Artificial Intelligence and the Computable City

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An Outline of the Talk

- AI and Cities: A Short History: Computer Models of Cities
- Emergence of the Smart City: High & Low Frequency Cities
- Big Data and Real-Time Streaming
- Now for Examples: Three Very Different Types of AI in Cities

  VR and AR, 3D City Models and BIMS

  Real-Time Simulation – Passenger Demand, Supply of Trains

  GeoDesign using AI

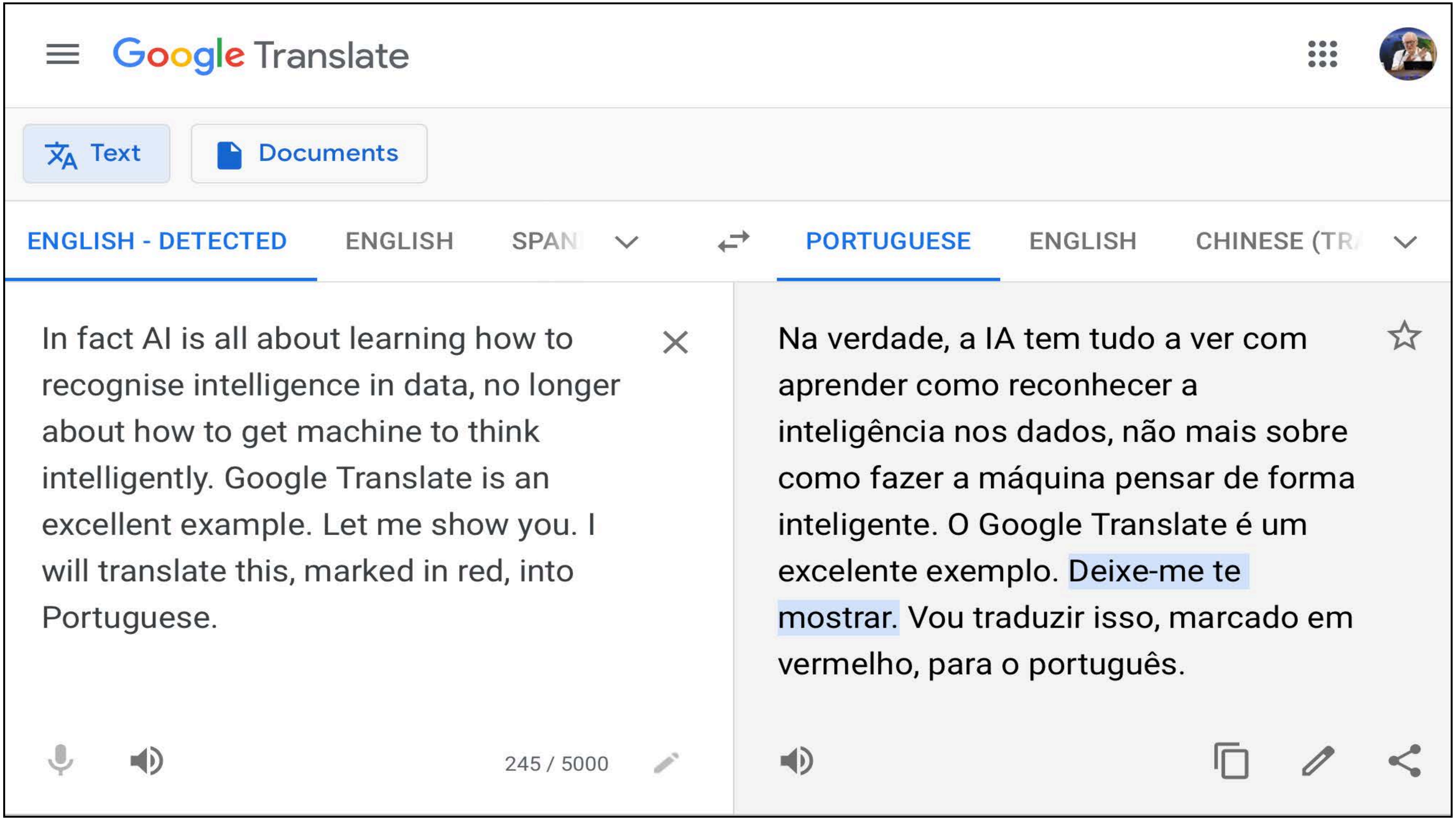
- Where Do We Go From Here? The Limits to AI

AI and Cities: A Short History: Computer Models of Cities

- At the outset, let us see where we have come from. The digital computer was invented during the second world war in the US, UK and in Germany.
- Almost as soon as it was invented, a process of miniaturisation began which has ended up 80 years later with the sort of technology you now see everywhere, on the desktop, in your smart phones, in platforms that power businesses and of course in new science.
- At the very beginning because the computer was likened to a brain by **Turing**, **von Neuman**, by **Rosenblatt** and many others, the prospect of using it to invent a new intelligence was mooted by the pioneers.
- The term AI was in fact coined by **John McCarthy** in 1956 at the first AI meeting, although Turing had written papers about intelligence before

- These early elements of getting a computer to embody an artificial intelligence were based on the notion that what was going on was formulating a thinking process – developing a program for decision making – and early AI was all about such models as in work of **Marvin Minsky** and **Herbert Simon**
- They made an early appearance in computer models of cities as ways of optimising the process of reaching informed decisions about the future (I should say the first computer models of cities and transport were built in the mid-1950s when computers were archaic).
- But by the mid-1980s, the early claims for AI were widely discredited. There was no way you could program a machine to think like a human and the field moved into its 'nuclear winter'
- Slowly however as computers got smaller, faster, cheaper, and as data began to grow and grow, the approach changes to one based on trying to find 'intelligence in the data,' not in our behaviour.

- As computers came to embedded into everything we could construct, they began to generate large volumes of data and the search for pattern in such 'big data' began to take change the approach to AI.
- In fact AI is all about learning how to recognise intelligence in data, no longer about how to get machine to think intelligently. ***Google Translate*** is an excellent example. Let me show you. I will translate this, marked in red, into Portuguese.


