Digital Twins, Turing Tests and Urban Models

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Abstract. Digital twins have become all the rage and are simply the latest stage in the process of using computers in the development of scientific theory and practice. If you go back to the 1920s, the term 'model' meaning a 'simplification of the real thing', or an 'abstraction' was barely visible but once computers emerged, the idea of computer models first, but fast on their heels, models of many kinds gained momentum. In science, the notion of theory has now become almost interchangeable with the idea of model. In this short note, I will focus on defining digital twins in the context of computer or digital models, raising paradoxes and conundrums that pertain to the semantics dominating the field. After some brief discussion of definitions, I will ask the question 'how do we define a good model' and then introduce variants of a 'relaxed version' of Turing's famous test that simply asks the question 'can you see the difference between the twin and the real thing'. This is one of many open question pertaining to such tests but then, using applications from our own work on digital models in London, I suggest that the way forward is to develop many variants, many examples, many applications of digital models of the same place, thereby initiating comparisons and providing platforms for their integration. We imply that many rather than one model, one twin, thus provides a much richer context for informed prediction.

Keywords: Digital Twins, Multiple Models, Urban Simulations.

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1. Preamble

The idea of the digital twin first emerged in production engineering where a twin was defined by Grieves (2014), first in 2003, as a digital rendition of a physical artefact or process used to both understand and usually control the process in question. Such twins of course are models, 'simplifications' or 'abstractions' of the real thing, a concept that usually throws most of the real world away, keeping only the essence of the artefact or process in question. Insofar as there is a difference between a model and a twin, then it is widely regarded that the twin explicitly 'shares information' with the real system, where that information is invariably digital. A model can also share information but it is somewhat less obvious for digital twins are usually closer to the physical system they are intending to replicate than many of the models that we use in thinking about cities. The idea of the twin is that it can merge in some way with the real system without it being the real system, and in this sense, there is a logic to the twin being a controller of the real system. But this is also a paradox in that the twin cannot be the same as the system simply because there is no point in constructing a twin identical to the real thing for it would then be the real thing. These definitions however remain somewhat ambiguous and the argument is thus one over semantics (Batty, 2018, 2019, 2021).

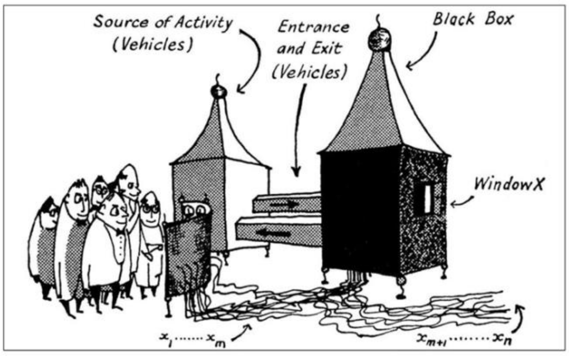
We will begin this short paper elaborating these definitional questions in a little more detail. I will first define the idea of a twin, suggesting that there might be multiple twins, triplets, identical and non-identical twins and so on. We may even have mixtures of twins that contain both digital and non-digital realizations. But I will also extend the notion of a model or twin of a real system to the idea that we ourselves must be embedded in the loop relating the model or the twin to the real world. In this sense, we cannot discuss models without relating to ways in which we extend the model-real world interface to the way we ourselves organize this juxtaposition. I will then extend the argument to ways of dealing with multiple models which have become significant as our computational and analytical powers have enabled us to build more than one model of the same system, without these different models conflicting with our own abilities to construct them.

If we have a model of a system, invariably we attempt to consider how good the 'fit' or estimate of the model is to the real thing. In computer modelling, if you want to see how good an AI actually is, the so-called Turing Test is as good a procedure as any and we will speculate here that in building computer models of cities – which we might consider in some circumstances as 'digital twins' – we will propose to devise appropriate Turing Tests for digital twins. Having sketched this background, I will then outline how several of us (in my centre CASA) are building computer models that all relate to the same place – the Olympic Park in East London – but these are all very different conceptions leading to different sorts of prediction and design (Batty et al., 2023). The key challenge is this "How do we integrate unlike models that pertain to the same place"; and "How close are the different realities we can define for that place". In this sense, the challenge is wider than computer models *per se* for it relates to how we integrate a very wide range of knowledge for different complexities of problem-solving (for different types of planning et al., 2023), different types of planning, and different kinds of future.

