the created phase1 data platform.

There have been significant efforts to create and normalize phase-I IIoT platforms on scale, like Industry 4.0 coined in Germany, Intelligent Transport Systems (ITS) leaded by the Department of Transportation (DOT) in the US and DG-MOVE[3] in EU, Smart City platforms spearheaded by countries like Singapore, within its Smart Nation[4] program, or city wide initiatives like Shanghai, Barcelona, and Soul, ranked the top 3 Smart Cities in the World by Juniper Research rankings[5].

Now is time to address phase-II of this digital transformation journey, and leveraging the concept of "Digital Twin"(DT) may reveal a wise decision. There is a need to digitize further cities and industries by deploying cloud-edge-iot solutions, which can be leveraged by ML/DeepL models through transfer learning, while also addressing privacy concerns through federated learning. Multiple players need to create services based on data from different sources within those domains or third ones. Should not be overlooked that stakeholders must obtain a sustainable return on their investment from phase-I, and foresee returns from phase-II, so realistic assessment of costs and a clear understanding of potential benefits and drawbacks will be demanded. Finally, to address all those new challenges more abstraction and normalization is needed to improve security, scalability, and maintainability.

DTs are poised to play a significant role in shaping the future of these domains by enabling data-driven decision-making, improving operational efficiency, reducing costs and downtime, and driving innovation, what can ultimately lead to improved performance, enhanced customer experiences, and increased revenue.

The **key point** is the **way in that DT aggregates and abstract several aspects** (location, 3D and math models, functional characteristics, behavior, etc.) of a subject (device, machine, street, city, vehicle, etc.) in a single concept (a DT), with different level of resolution. The same should apply to the different technologies involved in its conceptualization, like communication protocols, interfaces, data processing algorithms, ML, visualization, monitoring, storage, etc. so the interaction with the different DT become easier, and federation of DT evolve to recreate digital universes that replicates real scenarios where simulations, analytics and predictive maintenance become easier and standardized.

Global open standards that normalize the definition, design and interaction of DT must also allow to enhance and update existing DT by kind of a plug-in mechanisms, to be future proof and keep the pace of incoming innovations. There can be no doubt one of these innovations is going to be the integration of DT with GPT[6] like Large Language Models (LLM) a hot topic nowadays. Enhanced DT with efficient LLMs will improve user experience significatively, and allow DT to “talk” to each other, and create autonomous digital ecosystem that may change the way we organize industries.

This improvement will drive the Digital Twin concept to its next stage, giving the impression that they have cognitive capacities, that they are alive: a **Digital Soul** will be born.

1.2 Current Status

Recent technological advancements and the increasing adoption of IoT, simulation suites, Virtual, Augmented and Mixed Reality (xR), GIS technology, cheap and powerful communications (3GPP), real-time data processing, cloud-edge computing, and artificial intelligence have revitalized the concept of Digital Twin to organize these technologies into concrete solutions and services that can be easily understood, governed, scaled, and replicated.

While it is more common in engineering and manufacturing sectors, cities are timidly adopting DTs for a variety of use cases, including building emissions & energy consumption modelling, traffic management, economic development, mobility planning[7] and air quality monitoring.

The problem is the multitude of standards that may involve a DT design[8,11], and the lack of a global one accepted by the community. This causes siloed proprietary DT models, that reduce its interaction and integration, and can lead to wasted resources and missed opportunities for innovation and growth.

The Digital Twin Consortium[12] (DTC) is the most well-known global organization leading the stablish of best practices and standards industries. Its mission is promoting **standards and best practices** that will drive consistency in the development, implementation, and interoperability. But there are others like IDTA[13] from Germany industry focuses on industrial applications, DT Hub[14] from UK, DT Hub[15] from Australia New Zeeland all publishing its own models and tools to create DT. Additionally, several other associations are formalizing DT design such us the IEC and ISO Joint Technical Committee (JTC 1), the Emerging Technology and Innovation (JETI), and the Change2Twin Consortium in Europe. That opens the door to big players like Microsoft published its Digital Twin Description Language[16] (DTDL) based on the well-known JSON-LD to gain buy-in from developers.

Research Challenges

Annual revenue for urban Digital Twins is projected to grow to $2.5 billion by 2031, with a CAGR of 25 percent, according to Guidehouse Insights[17], although we may consider these studies as pre-ChatGPT, in which the possibility of LLMs and DT integration couldn't be foresee, still represent a good opportunity to innovation and research.

To successfully implement DTs technology globally, several research challenges need to be addressed. One major challenge is the lack of global standards and normalization, resulting in siloed proprietary DT models. This reduces their interaction and integration, leading to wasted resources and missed opportunities for innovation and growth. To address this, standardized DT models that can be shared and reused across industries need to be developed. Another challenge is the massive amount of data required to operate DTs effectively, and the need for the data to be clean, structured, and organized for use. Effective data management strategies and technologies are necessary to handle the vast amounts of data generated by DTs, ensuring data quality, protection, and re-utilization for AI models training. Security and privacy mechanisms are essential to protect the data generated by DTs, which can contain sensitive information, while allowing for interoperability and data sharing. Here is where blockchain based technologies standout.

Effective, open and standardize human-machine and machine to machine interaction mechanisms are necessary to enable effective collaboration between humans and DTs, and digital twins themselves. Finally, lifecycle management mechanisms, monitoring and governance are necessary to ensure DTs remain up-to-date, consistent, and relevant, so their lifecycle management must be carefully planned and executed.

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