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AGENT-BASED DIGITAL TWINS (ABM-DT) IN SYNCHROMODAL TRANSPORT AND LOGISTICS: THE FUSION OF VIRTUAL AND PYSICAL SPACES

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ABSTRACT

Synchromodality/Synchromodal transport is to support real-time optimal integration of different transport modes and infrastructure in order to induce a modal shift from road to inland waterways and rail. Such an integration will contribute to making modal choices, synchronization of orders and available capacities more dynamic, flexible and acceptable in terms of costs and lead-times. In this regard, new technologies and their real-time inputs have to interact with freight models to support decision makers on a continuous basis. This is why a symbiosis between virtual environments and physical environments is proposed that can bring academic models closer to the end users. The paper demonstrates a first proof-of-concept for long-distance Digital Twin solutions by connecting real-time data feeds from the physical system to a virtual GIS environment that can be utilized in real-time synchromodal deliveries.

1 INTRODUCTION

As the ambition of the European Commission is to shift 30% of freight transported by road to environmentally friendlier modes by 2030, and 50% by 2050, the modal choice criteria of shippers play an important role to achieve such shifts. The findings of the modal choice literature often yield higher user preferences related to road transport based on the shippers needs who perceive intermodal transport as a slow and inflexible solution with a limited service offer (Meers et al. 2017). Synchromodal transport/Synchromodality presents an extension of intermodal transport by including real-time re-routing of loading units over the network to cope with disturbances and/or customer requirements. This development is to support optimal integration of different transport modes and infrastructure in order to make intermodal transport more dynamic, flexible and acceptable (for more information about the concept and its applications, we refer the reader to the review of Ambra et al. (2019b)). With the advent of new (simulation) technologies, increased computational power, Internet of Things (IoT) and GIS platforms, synchromodal transport can accommodate dynamic and flexible decision processes in (near to) real-time. Besides synchromodal transport, the paper further addresses the digital twin concept as it has the ability blend the above. Digital Twins are the latest wave in simulation technology as it uses simulation models to project possible behaviour(s) of the real system. Simulation technology's inception is dated around the 60s when simulation was limited to a small range of individual topics such as mechanics, when in the 80s it was used in fluid dynamics and other engineering designs. Starting from the year of 2000, simulation allowed for multilevel and multidisciplinary system approaches to test and assess overall system designs, and from 2015 onward, simulation has formed the core of the digital twin concept by providing seamless assistance along different tasks and processes with direct connection to operation data (Boschert and Rosen 2016). Gartner claims that digital twins will be adapted by half of large companies who will consequently gain a 10% improvement in effectiveness (Pettey

2017). Hence, the concept is receiving more attention, but it has never or rarely been considered in the synchromodal context. This paper reviews the digital twin concept and its current applications in order to understand what it is, but also what it can become. Since simulation technology forms the backbone of the Digital Twin, a Digital Twin Environment (DTE) is needed where digital twins (digital instances) exist and test their performances. As the digital instances need to posses a certain level of self-awareness and decentralized routing and solution discovery, agents from the agent-based modelling (ABM) and multi-agent based systems (MAS) are considered for such purpose. The DTE herein is represented as a digital map by using Geographic Information System (GIS) with a great level of detail that will facilitate accurate navigation, route finding, and spatial awareness of agents.

Based on the work of Ambra et al. (2019b), none of the synchromodal studies have addressed the potential symbiosis between digital twins and synchromodal models; that would take the current state of the physical world, evaluate future probable outcomes in a risk-free virtual world, and provide solutions back to the physical world iteratively or on request. This paper is to fill this gap by glueing the real physical system with virtual environments (where models and algorithms operate) via digital twins. The objective of the paper is to deepen the understanding of digital twins and their broader role in synchromodal processes. More specifically, the paper explores how offline virtual models can be connected to real-time data feeds in order to reap the benefits of current positions and working conditions of assets in real-time when deploying algorithms or evaluating near-future scenarios. We mainly focus on the connecting mirror-element where physical assets are translated into digital instances together with their parameters.

The paper is structured as follows: section 2 briefly reviews the digital twin concept, agent-based models and their applications. Section 3 concerns the virtual and physical environments, and a mirroring approach which links the virtual dimension with the physical dimension. Section 4 presents a simple demonstration of our real-time data feed that is used by the virtual model on start-up, followed by discussion and concluding remarks in section 5.