Google Translate
Text
Documents
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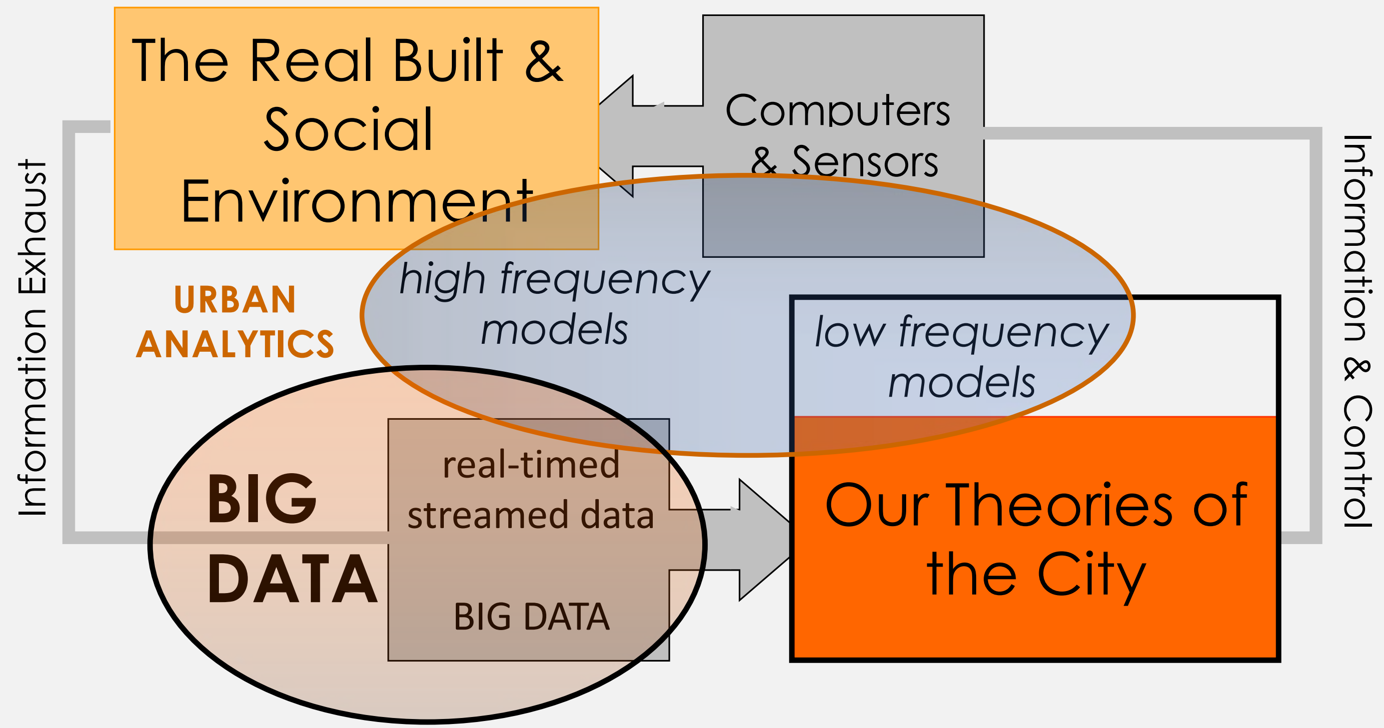
In fact AI is all about learning how to recognise intelligence in data, no longer about how to get machine to think intelligently. Google Translate is an excellent example. Let me show you. I will translate this, marked in red, into Portuguese.
Na verdade, a IA tem tudo a ver com aprender como reconhecer a inteligência nos dados, não mais sobre como fazer a máquina pensar de forma inteligente. O Google Translate é um excelente exemplo. Deixe-me te mostrar. Vou traduzir isso, marcado em vermelho, para o português.
245 / 5000

The Emergence of the Smart City: High & Low Frequency Cities

- Let me now turn to smart cities. For a long time, from the 1950s onwards, computers were used to analyse and understand the city better and to let us make predictions of their future. There as an early effort as I noted to develop models that mirrored how we made good decisions but there were found to be far too simplistic and were abandoned. This is the nearest we got to AI in those days.
- But in the last 20 years, computers have been scaled to the point where along with sensors they can be embedded in the city. One image of this is that 'the city is becoming a computer' and that we face the conundrum now of using computers to actually study systems composed of computers.
- To an extent this is what we mean by the smart city – city generating data in real time and ourselves using this data to make the city better

- The smart city has thus emerged essentially as ***the high frequency city***. That is the 24 hour city or the city over short period.
- This is not the ***low frequency city*** that we has really been the object of our concern for many years, almost as long as the time between when computers were first invented and the emergence of smart mobile devices.
- Thus many ideas we have about the long term city barely apply to the short term
- Let me throw onto the canvas a picture of how I see people studying the city from whatever perspective interacted with the smart city.
- As well as the term smart city, I am assuming that such cities represent the way in which we capture and use big data (as well as other forms of data) in the quest to improve the sustainability and the quality of life of the city.

Let me define the smart city from a simple diagram. I have used quite a bit but it helps focus ideas.

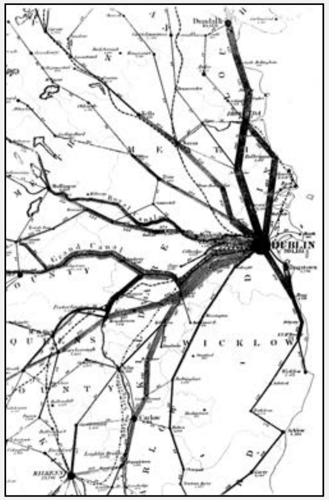


Big Data and Real-Time Streaming

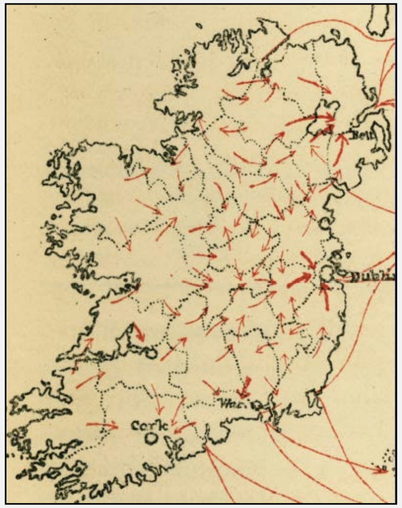
- A couple more points before we continue
- The way we access the smart city is through technologies that let us generate and use data and its useful equivalent – information (data) is key
- Access through mobile and fixed devices like phones, smart cards, through fixed sensors which record transactions and so on
- These usually complement rather than substitute for data which we collected and used in the past
- This has introduced time into our thinking
- This is all part and parcel of increasing complexity; more time scales, more opportunities, more diversity

- Data is big with respect to its volume. I know there are other definitions – velocity, variety, volume, etc. but to me, data is big if it requires large use of computer memory implying volume.
- The conventional definition in business is the Five V's – volume, velocity, variety, veracity, value. In fact people have made up other 'Vs'
- In cities, data usually implies numbers of locations and their attributes but locations imply interactions.
- Thus data are relations between locations and in essence if we have n locations, we have n^2 interactions. Thus small data can become big, and there is a caveat, small data can be good data too
- There are many really good examples of big data being used in the past especially flow and mobility data
- I give some examples on the next slide

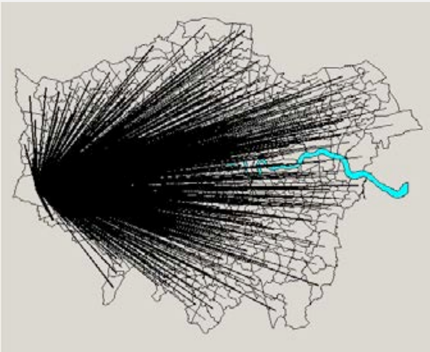
Examples: Dublin 1837, Ireland 1888, London 1955, 2011

