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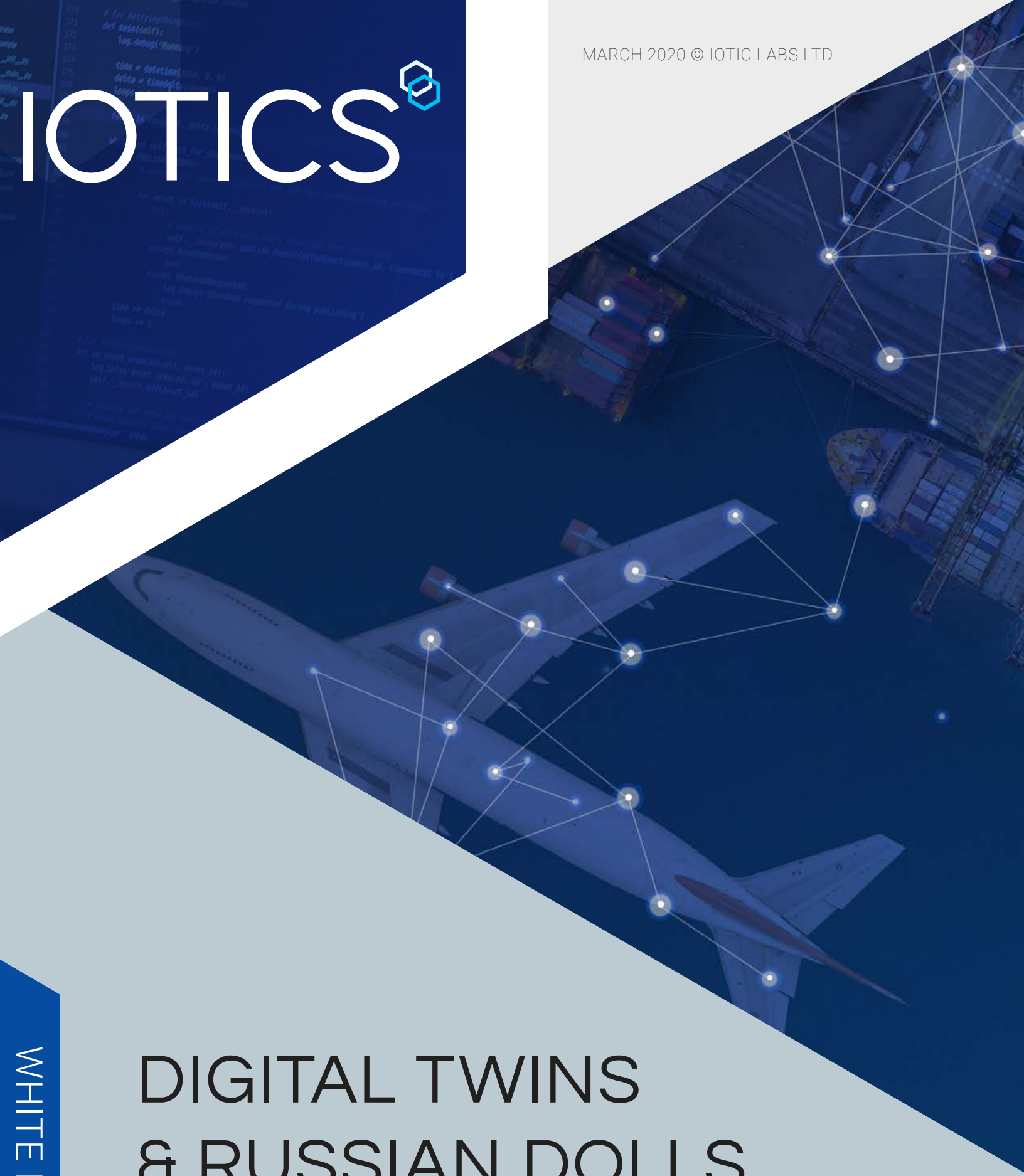