2. Many Definitions: Digital Twins and Computer Models

The predominant conception of a digital twin is that it is an abstraction of a physical system of some sort. In this sense, the physicality is 'hard' rather than 'wet' or 'soft' and in this way, digital twins are much more difficult to reconcile with systems that are predominantly socio-economic or human-behavioural. However even in physical systems, it is hard to restrict them to purely physical representations because the human is always in the loop somewhere; and often there is more than one digital twin that needs to be developed for a single physical system. Moreover there can be multiple models of a system which reflect the intuitions and behavioural intentions of the humans who are constructing the twins in the first place. Gordon Pask's (1961) cartoon from his book on **An Approach to Cybernetics** is a wonderful rendition of all the conundrums that plague any simple definition of a digital twin and we show it below.

In Pask's cartoon, the humans are clearly in the loop with the sensors representing another key feature of a digital twin – that the twin must interact and transfer information between the real thing and its twin or model. Moreover in this cartoon where the model begins and the real system ends is somewhere in the black box and much of the work on defining good models and twins is getting the relationships right between the real system, its wider environment, the twin and its own environment and the human beings who pervade the whole thing.



Gordon Pask (1961) **An Approach to Cybernetics**, Radius Books, London

Fig 1: What Bit of the Picture is the Digital Twin?

A related feature of the digital twin is that it is often a controller of the real system in terms of its feedback and even merger with the real system can relate to the control mechanism which in turn is part of management. Digital twins like some models have predictive capability but there are models that only have predictive capability and are not simulations of a real system. In this sense, one cannot have a digital twin of the future without it being a twin of the present or past. Or can one? The ambiguities of the idea are legion. Last but not least, we might have many digital twins. Every variant of a single model might be a twin for there is no reason why one model cannot generate many versions of itself, simply by continually tweaking its elements. There may be ecosystems of digital twins, integrated twins, twins with different degrees of identity and so on. Much has yet to be worked out and in this note, I will throw out many open questions as to how we might begin to explore such new interpretations.

3. How Good Are Models? How Good Are Twins? Turing Tests

When we build a model, we usually accept the mandate that we need to make it as close as possible to the real thing. Very often this involves tweaking and fixing parameter values that tune it or calibrate it closer to the real thing but it can also involve us in acquiring more data from the real system itself so that it can be trained to produce better and better simulations. Most if not all the models that we build for city planning so far, are much removed from the richness and diversity of the real city and we would be hard pressed to think of many of our models as being twins in the human biological sense. But if we were confronted by a real system that we could not get access to directly and a model of that system that we did not construct, then to see whether the model or digital twin was a good replica of the system, we would expect the outcomes of the model to be identical to those from the real system. This essentially was the test that Alan Turing threw out as the challenge for figuring out if computers could ever simulate human intelligence. We cannot explore its limits here but essentially it consists of a human – me or you – interrogating a system where we have no access to it other than through asking questions. If you consider the answers to the questions are those you would expect of a human, than the system passes the test and we assume it is human. We can modify this kind of test to figure out if the model's predictions that we have are the same as those coming from the real system. In Gordon Pask's cartoon, if the output delivering information from the real system (through the wires) – the traffic flows – are the same as those from the model, then for all intents and purposes the twin is the model. There is much work to do on using this paradigm to improve our models but we do not have time here to progress it. The big problem in actually enabling such a test is not knowing anything at all about the system in advance, and as far as I can see, this is never possible.

One feature of Pask's cartoon is that his models and systems are strongly physicalist. In fact in our field, the emergence of 3D representations of cities which appeared alongside socio-economic (usually 2D models) has brought the idea of the digital twin closer to the immediate reality around us. Two of our examples that we will briefly note in the next concluding section focus on physical representation while another two focus on social and economic systems. To an extent, no one has sorted out how important the medium of representation is to digital twins so far. They are manifestly digital of course but can the real system itself be digital or does it have to have some physicality for the twin idea to be significant? Is it likely that digital twins are composed of non-digital as well as digital components and does the fact that the human is always in the loop discount the idea that a digital twin is always more than a computer model?