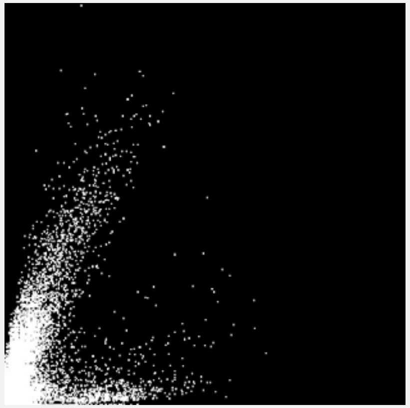


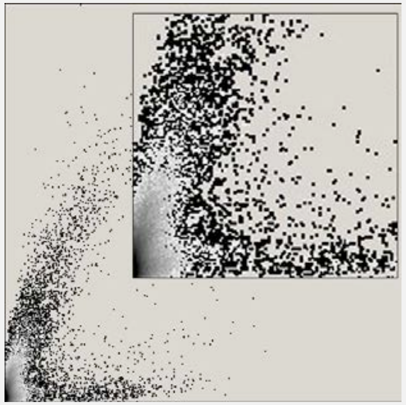
Harness, 1837



Ravenstein 1888







Now for Examples: Three Very Different Types of AI in Cities

I am going to look at three very different conceptions of the spatial and physical structure of cities, three different sorts of model where there are computers, big data, AI of various sorts. In a sense, this is what we have to grapple with – cities are full of computers and if AI relates to computers then AI is everywhere

- First using a physical representation of the elements that define the buildings in the city – building in digital representation, VR, AR and thence BIM – the hf city
- Second of flows of traffic which is a problem in demand and supply in term time; this is also the high frequency city
- Third, a model or method of design that incorporates AI directly as machine learning

VR and AR, 3D City Models and BIMS

From Architectural Design, Volume 75 (6), 42-47, 2005

As the digital revolution deepens and pervades every aspect of daily life, virtual realities begin to penetrate one another in a multiplicity of ways. The amount of sensing data being compiled on the city grows, enabling the construction of virtual realities that can, in turn, be transformed for diverse purposes. Here, Michael Batty and Andrew Hudson-Smith from the

42

1. Virtual Cities

Jean Baudrillard (1994) defines a simulacrum as a 'simulation of a simulation', a model of a model if you like.[1] In terms of cities in the digital realm, it is easy to translate such a conception into multiple layers of abstraction that we build up from the raw data we sense, perceive and explain in simulating urban form and structure. A generation or more ago, when computers were first used to represent cities, typical simulations were immediate and direct. Either the geometry of the city was used to construct digital 'iconic' models through which one could navigate, and sometimes use for CAD (computer-aided design), or geographic and economic functions were represented using 'symbolic' mathematical models that could be analysed and manipulated for the same ends: better design, better planning. As the digital revolution has matured, these conceptions have blurred, and now there are mathematical models that sit within iconic models, and vice versa, whose symbology exists on many levels. More importantly, perhaps, as computers have come to be used in everything from extracting data remotely, to mining it to find new

Figure 1: View west from Tower Bridge across Virtual London, showing the raw geometry of the virtual city before it is populated with data.

patterns, visualising it in diverse ways, modelling it for the same diversity, and embedding users virtually into the process of use, models have come to be represented within models, worlds within worlds, as the power of recursive digital construction has gathered pace. This is simulacra: virtual cities within virtual cities where such embedding twists the process in curious but illuminating ways.

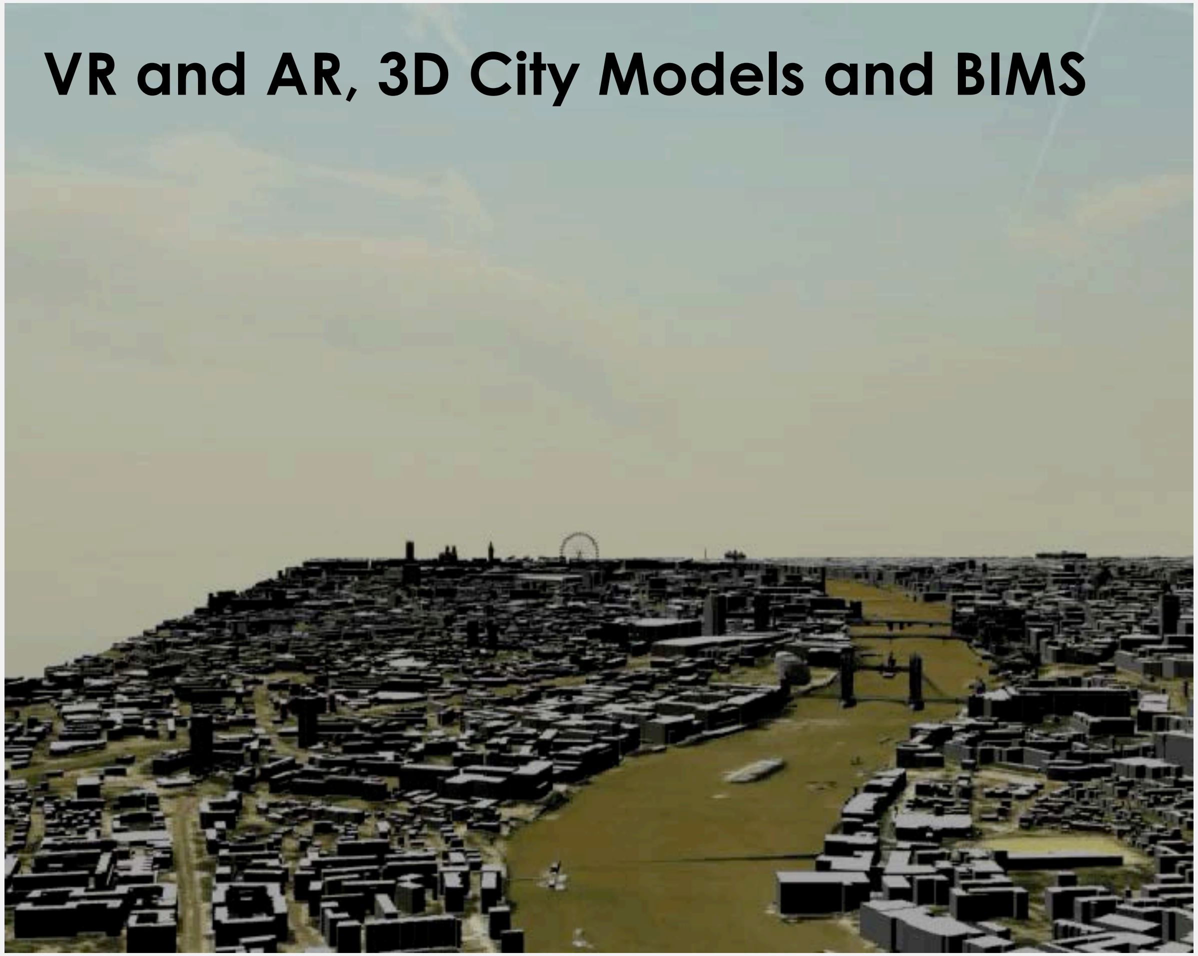
We will begin by describing the construction of a digital iconic model of central London that we somewhat euphemistically refer to as 'Virtual London'. Virtual London is in fact a 3-D geographic information system (3-D-GIS), which is in essence a large spatial database that can be analysed and queried. We can view it in 3-D because we can hold and file the data via digital representation of streets and building blocks. However, this is just one way of viewing the data – one perspective on the virtual city – and there are many others that need not stress the spatial dimension nor its built form. We construct this model as a series of data layers that we can overlay in 3-D. We can then embellish the model, adding a variety of digital media that we can deliver and display in everything from web browsers to holographic-like displays.