2 LITERATURE REVIEW

2.1 Agent-based Models and Applications

Agents in the ABM and MAS paradigm are perceived as different objects or entities that have been used for multiple purposes. This makes the agent understanding rather ambiguous. For instance, Sim (2011) applies agent-based approaches to managing cloud computing infrastructures. An agent-based testbed is used for simulating cloud commerce consisting of provider and consumer agents acting on behalf of recourse providers and consumers. The work of Nascimento et al. (2018) takes into account the environmental context in which feedback-evaluative machine learning enables MAS to reconfigure. In their study, embodied agents are physically explicit and may represent robots, wireless devices etc. In this regard, it can be inferred the logic and knowledge can be technically embodied at the network edge. As for edge computing, Bumgardner et al. (2016) focus on supporting real-time streaming apps at the network edge. These are resources found on the edge of a network. Most of the tasks are delegated to agents with the aim to carry out context-aware computing. Thus, context-aware computing can be used for representing a system that understands the context and takes actions based on a specific environmental context (Sezer et al. 2017).

Agents have been used for managing traffic and vehicles as well. Some earlier work took into account real-time agent-based traffic detection and management with Foundation for Intelligent Physical Agents (FIPA) standards (Chen et al. 2009). The authors deploy control algorithms to respond to unforeseen events. FIPA compliant agents communicate by exchanging messages which are expressed in FIPA agent communication language (FIPA-ACL: precise syntax and semantics for agent communication). However, the standard seems so be outdated and not used anymore. van Katwijk et al. (2004) use a test bed that conforms to the specifications as set by FIPA as well. The authors' aim is to construct an ontology for traffic control through the use of their testbed for different cooperative traffic control problems. They contribute to the road-traffic management research by developing a software environment for multi-agent control systems. Dynamic re-routing based on traffic conditions is studied by Chen et al. (2018). In their case, edge computing with limited storage and computing capacity could not meet the requirements for long term cognitions of users (car drivers) and environment. The authors thus introduce a human-centric architecture embedded with cognitive intelligence that extracts data from physical and network space by unloading to the cloud. Tomás and García (2005) use agents to support traffic operations and to test strategies for meteorological road incidents. A meteo agent supervises the parameter provided by the sensor. It uses the parameter to detect weather conditions via automated if-then conditions.

To foster accountability and trusted interactions in intelligent distributed systems, recent trends advocate the blockchain technology (Calvaresi et al. 2018). Nevertheless, based on the authors' review findings, MAS and blockchain papers are mostly conceptual and they lack in-depth analysis and concrete demonstrations. It is demonstrated in Ferrer (2018) that by combining peer-to-peer networks with cryptographic algorithms, a group of agents can reach an agreement on a particular state of affairs and record the agreement, without the need for a controlling authority. In fact, such approaches could be relevant for consensus-seeking algorithms when dealing with distributed entities who have varying objectives and preferences.

Based on the work above, agents are used as entities that represent human behaviour or tasks via engines; interface agents, XML plan agents, web agents and directory facilitator agents. None of these represent assets or vehicles as such, and our paper is to fill this gap by focusing on agent-representation of assets as digital instances (digital twins). To understand the digital twin concept better and to position our contribution more accurately, we continue by reviewing digital twins and their applications in section 2.2.

2.2 The Digital Twin Concept and its Applications

The Digital Twin (DT) term itself was introduced to the broad public by NASA in its technology roadmap for modelling, simulation, information technology and processing where the DT is defined as "an integrated multi-physics, multi-scale probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin" (Shafto et al. 2012). Since then, the term has been altered and also challenged by different authors. Boschert and Rosen (2016) perceive it as a description of a component, product or a system that evolves with the real system. Grieves and Vickers (2017) define it as a set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical level. According to Alam and El Saddik (2017), the DT is "an exact cyber copy of a physical system that truly represents all of its functionalities". Zheng et al. (2019) term the DT as "an integrated system that can simulate, monitor calculate, regulate, and control the system status and process".

Even though there are other terms which depict the notion of physical and digital objects interacting on a continuous basis such as the digital mirror model, digital reflection, avatar or a digital shadow, the DT term appears to be adapted by most of the authors in their applications. For clarity purposes, we distinguish **digital models** (simulation models with no realtime-data flows), **digital reflections/shadows** (models with one-way real-time data flow) and **digital twins** (with data and information exchange flows both ways between the physical and virtual system). A DT is thus not a mere detached virtual representation of a physical twin, but rather a living organisms that interacts with its physical twin via sensors and receivers connected through the Internet of things (IoT) or ICT.