WHITE PAPER

DIGITAL TWINS & RUSSIAN DOLLS

MARK WHARTON & ALI NICHOLL

DIGITAL TWINS & RUSSIAN NESTING DOLLS

by Mark Wharton & Ali Nicholl

Throughout 2019 we saw the rise of Digital Twins, with implementations expanding beyond visualisations to through-life 'live' versions of entire processes, assets, and environments. These digital Data Twins which model entire data estates and interact in real-time across corporate boundaries will continue to deliver in 2020. They will deliver on the promises and potential once they can meaningfully securely interact with each other, as we outlined in "Digital Twins and a Dynamic Model of the World".

However, as the interactions between Twins increases, so too do the potential complications. Paul Miller at Forrester, in his paper "Untangle The Digital Twin As Part of Your Product Strategy" discussing the value of Digital Twins, warned of the need for users to be aware of the potential complications that arise from the Russian Nesting Doll nature of twins. Russian Nesting Dolls, or Matryoshka Dolls, nest inside one another each revealing a smaller figure inside it.

Digital Twins as virtual versions of assets, systems, and processes can be seen in a similar light. Twins of individual components (fan blades), form complex assets (turbines), nested inside large assets (engines), inside asset platforms (planes), which form part of a service (airline route), as part of a digital ecosystem (transportation). Each of these Twins is equally valid, capable of interacting across corporate boundaries, and has value – albeit that this may vary depending on a user's role in the supply and demand chain, needs and focus.

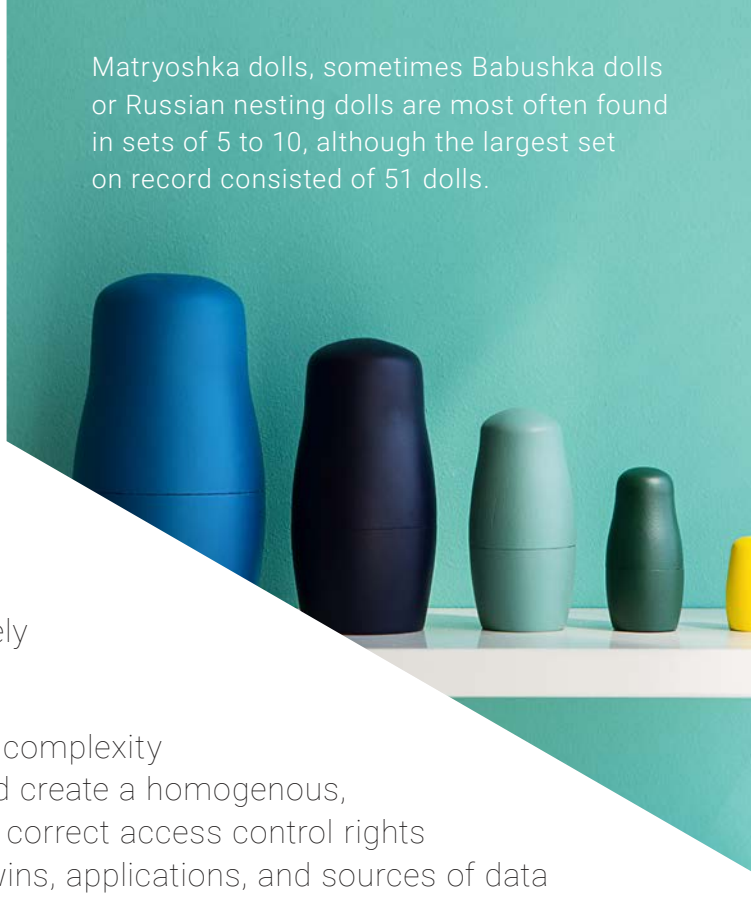
The potential complications of nested Twins, especially those whose constituent Twins are owned and operated by multiple disparate entities, and the difficulties of navigating or mapping their interrelations and interactions are not to be underestimated.