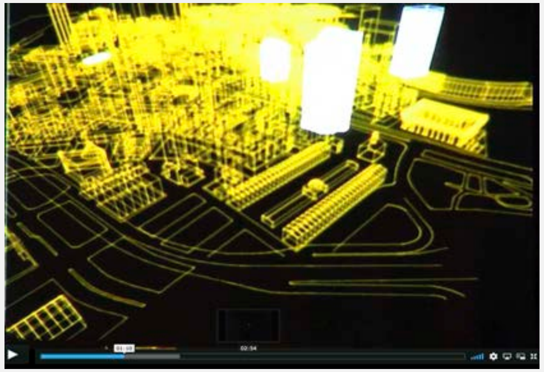
Such models can also be imported into other digital media. We illustrate the conception of a simulacrum by embedding it within a virtual world – a virtual design studio or exhibition space – which users can enter as avatars and then view and manipulate the model in the presence of other users, who are also avatars. This embedding can be recursive in that we can enter such worlds, view the model and then fly through it, adding new digital media at points where we need to render the environment with different images. Like many of our simulacra, Virtual London is designed so that users can learn about and redesign their environment in a

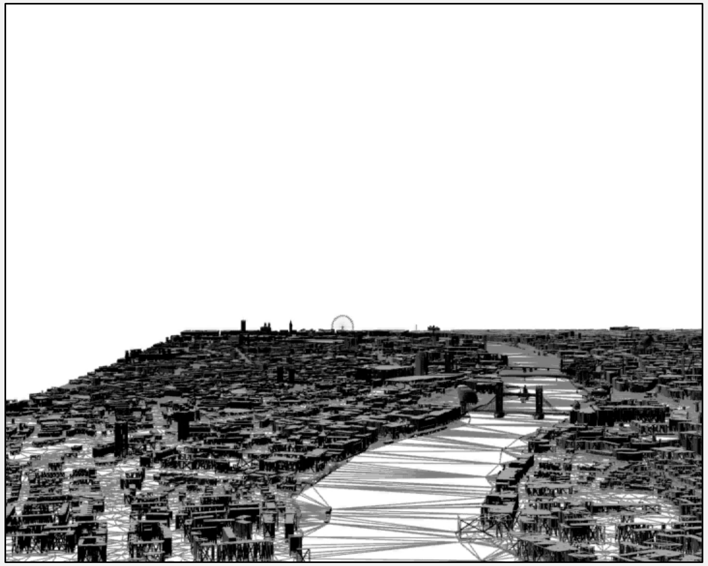
Figure 2: Building the virtual city in layers from the ground up. (a) Extruding parcel data to average height and inserting a LIDAR image of St Paul's Cathedral into the scene. (b) Adding a digital panorama of the area around the Swiss Re headquarters building.

44

VR and AR, 3D City Models and BIMS







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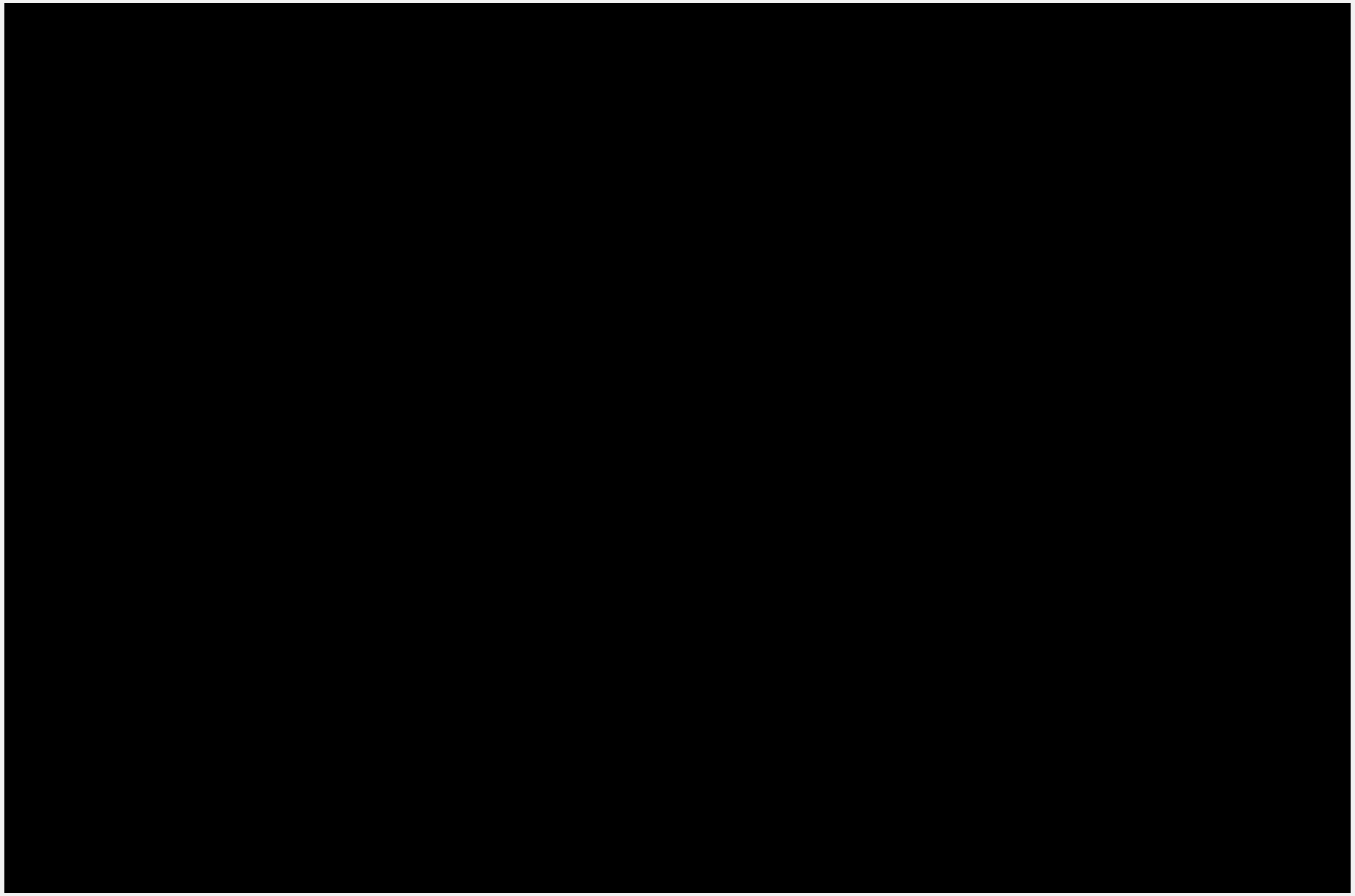
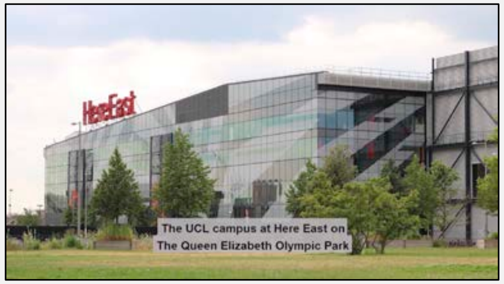