4. Multiple Models and More Than One Twin: Different Models of the Same Place

As we noted in the preamble, several of us in our group in CASA are quite independently building digital models of a part of east London centred on the 2012 Olympic

Games site. The idea that we should compare, indeed integrate these models, is intellectually interesting and professionally relevant in that these models are focused on different aspects of location, all of which fit together in the future planning and design of the area. The precise focus is the Media Centre at Here East which was originally constructed as a non-intelligent building that is being retrofitted as a Building Information System or Model for its continued digital maintenance and monitoring. There is a lot of educational IT in this place. The whole Park area is being modelled using a 3D Model into which real time data is being piped into its physical form where new transport facilities have recently been developed with the opening of the Crossrail high-speed railway.

My own work consists of a much wider project building a land use transportation model of Britain at the scale of Census zones which are on average about 5000 population in size. This model covers all the travel in the Park but of course sets all this in the context of new infrastructure projects in Britain. We are developing lots of other models – which we do not consider simulation models *per se* but are digitally informed urban analytics that help us figure out what is going on in the area. As we build more digital models, it becomes increasingly apparent that the search for a single best model is wrong headed or at least limited – the way forward is many models (Batty, 2021) not one. Fortunately computing systems and data have now arrived to make this possible.

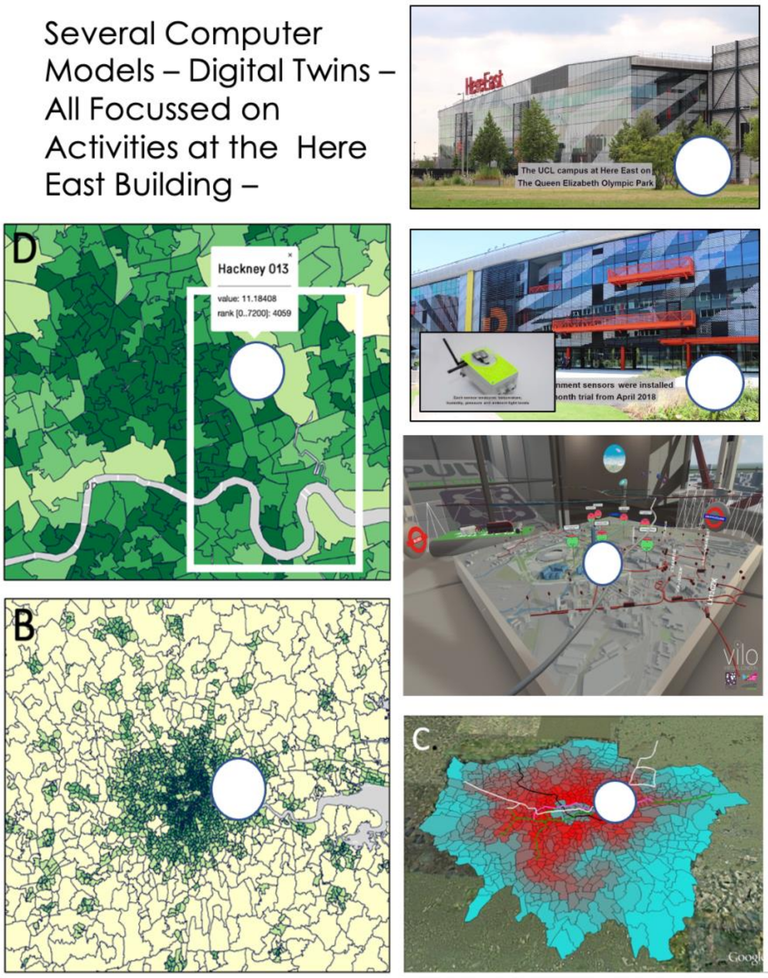


Fig 2. Images of Many Digital Twins – Computer Models – Centred on the Olympic Park in East London, on the 'Here East' Building, the Media Centre (top right and below top right), the Virtual London model (bottom right_ above the London Land Use Simulation Model (SIMULACRA) and then bottom left and above the National QUANT Land Use Transport Model.

5. Open Questions, Focused Answers

This essay is merely a taster to a much bigger programme on digital twins in many fields and many places. We need a much clearer sense of the limits to what a digital twin is. There is little doubt that in an evocative sense, digital twins intrigue the academic world and it is attracting groups to consider that computer models represent a way forward to bring different ideas together and progress them in digital fashion.

These ideas can be spun in countless ways but it needs good examples to make progress. Many open questions remain, in particular how problem contexts can use different digital twins of the same system, be it a place, a sector, a machine and so on. Federations, ecologies, and systems of digital twins are currently being proposed and developed, and we face an urgent task in absorbing their implications for how we develop better science.

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