In this article we outline the nature of the challenge, draw a parallel to a similar challenge that technology has already faced, and propose that Semantic Web technology offers a solution. The semantic solution can evolve to meet the complexity necessary for Digital Twins to truly enable Digital Ecosystems and the solutions, products and services they deliver.

A quick note on Digital Twins and Digital Ecosystems.

Digital Twins are not visualisations of assets, 3D models, or pictorial representations. A Digital Twin is a live digital version of any endpoint - asset, process, system, place or person – with access to all its data throughout its entire life. Digital Twins exist within Digital Ecosystems where Twins securely and selectively share information across corporate boundaries in real time via brokered interactions. There are, of course, variances in this definition, the Advanced Manufacturing Research Centre defines a Digital Twin as a "live digital coupling of the state of a physical asset or process to a virtual representation with a functional output.", but the importance is repeatedly placed on their live and functional nature.

THE COMPLEXITY OF NESTED TWINS



Matryoshka dolls, sometimes Babushka dolls or Russian nesting dolls are most often found in sets of 5 to 10, although the largest set on record consisted of 51 dolls.

Russian Nesting Dolls are a good analogy for the challenges emerging with Twins. One Twin on its own is a useful thing, but they come into their own when they form a digital ecosystem of twins: in a domain (such as a smart city); or an enterprise (where barriers between silos can be broken down); or in a consortium of collaborating enterprises (where relevant data can be shared securely between the participants).

The twin-based digital ecosystems abstract away the complexity of heterogeneous systems, APIs and data formats and create a homogenous, asset-focussed view of the underlying world. With the correct access control rights in place, interactions can be brokered between the Twins, applications, and sources of data and allow control interfaces to be actuated to orchestrate change across the digital ecosystem.

Despite the homogenous, asset-focused view of the underlying world, the complexity goes beyond twins nested inside one another. A simple hierarchy of Twins is not going to be sufficient to model the real world.

Parent-Child is not enough

Describing the nesting problem of the Digital Twin as a "Russian Nesting Doll" is a good image, but it is limited on 3 counts:

- Not everything is the same "shape" - A train is not a carriage is not an engine is not a turbocharger. They almost definitely won't be made by the same companies, or be registered on the same systems;
- Not everything nests one-to-one - a train might have many carriages; and…
- …there might be more than one dimension to nesting. Manufacturers make trains and operators run trains, but manufacturers lease trains to more than one operator and operators run trains from more than one manufacturer.

If we are to avoid the complexity that comes from moving beyond parent and child nested Twins, we need to consider how else we can relate without strict parent and child hierarchies.

Where have we seen the challenges and solutions to these hierarchies before?

In a word, databases.

EVOLUTION OF DATA BASES

Originally there were hierarchical and network databases which required the programmer to understand the structure of the database and write the traversal code to get to the data. This is reminiscent of the emergence of hierarchical Twins, where the relationship between Twins requires an intelligent understanding of the relationship between the assets they are coupled with.

In early databases, paper-chasing code polluted the business logic and led to the development of the relational database and SQL where the database code is not part of the business logic - a declarative approach. Now we have no-SQL databases, graph databases and semantic triple-stores alongside specialist time-series database, and so on.

Digital twin as a database evolution

You can think of the data Digital Twin as an evolution of database technology. A Twin is the focus of the data for that asset, be it metadata about the Twin itself, static data for the Twin, real-time data or an event stream. A Twin is like a row in super-table in a yet-to-be-invented database which mashes all the data for a real-world asset into a useable form for consumers of that data.

THE NEED FOR SEMANTICS

Useable for whom? Twins aren't designed to be used by individuals: their proliferation, power, and complexity of interrelations open up the possibility of autonomous interoperability, meaningful interactions between systems and processes, leveraging the power of Event Analytics, AI and Machine Learning. Twins are designed for a machine-readable world.