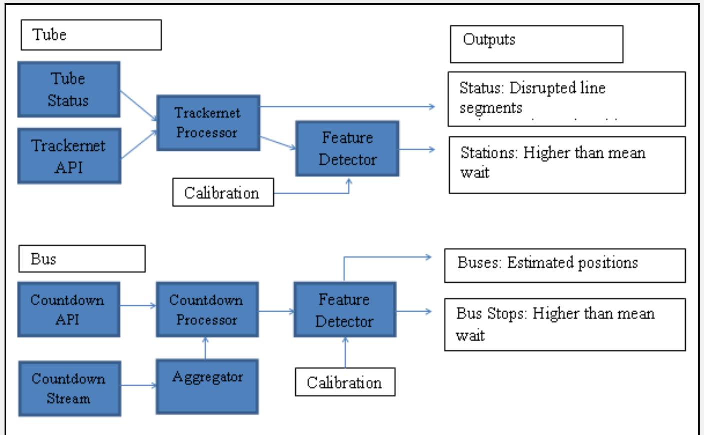


Artificial Intelligence and Smart Cities

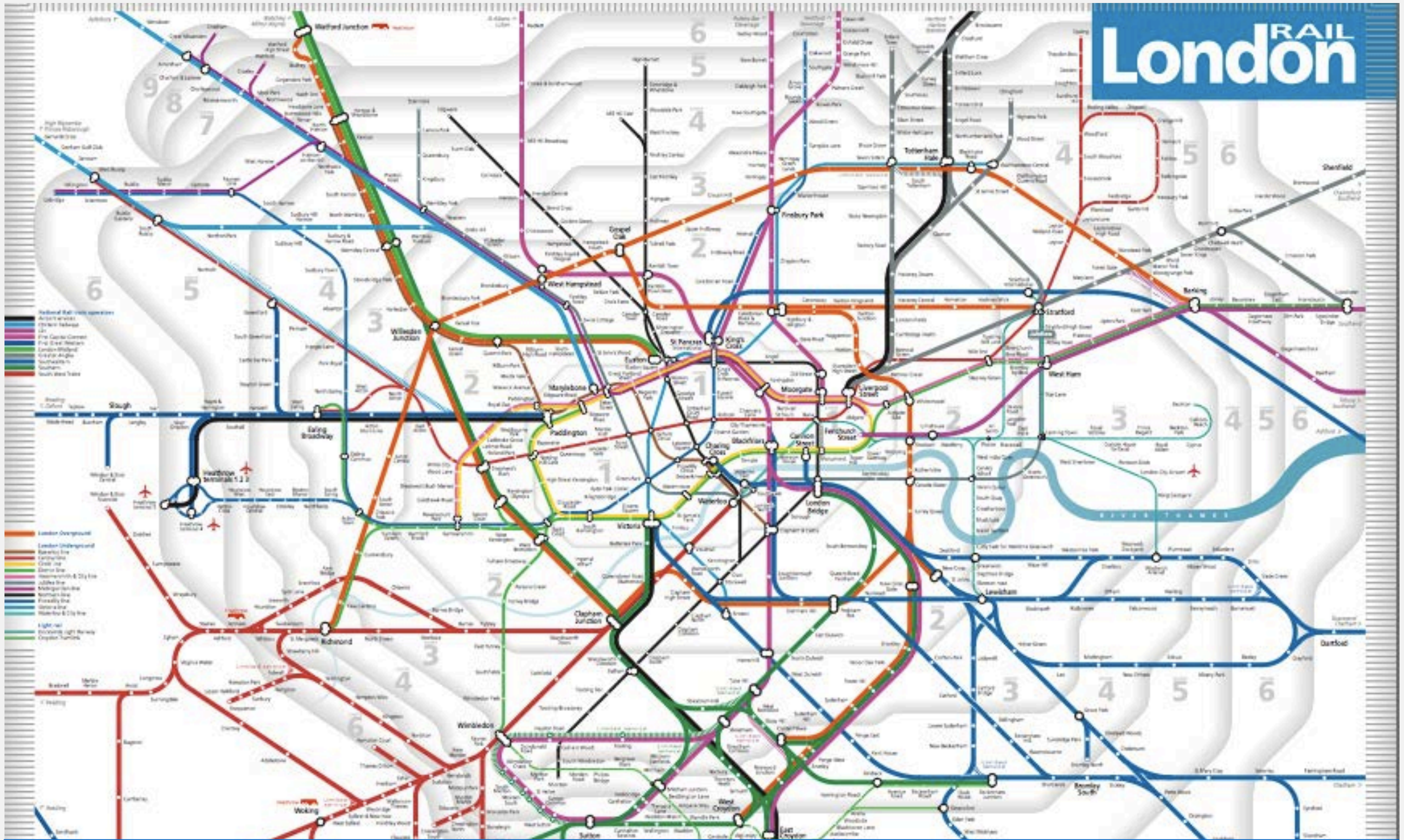
Real Time Simulation: Passenger Demand and Trains Supply