With regard to the existing applications, Brenner and Hummel (2017) have developed a digital shop floor management system based on the DT notion. A three-dimensional DT is devised by Knapp et al. (2017) in manufacturing to predict variables affecting metallurgical structures. However, the digital representation is not connected to its physical counterpart via sensors and the DT notion does not clearly correlate with the earlier definitions. Schleich et al. (2017) propose a simple reference model for DT in product design and manufacturing. In the work of Söderberg et al. (2017), the DT is referred to as a simulation for real-time control and optimization of products and production systems, where the authors specify data models to move from mass to a more individualized production. Alam and El Saddik (2017) develop a driver assistance application where the DT is to identify various driving events and provide recommendations for drivers, insurance companies and emergency units. Uhlemann et al. (2017) introduce a learning factory based on the DT to demonstrate its benefits and familiarize the workers with new technologies and their implementation. Tao et al. (2018) focus on how to generate and converge cyber-physical data and apply their framework in three cases that relate to product design, product manufacturing and product service. Lastly, Zheng et al. (2019) apply the DT to model a welding production line.

The research positioning and novelty of our work lie in the fact that current digital twin applications (published in journals) have been so far applied to manufacturing, shop floor management and product engineering designs of artefacts/objects. As the scope of current research is confined to 4-wall environments and products, we take the DT concept to the next level by exploring its potential use outside of the 4-wall environments and object designs, by adapting the concept to synchromodal freight transport processes and long-distance movements of assets in geographic space by using Geographic Information Systems (GIS) and agent-based modelling (ABM). We pose the following research question: How to fuse virtual and physical environments for long distance flows, and what systems or models can depict these?

3 METHODOLOGY

Synchromodal transportation is another word for modal shift and can be also perceived as real-time optimized Intermodal transport. The goal is to shift freight from roads to inland waterways and rail to decrease the pressure on the roads as well as the negative external impact freight transportation has on human health and the environment. Given the projected growth of demand, the road network faces an increasing threat of becoming more congested due to the ever-increasing number heavy goods vehicles. To make the inland waterways and rail more more attractive and acceptable in terms of higher reliability as well as service levels, they have to become flexible, dynamic and adaptable. In this regard modal decisions should be taken as late as possible based on real-time contextual information and operational developments (new/cancelled orders, weather conditions, infrastructural developments, disruptions etc.).

From a research point of view, nearly all synchromodal models have an analytical character (Ambra et al. 2019b). This means that abstract mathematical spaces of analytical models do not posses x and y coordinates (latitude and longitude) necessary for querying positions of assets, their surrounding entities, distances and estimated lead-times given their geo-locations. Such environments render dynamic re-planning during model executions difficult. Furthermore, Euclidean distances in Euclidean space do not represent routes with high precisions as the topographical features of the earth's surface may very in space and time. Therefore, more realistic and accurate virtual spaces are necessary for models to operate, such as spaces based on Geographic Information Systems (GIS). A virtual space that encompasses such geo-features is presented in section 3.1.

3.1 The Virtual Space

The virtual dimension is depicted by digital models which are used for gaining knowledge and creating added value as well as providing a risk free environment for risk analysis. Furthermore, they are used for evaluation of what-if scenarios prior to implementation of solutions in order to reduce financial losses or assess phenomena yet to be introduced in the physical system (real world). The virtual dimension is to assess relationships among entities, simulate error handling and many more.

To provide an example of a virtual GIS-based environment, we introduce the SYMBIT model. SYMBIT is a computational model that generates or reproduces data through agents which need scheduling, behavioural rules and certain level of knowledge. The right-hand side of Figure 1 (supply) contains GIS data and