The semantic web was developed by Tim Berners-Lee and others in the early part of the 21st century. It's not been a huge hit in the internet of people because people understand semantics intuitively. People don't need to know that this photograph is of a dog and dogs are furry: they learned this when they were toddlers. For machines, it's another story. Semantics have made a big difference to web-crawlers, for example in the case of opening hours. Markup from https://schema.org/openingHours allows a web-crawler accurately to interpret the times in a website as the opening hours for a restaurant, not as their phone number. This type of machine-readable interoperability is important for Twins in a digital ecosystem. Twins need to understand what the other Twins are saying about themselves in an unambiguous way.

Progression of semantics

The semantics that describe a Twin so that it can interact with others progress from simple to complex along this path: a) What am I? - What type of thing am I? Am I a person, an engine or a transport hub?; b) What can I do? - What data can I provide, what control interfaces can you actuate?; c) Where am I? Geo-location, domain, district, etc.; and d) How do I fit in?

This last one is the root of the Russian Nesting Doll problem. Where does this Twin fit into the digital ecosystem of other Twins? What is its context? What are its relationships to those Twins, are they simple or complex? Is there one relationship or many? Let's consider a simple hierarchy - cars have engines, wheels and gearboxes. Gearboxes have selectors and gears. Gears have bearings etc, etc.

The problem is not just about nesting - it's about data flow. If you have an aggregate Twin like the car does the Twin of the car present all the data from the child Twins, or does it point to the children and allow you to get the data from them?

Semantics as the "place" for relationships

Given that the need to define relationships between Twins exists, the problem with a lot of solutions is where does that linking data go and how is it queried. At Iotics, we started from the premise that all Twins in our environment would be defined by their metadata. "The metadata prescribes the API" was one of our guiding design principles from day one. Separation of the data and metadata has always seemed natural to us. Now, the infrastructure of Iotics' operating environment to store these links allows for the flexibility of relationships that are enabled by the semantic web technologies, and for queries and inferences to mine these relationships to find related sources of data.

Semantics and relationships

From the early days of the Semantic Web, one of the key uses for the technology was in defining people and their relationships. The "Friend Of A Friend" (FOAF) definitions, an Ontology in the jargon, were defined as early as 2000 to describe these interactions. A quick Google for language- and cultural- independent family relationship ontologies will show how complex these interlinkings can become. The relationships between Twins in any Twin-enabled Digital Ecosystem can be more complex than this, but the flexibility and extensibility of the Semantic Web allows them to be modelled.

At Iotics, we believe that the relationships between Twins should be stored in the semantics, away from the data and controls. This allows proper separation of concerns in the Twins and the flexibility and extensibility given by the semantic relationships. This was another of our guiding principles - "The Twin is in control of its own destiny".

CONCLUSION

Twins and Semantic Technology enable us to deliver on the promise of Digital Ecosystems, avoiding the limitations we saw in the analogous hierarchical databases with their focus on the logic of the databases themselves, not the business logic which drives value. Twins on their own provide information, but not insight. Without accurate relationships, they restrict our understanding of the real-world complexity they purport to model. The hierarchical challenge presented by nested twins is only the beginning. We must be able to facilitate the Twin's interactions and relationships dynamically, in all their highly variable, overlapping, messy, multi-party nature.

Implementing the Semantic Web and Digital Twin-enabled Digital Ecosystems is not easy, but it is necessary. Iotics has built the patented operating environment and toolset to enable real-time Digital Ecosystems that can broker, secure and leverage the complex interactions of Digital Twins across corporate boundaries. This allows the virtual Twins to live and interact in the same way as their physical counterparts, creating the mirror of life we expect and demand.

Mark Wharton is Co-Founder at Iotics where his focus is autonomous interoperability, enabling machine-readable semantics to drive diverse solutions with minimal intervention. Ali Nicholl leads engagement across the Iotics ecosystem. A founding team member he is passionate about enabling others with semantically-defined twins.