Demand by Travellers

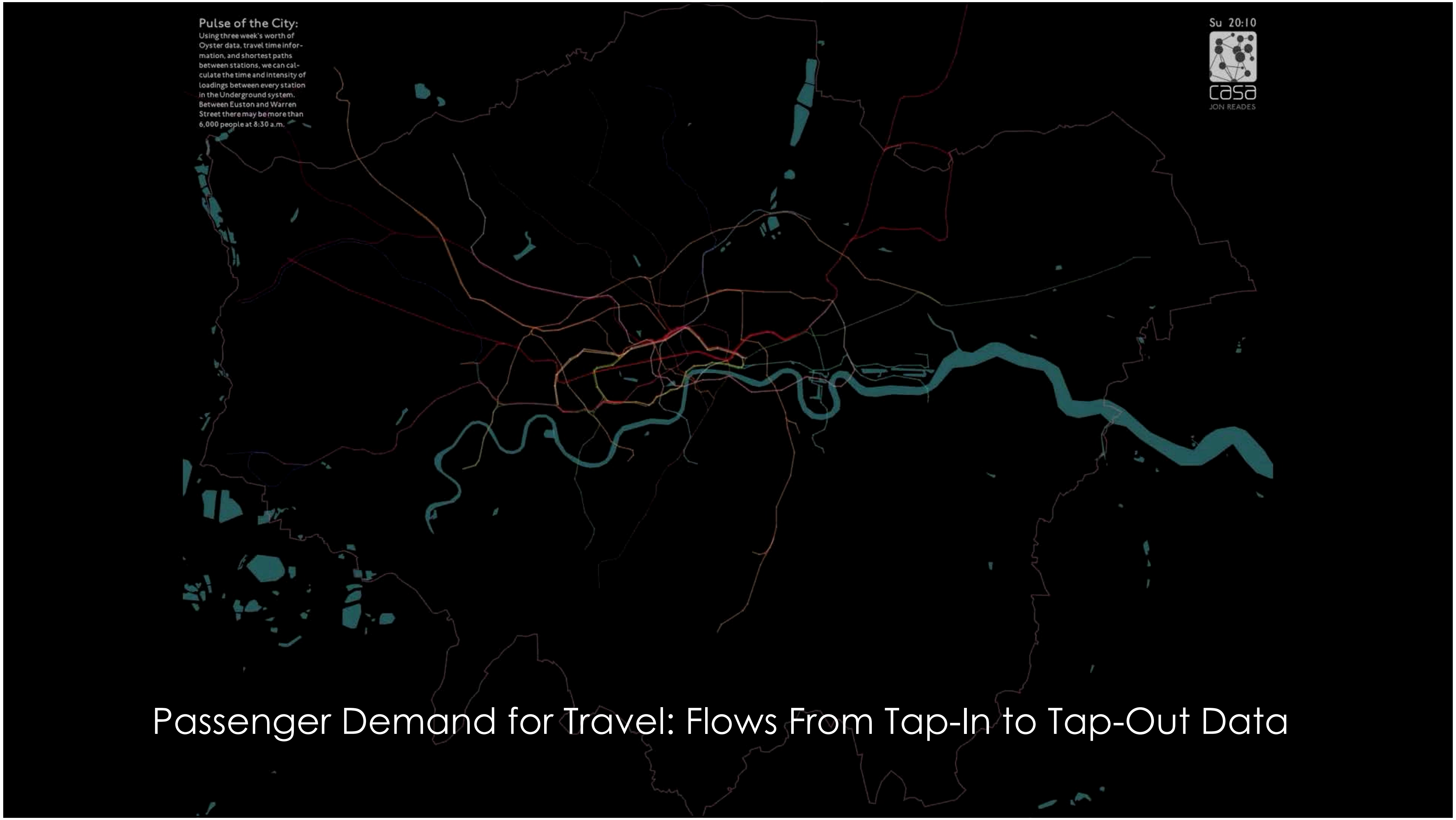
Supply of Trains



How do we match demand & supply without passenger tracking?

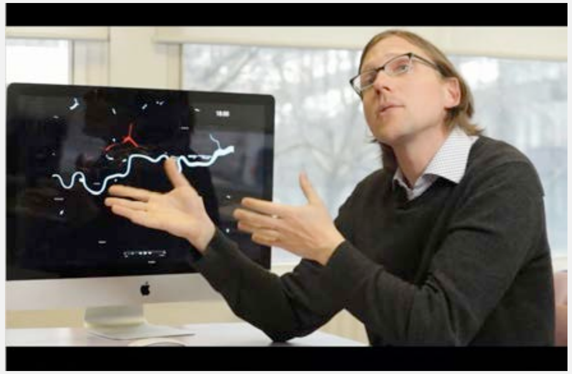


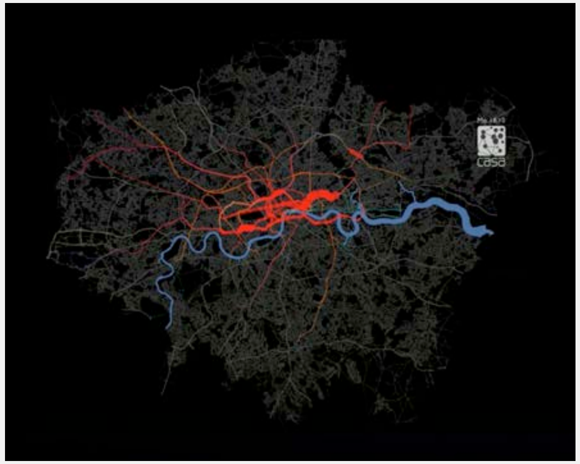
Tube, Overground and National Rail Networks in London
where Oyster cards can be used



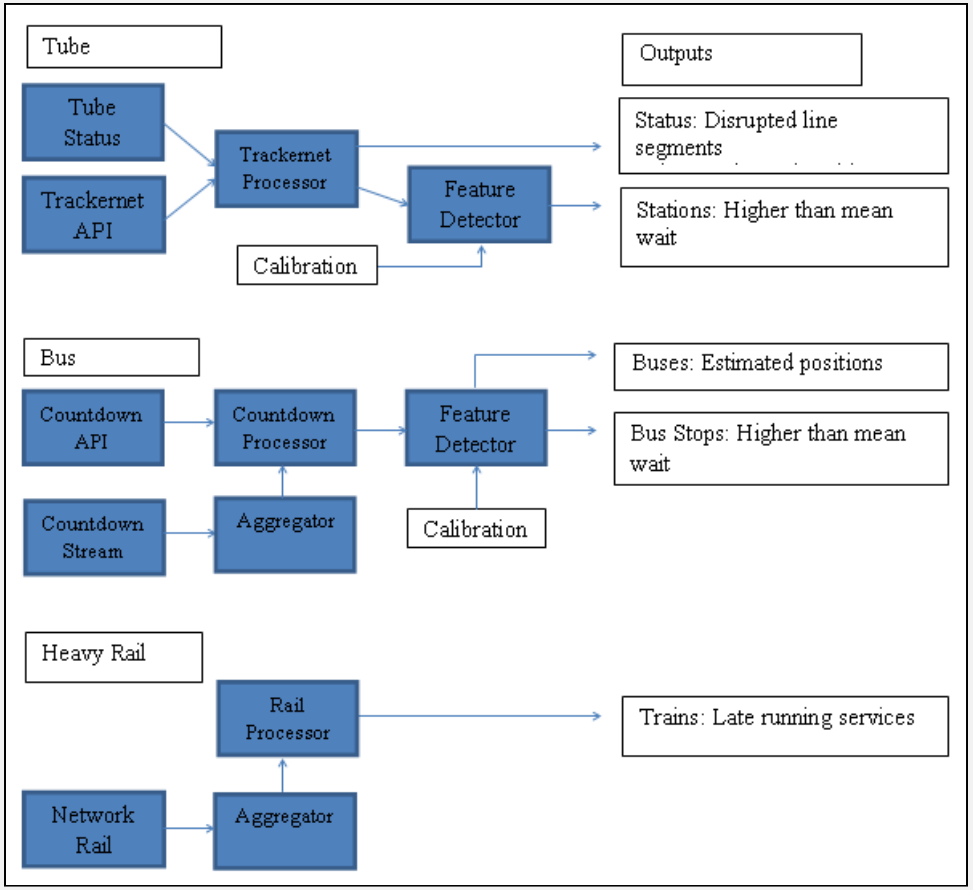
Passenger Demand for Travel: Flows From Tap-In to Tap-Out Data