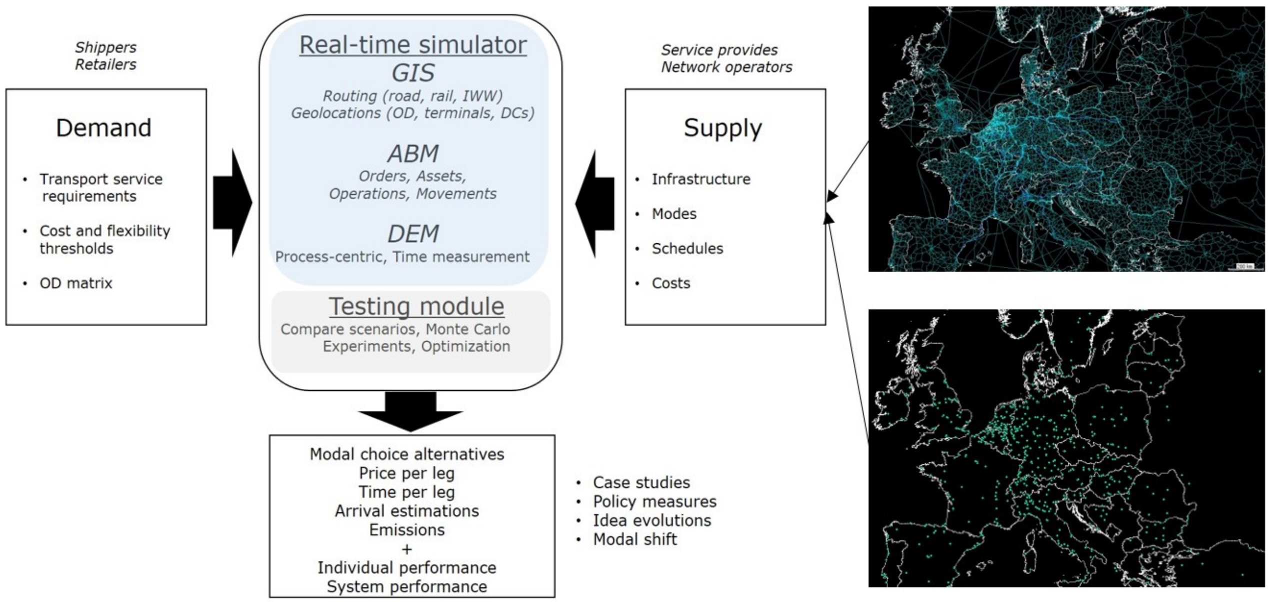

Figure 1: Input and output of the SYMBIT model.

specifications for roads, inland waterways and railways. The main modelling canvas of SYMBIT is a digital map that comprises of vector files, also called shapefiles, acquired from ETISplus which is the European Transport policy Information System, and Eurogeographics. The vector data files contain the TEN-T networks for roads, railways, airports, ports and the watercourse system identified by Directorate-General for Mobility and Transport (DG MOVE). The left-hand side (demand) is included in SYMBIT on an ad-hoc basis. For instance, the transport requirements, Origin-Destination (OD) matrices and preferences are incorporated based on the study context, as these may vary for different shippers and retailers. GIS provides the real-time simulator with detailed and realistic routing for moving agents and geo-locations of stationary agents. Agents are used for depicting assets and their movement as well as how they are supposed to operate. The DEM element is process-centric and forms the main fibre of time via discrete time steps which are small enough to mimic real-time dynamics. In the Digital Twin notion, the virtual space needs to be connected to the physical space by real-time data feeds. The following section 3.2 addresses what applications can provide such inputs.

3.2 The Physical Space

The physical dimension is more diverse and complex compared to the abstracted virtual space. This space is governed by dynamic decisions of people that route and relocate assets and their capacities. Objects and assets need to be connected via IoT technology or GPS devices that allow for collecting data about the physical dimension and translating them into digital instances (agents) in the virtual world.

If we translate this outside of the simulated environment, real-time mode selection requires involvement of extra parties in the process to solve transparency issues as to who has the cargo and where it is located. Crucial elements in this regard are situational awareness of the current system state and projections of how the system will evolve once different actors take different actions. While there already exist real-time control towers (ESRI geo-event server, MPO, ActiveViam etc.), and data fetching/scrapping tools (Webhouse.io, VisualScrapper, Spinn3r etc) that have the ability to integrate data via JSON at a single reference point, these applications provide past and present positions of assets and trends. Our paper departs from the past and present assets' states and focuses on how future problems could be mitigated, and emerging opportunities utilized, if there is a possibility to speed-forward into the future. In order to estimate where assets (barges, trains and trucks) will be in 2, 3 or 5 hours based on congestions levels and infrastructural developments, and which terminals, distribution centers but also other moving assets will be in their vicinity, is a challenging task that requires substantial research and modelling. The physical space, and the interplay of entities and their systems that capture it, is depicted in Figure 2.

