Digital twinning - an introduction to a rich engineering discipline

Simply put, digital twins combine a real-world system with a digital model

Beyond that, however, there is enormous variety in what they actually are and how they are used. Large virtual worlds for gaming; detailed models of components and machines that haven't even been built yet; models of the atmosphere – models of the atmosphere of planets we'll never see; air traffic control; traffic maps on your phone. These are all digital models of real world things. With this variety in mind, it's hard to nail down just what makes a digital twin a digital twin.

There have been various attempts to define the term 'digital twin', all of which are more-or-less useful depending on the circumstances. We've found, though, that debates on the meaning of the term often impede a more important discussion about what it is you're trying to achieve and what you need to build in order to achieve it.

Most twins are used to help people make decisions about the real world, so one way to be inclusive when talking about digital twins is to view them as a decision-support mechanism – something that supports a command-and-control loop, or cybernetic cycle. They're a way of collecting and interpreting information and executing a decision. In this view, a twin consists of the real-world system of interest, sensors that instrument it, data about it, a structured model of it, a way of visualising that model, a way of rehearsing changes to that model, and some way in which those rehearsed changes can be implemented on the real system.

When the UK set out its vision for Cyber-physical Infrastructure, it defined a digital twin as being when that last control step is also digital. This is true in some circumstances such as satellite control, and SCADA systems, but is rarely true in softer scenarios such as environmental and social modelling. In contrast, the cybernetic loop approach lets us recognise that there are lots of digital decision support systems that are part of the digital twin family, but don't have to be completely digital in both directions. This is still usefully simple and lets us recognise that twins can develop from simpler to more complex models.

There are many ancillary and supporting technologies and disciplines that are important for digital twinning. Cyber-security, for example. This plays a vital role in digital twinning, but it plays a vital role in connected digital technology.

What differentiates a digital twin approach from other big data approaches is the use of a pre-defined model. Now, there are situations where 'collect it all and make sense of it later' is the best approach, if taken with due care, but for many scenarios it is important that the data is contextualised from the get-go. That context is provided by the model, which dictates the standards and formats for, quality criteria for, and relationships between data, as well as capturing the ontology implicit in the information.

As every digital twinner and every model-based systems engineer knows, all models are wrong, but some are useful. This has two important consequences. Firstly, the model is going to be purpose-driven – modelling choices will be made in order make something useful. A degree of clarity and consensus about that purpose is important. This can make it challenging to combine digital twins that were built with different purposes in mind, and it may be better to combine their underlying data in a new model. Secondly, the choices you make about what you model mean that it will be an imperfect reflection of reality. All models fail – indeed, studying how they fail is one of the more interesting parts of our discipline – and you need to be very aware of the assumptions and simplifications that are baked into your model.

If the core of what differentiates digital twinning is its use of models, then what makes it so hard to define is the range of models that can be developed. As noted, digital twins encompass systems that range from games (which include a model, a simulation, and a visualisation function); through monitoring (which include sensors, data, a model, and some visualisation), experimentation (data, models, simulation), and design (models, visualisation); to C2 systems – ATC is digital until the final control step, SCADA and spaceflight are fully digital. But they also model systems as diverse as buildings, utilities, factories, aircraft, the environment, individual people – individual organs – and social groups. Each of the technologies that make up a digital twin (the sensors, models, and visualisers) need to be adapted to the system being modelled.

Finally, the operational purpose of a twin can vary enormously, even between twins of the same system.

So, one twin is not like another. They can consistent of different components, modelling different systems, for different purposes. Indeed, within our industry, we see many different specialisations and focusses from different companies and experts.

Threading through all this variety, however, are a few consistent themes:

Data engineering – its collection, collation, curation – is vital discipline in digital twinning

Applying commercial and contractual constraints on the handling of data in hard twins is as important as applying GDPR and privacy constrains in soft twins.

What twins allow decision makers to do is extract the information that is encoded in the data more easily because the data is contextualised in a model. One consequence of this is that as data sources are integrated into the model, they contextualise each other and reveal information that may not have been explicit in any one set. This leads to a failure of anonymisation and potentially breaches of confidentiality. If these risks, therefore, are to be treated it must be at the information level; at the data level, they can only be terminated.

Models are powerful statements of consensus and shared understanding even if they are not filled with real data

They encode all the prejudices and assumptions of the engineers who built the system, and their results will reflect that. Pre-Copernican models of the solar system fitted the available data to one paradigm; later models were changed to reduce the cost of data-fitting. Different economic models provide very different interpretations of the same observations. Models must be kept under review; adhering to them as if they are reality itself is a mistake. The map is not the territory.

Information presentation from a model-based twin can be enormously powerful – even when it is wrong

Digital systems are very capable of presenting information that gives a false sense of accuracy; or hide key facts – digital navigation charts have led to some dangerous errors when used at inappropriate scales.

However, with these risks in mind, digital twins continue to offer some of the most powerful tools for making use of digital data that we have yet developed, and their potential is expanding at an accelerating rate. Because you can improve a twin in any of its technological elements, and because all of those elements are subject to exponential technological advancement right now, the twins we see today are just a pale hint of what we'll be able to develop and use in the near future.

Speak to us about your challenges

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