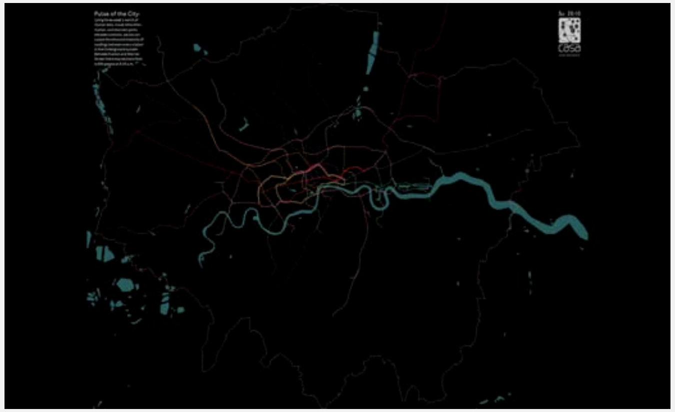

OYSTER GIVES UP PEARLS



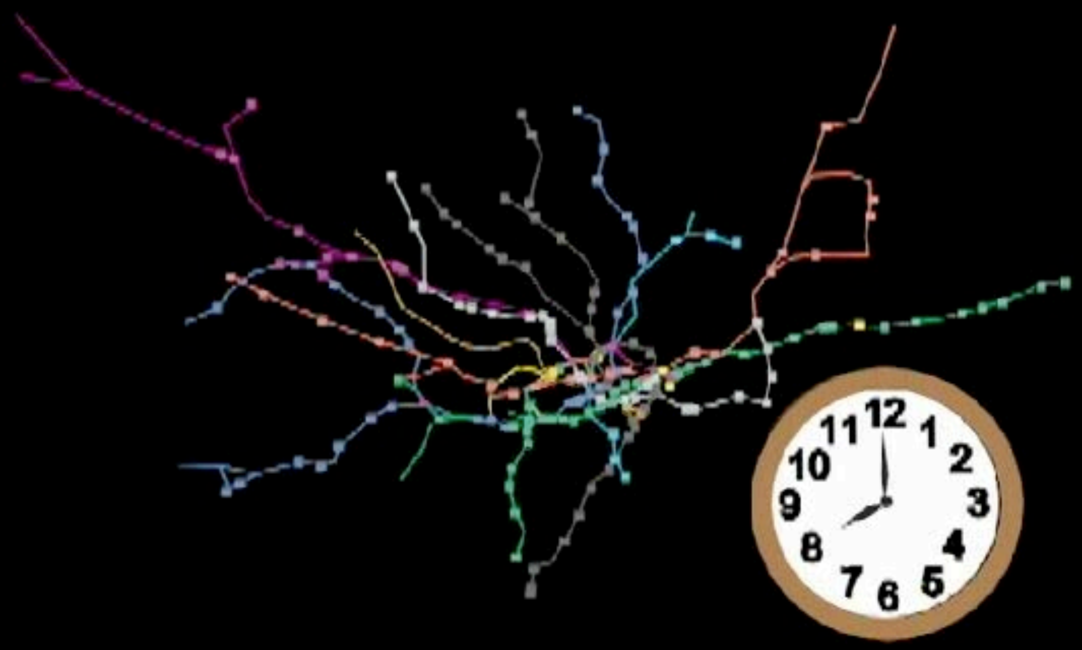


The Public Transport System in Terms of Vehicle Flows and also Passenger Flows from Oyster