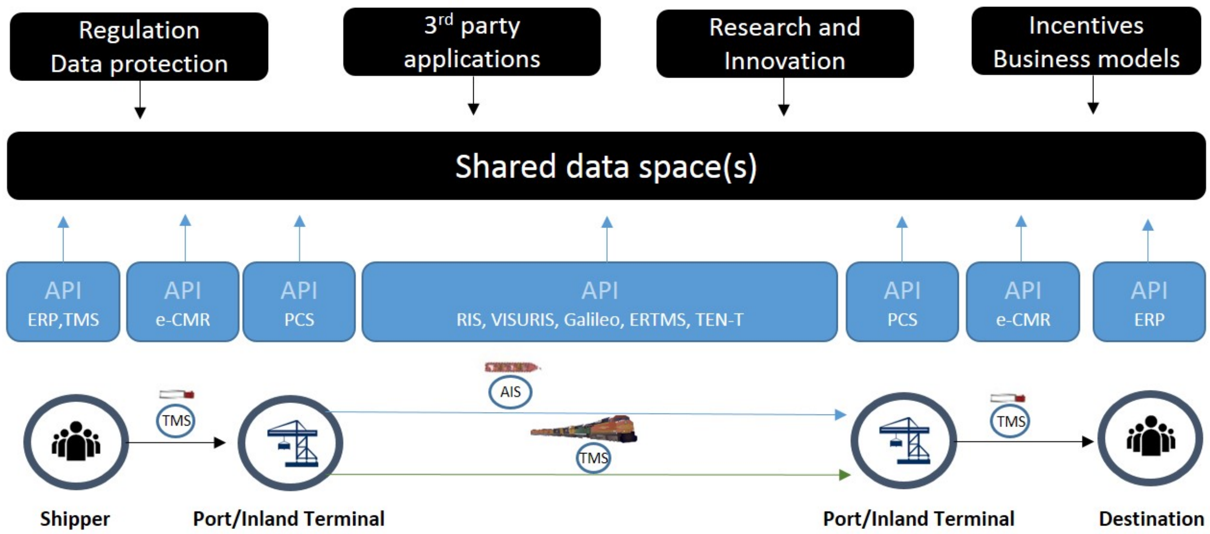

Figure 2: An integrated overview of systems and entities necessary to introduce transparency and facilitate data exchange in synchromodal transport.

To demonstrate the very first long distance synchromodal digital twin (technically a digital reflection as the data flow will be one-way in this paper), the AIS API is selected which is the Automatic Identification System for vessels. AIS was used as a ship-to-ship communication device for collision avoidance. It has however evolved from this narrow application to commercialized applications, by platforms such as marinetraffic.com and vessel finder for instance, due to its ability to transmit vessel information regarding its name, speed, position, course etc. The following section 3.3 sheds more light on the symbiosis between the physical and virtual spaces.

3.3 The Mirror: Connecting the Physical and Virtual Environments

The theoretical basis of this paper rests on the notion that the DT relates to a living dynamic simulation environment that mimics the real physical system by continuously updating its virtual environment in order to provide support to certain tasks and evaluate most probable implications. In fact, the digital virtual environment exists in parallel with the real system and updates itself through sensors based on specified intervals and/or events. The DTs are digital instances ($\mathbb{A}$) of the physical objects represented by agents. The DTs exist in a Digital Twin Environment (DTE) depicted by the environment of SYMBIT. The Physical Twins ($\mathbb{P}$) represent assets such as barges, truck, trains, vans and parcels that may send and intercept messages via sensors and receivers. These assets will be then converted into agents within the SYMBIT environment. As far as physical twins are concerned, p $\in \mathbb{P}$ posses various parameters $(p_{id}, p_c, p_s, p_d, p_{eta}...)$ where p_{id} is the identification number of the physical asset, p_c are the asset's coordinates (latitude/longitude), p_s its current speed, p_d its destination and p_{eta} is the estimated time of arrival.

$$\delta : S_{t-1} \times I_{url} \rightarrow S_t \tag{1}$$

$$\ddagger : \mathbb{P}(S_t) \rightarrow \mathbb{A} \tag{2}$$

The parameters determine the state of each p which means an update function renews the parameter values of p. The update function δ (eq 1) takes the last known state S_{t-1} of p and updates its state, hence all its parameters, by an input from a real-time data feed from a URL link (I_{url}). A transition function $\ddagger$ then takes the updated states and parameters of the physical twin $\mathbb{P}(S_t)$ and converts it into an agent type $\mathbb{A}$ (eq 2). The $\ddagger$ also symbolizes the parametrical unity and symbiosis of $\mathbb{P}$ and $\mathbb{A}$. Figure 3 illustrates such a transition.

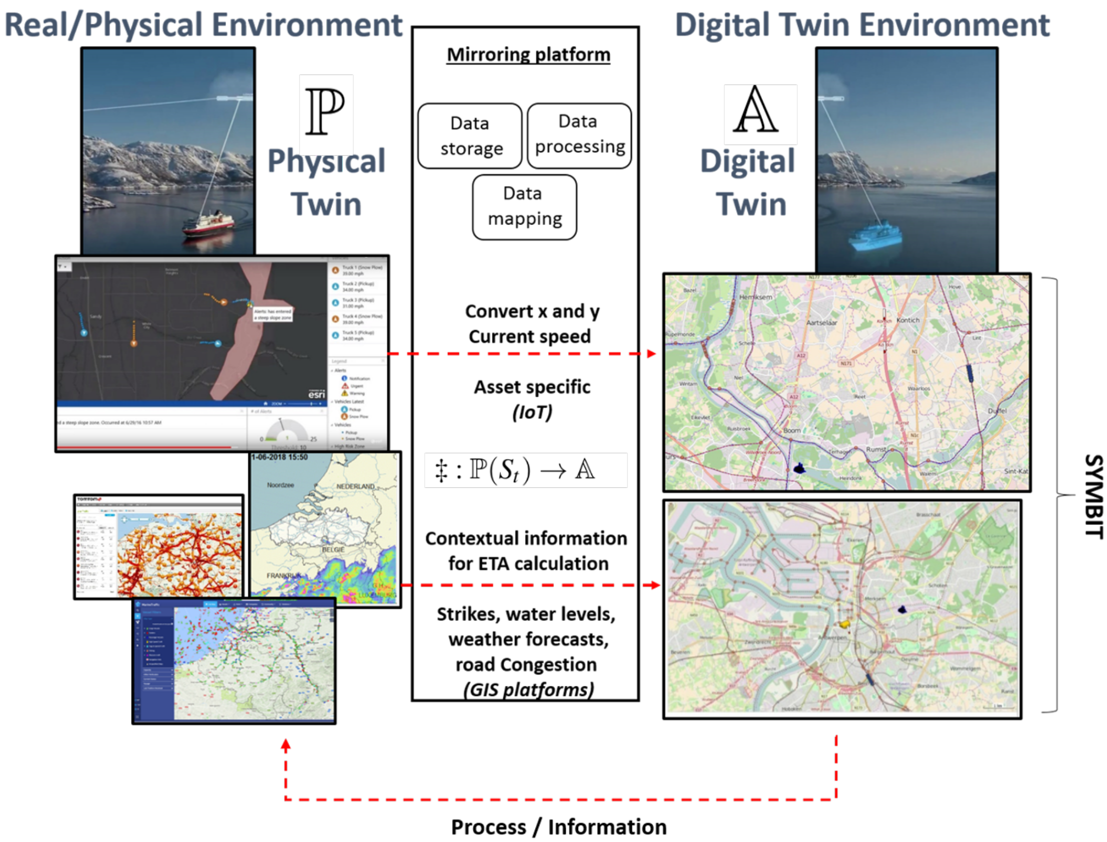

Figure 3: Demonstration of a mirroring platform. Left-hand side figures are borrowed from ESRI, waterinfor.be, marinetraffic.com and Mfame. Right-hand side is the virtual environment of our SYMBIT model.

The next steps are taken from Microsoft Excel practices that are mainly used for monitoring stock exchange data in real-time. Algorithm 1 depicts how an agent $a \in \mathbb{A}$ and its parameters are set-up by mimicking physical assets through an external URL link. The steps in algorithm 1 present a neat and simple way of acquiring actual real-time positions of assets and their working conditions. Functions and rules that concern $\mathbb{A}$ and their simulated environment, improve the system in the virtual space. In this regard, physical dimensions can be easily connected to virtual GIS systems (such as SYMBIT) for long-distance flows by using AIS data feeds via satellites (section 4).

4 PROTOTYPE IMPLEMENTATION

In this section we demonstrate a connection between the physical and virtual space. Agent-based modelling in virtual spaces are relevant for simulating and assessing interdependent specificities that create a complex system or an array of complex sub-systems. The complex systems thus depict the supply chain nodes,

Algorithm 1: Transition function (‡) set-up

input : $p_{id}, p_c, p_s, p_d, p_{eta} \in \mathbb{P}$
output: $a_{id}, a_c, a_s, a_d, a_{eta} \in \mathbb{P}$

// converting physical twins to agent types via their parameters
$Excel \rightarrow Data \rightarrow from\ HTML$ // connect excel sheet to a URL link (AIS data feed)
Transpose data so that $p_{id}, p_c, p_s, p_d, p_{eta}$ are column headers
Establish $refresh$ event every minute to update parameter values
for $\forall\ p \in \mathbb{P}$ **do**
  // On model start-up
  Initiate $\delta : S_{t-1} \times I_{url} \rightarrow S_t$
  get $p_{id}, p_c, p_s, p_d, p_{eta}$ from excel
  for $\forall\ a \in \mathbb{A}$ **do**
    Initiate $\ddagger : \mathbb{P}(S_t) \rightarrow \mathbb{A}$
    // Load agents from database (excel sheet with AIS data feeds)
    $a_c \leftarrow self.latitude$ and $self.longitude$
    $a_{id} \leftarrow p_{id}$
    $a_s \leftarrow p_s$
    $a_d \leftarrow p_d$
    $a_{eta} \leftarrow p_{eta}$
    $MoveTo(a_d)$ // from the last known location of p_c, the $a \in \mathbb{A}$ will speed- forward to assess various scenarios and risks

transportation processes (within inland waterways, rails, roads...) and other dynamic processes at ports and terminals. Digital Twins can thus operationalize and synchronize the system(s) in real-time based on data feeds (section 3.2) and feedback loops that guide all the stakeholders and decision makers. In our previous work, that concerns the virtual dimension, dynamic features have been tested in SYMBIT's digital GIS environment already, where triggering events and firing rules induce reconfiguration and re-routing protocols of assets to assess modal shift and resilience to disruptions (Ambra et al. 2019a) . This study was based on the bayesian inference as the forms of uncertainties were expressed in terms of probabilities and consequently assessed by Monte Carlo simulations. Furthermore, stochastic insertion of extra service points, their impact on LSPs' lead-times and load-factors, and dynamically changing speed parameters by means of geo-fences, have been tested as well for a small sample size (Ambra et al. 2020). To gain more insights regarding the two studies in terms of experimental designs and results, we refer the reader to the above journal publications. As these models - and many other models in general - operate in closed virtual environments, integrating them with current real-time states is imperative in order to gain an updated view of working conditions on model start-ups. This is why the mirroring element is considered in this paper; to showcase how such an integration can be set up. Nevertheless, once the real-time data feed is established, other agent-based models that work with GIS libraries, such as the two examples presented in Ambra et al. (2019a) and Ambra et al. (2020), can receive initial locations and agent parameters in real-time. From that point onward, the models can carry out their logic and fulfil the purpose for which they have been designed.

Therefore, Figure 4 showcases the steps depicted in Algorithm 1. The elements highlighted in red represent the real physical system captured by real-time updates via the Automatic Identification System (AIS). As mentioned earlier, the AIS was initially used for vessel-collision avoidance. However, the transponders on vessels are now used to detect AIS signatures by satellites which makes tracking of vessels in space and time possible (by providers such as VisuRIS, vesselfinder, marrinetraffic, ...). The elements highlighted in blue represent the SYMBIT's virtual space (constructed in Anylogic) where incoming messages are converted into variables the model can work with. As the cells provide automated value updates (Figure 4 , red), the SYMBT model (Figure 4, blue) adapts the new parameters values on each model start-up. In this regard, the virtual dimension can speed-forward into the near future, and by providing process-centric simulations, can assist data-centric models in evaluating risks or potential bundling scenarios as well as the impact of extra service points and deviations once other entities and their interactions are accounted for. Thus, this demonstration is a first step towards connecting established models to ongoing and ever-changing physical systems, so that decision-makers and modellers can introduce adaptable elements and features that are rarely connected to real-time data feeds; since most models for long-distance freight transportation operate in closed virtual systems as standalone simulation models, and not as digital twins or digital reflections.

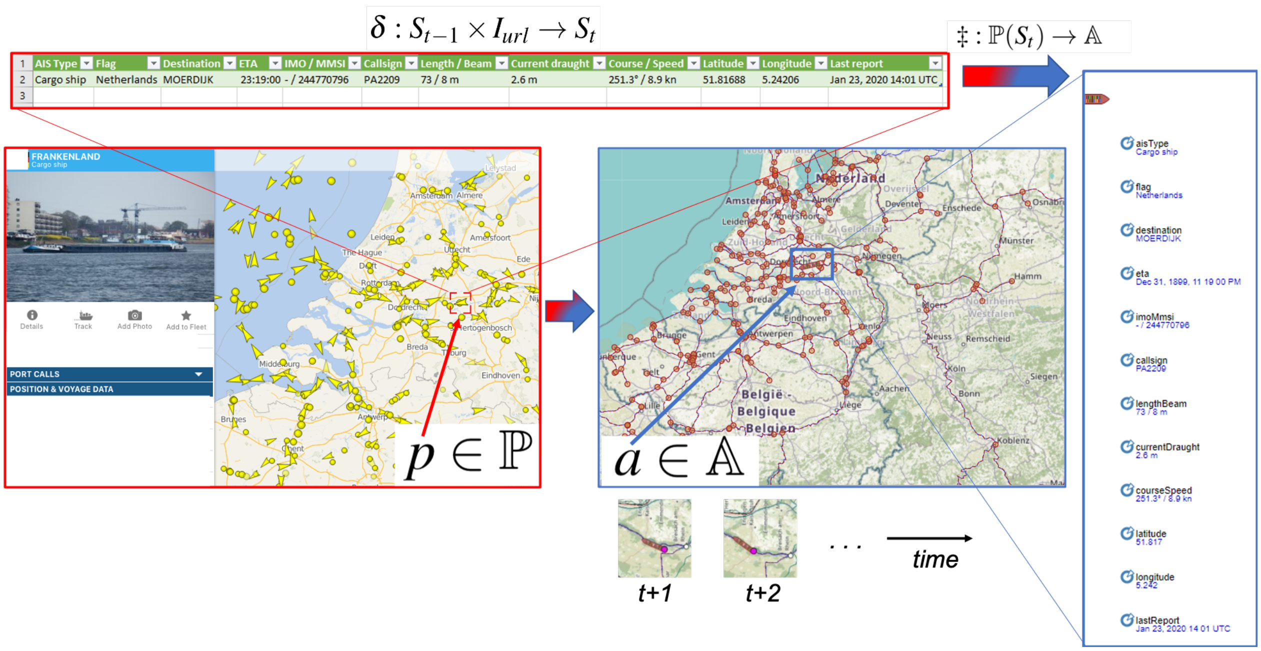

Figure 4: Illustration of a data-feed from the physical system (red) to SYMBIT's virtual system (blue).

5 DISCUSSION AND CONCLUSION

Besides descriptive analytics that capture mainly current and historical trends, designing and implementing the Digital Twin is now more accessible thanks to the communication technologies discussed throughout this paper. As a matter of fact, digital twins and simulations can guide and push companies towards more sustainable operations by increasing fill rates and shifting to other modes, but the benefits need to be quantified and justified for them to adapt.

Most of the papers that claim to present Digital Twin applications misuse the term, and the review of Orozco-Romero et al. (2019) also shows that the development of complete digital twins is not mature, while the concepts such as the digital model and digital shadow are more advanced. In this respect our paper addressed the digital twin concept for long-distance freight flows and demonstrated an initial step towards digital twins for such flows (by technically describing a digital shadow). More research efforts have to be directed to issues as to how to communicate process specifications and other information from the virtual system back to the physical system. Since the demonstrated case concerned inland waterways, the potential combination of different modes (road, rail, etc.) is still rather challenging due to the lack of straightforward direct availability of real-time data inputs when integrating responsive planning systems.

The paper explored the digital twin concept and its potential role in synchromodal transport. From a methodological point of view, agent-based modelling has an ability to simulate information availability/exchange that is linked to consequent reactive agent behaviour induced by it. This ability was tested in the SYMBIT model in previous work (Ambra et al. 2019a; Ambra et al. 2020) by exposing static and dynamic solutions to disruptions and newly incoming orders where individual agents reconfigured based on their positions in space and time. As far as the digital twin dimension is concerned, simulation-based solutions are useful for failure prediction, developing systems, new designs and optimization of various system processes. The digital twin concept presents an imperative step to fuse virtual models with physical environments and their processes. More data availability and accessibility can improve synchromodal models and planning tools in order to provide more flexibility, higher speed, reliability and transparent overview of ongoing freight transport processes; these are the aspects that hinder most shippers from using intermodal services.

After demonstrating the very first long distance synchromodal digital shadow, we will assess how both-way data flows can be achieved and how the system evolves and adapts on a continuous basis from an empirical perspective; when the assets react to the inputs and digital instances update in parallel. To further explore and deepen the understanding of digital twins for synchromodality, universities and industrial representatives are engaged in a DISpATch (Digital twIn for SynchromodAl Transport) project. DISpATch focuses on connecting the modelling logic embedded in virtual environments with the physical system processes, and vice versa. The project consortium will devote 4 years to this task by combining inventory management algorithms, integrated network planning and freight transport uncertainty and predictability simulations, to further contribute to advancing synchromodal transport and the physical internet in Belgium and Europe.

To conclude, IoT, GPS and GIS platforms will play an imperative role in creating a symbiosis between simulation models and real-time data platforms that communicate current and historical developments about asset movements within their network(s). The scientific community, transport users, transport providers and policy makers can expect many new developments in terms of models and applications that will, hopefully, contribute positively to the roadmap towards the 30% reduction of road freight transport by 2030 and 50% by 2050.

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