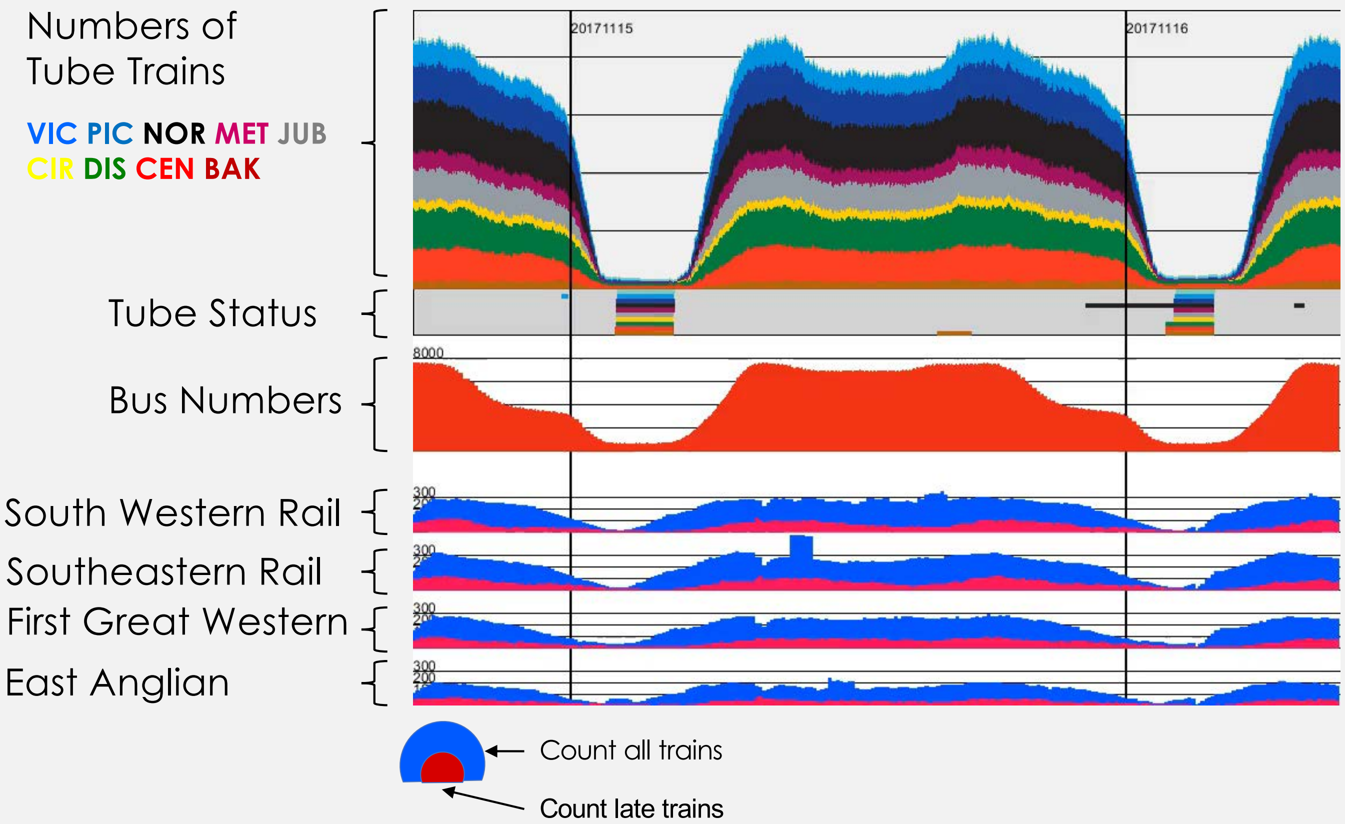




Supply of Trains From the Tracker-Net



Streams of City Data



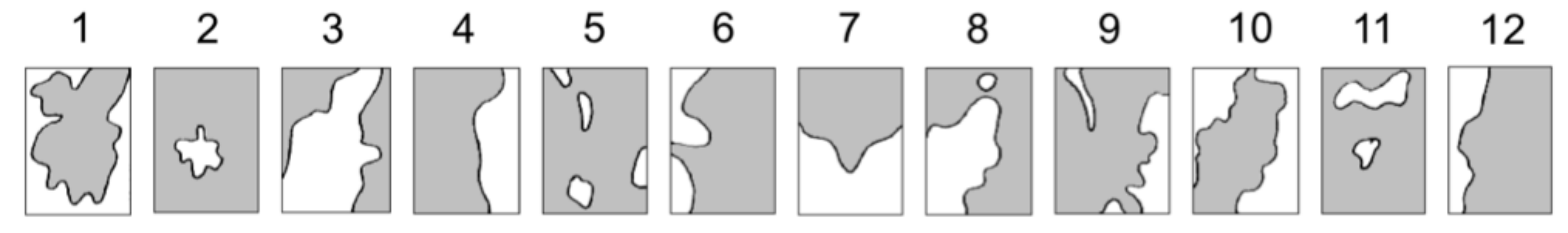
Big Data in 1939

8 March 1939: Some of the four million tickets collected from London Underground passengers are examined in a survey by London Transport to discover the most and least used routes to help future infrastructure development

GeoDesign using AI

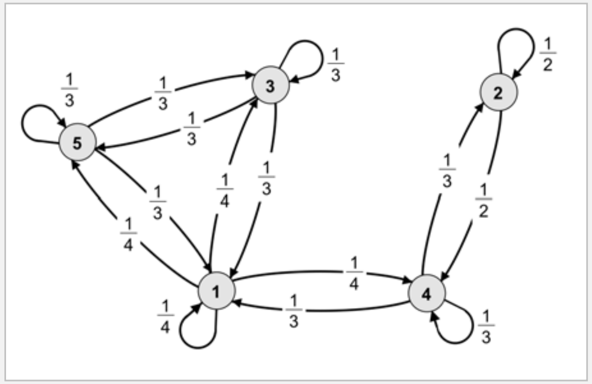
- This is my last example and it is quite simple. In planning and design we often use a method of compromising – reducing conflict between different factors that need to be resolved to produce a solution.
- The most obvious and perhaps the simplest of these is where we are searching for a solution which 'optimizes' with respect to different conflicting factors.
- We can of course add these factors together and produce an average but this does not take account of their relative important given to them
- Let me illustrate an example where we have 12 factors that we can map spatially and each of these factors indicates the best location for a housing development or any facility. The method works as follows:

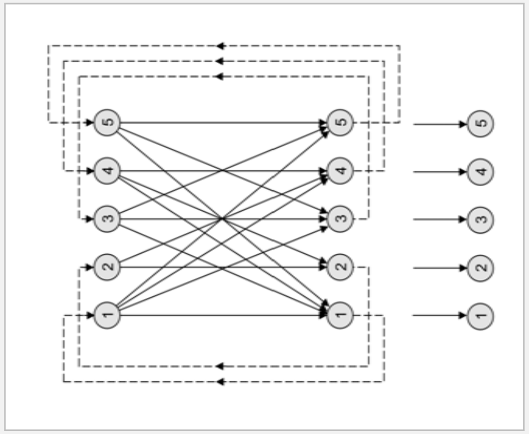
Key Factors Affecting Residential Development

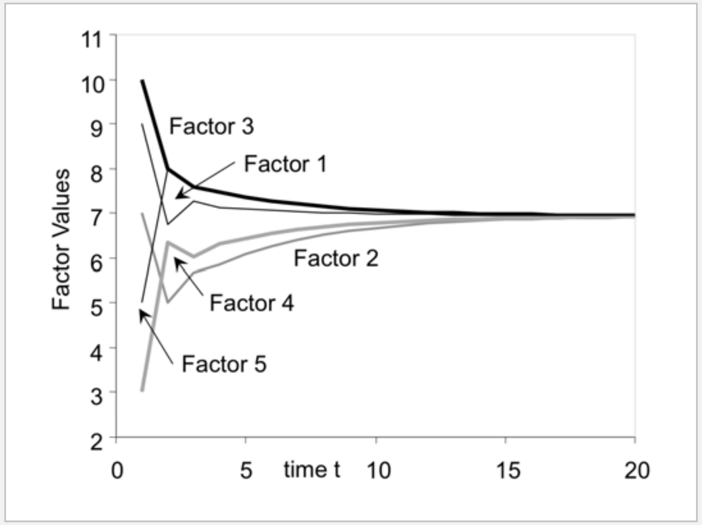


1. Accessibility to Existing Urban Services
2. Costs of Spatial Congestion
3. Accessibility to Recreational Amenities
4. Areas of Acceptable Micro-Climate
5. Areas of Water Catchment and Poor Drainage
6. Institutional Constraints Imposed by Government
7. Accessibility to External Urban Markets
8. Subsidence and Extensive Industrial Pollution
9. Areas of Suitable Topography
10. Rural Amenity Areas
11. Historic Urban Areas
12. Conservation of High Quality Agricultural Quality

- A set of factors showing the desirability of land development –our opinions expressed as maps. These conflict with one another
- We form a network showing the strongest conflicts We make sure the network is connected - this implies weights. We perform the averaging:







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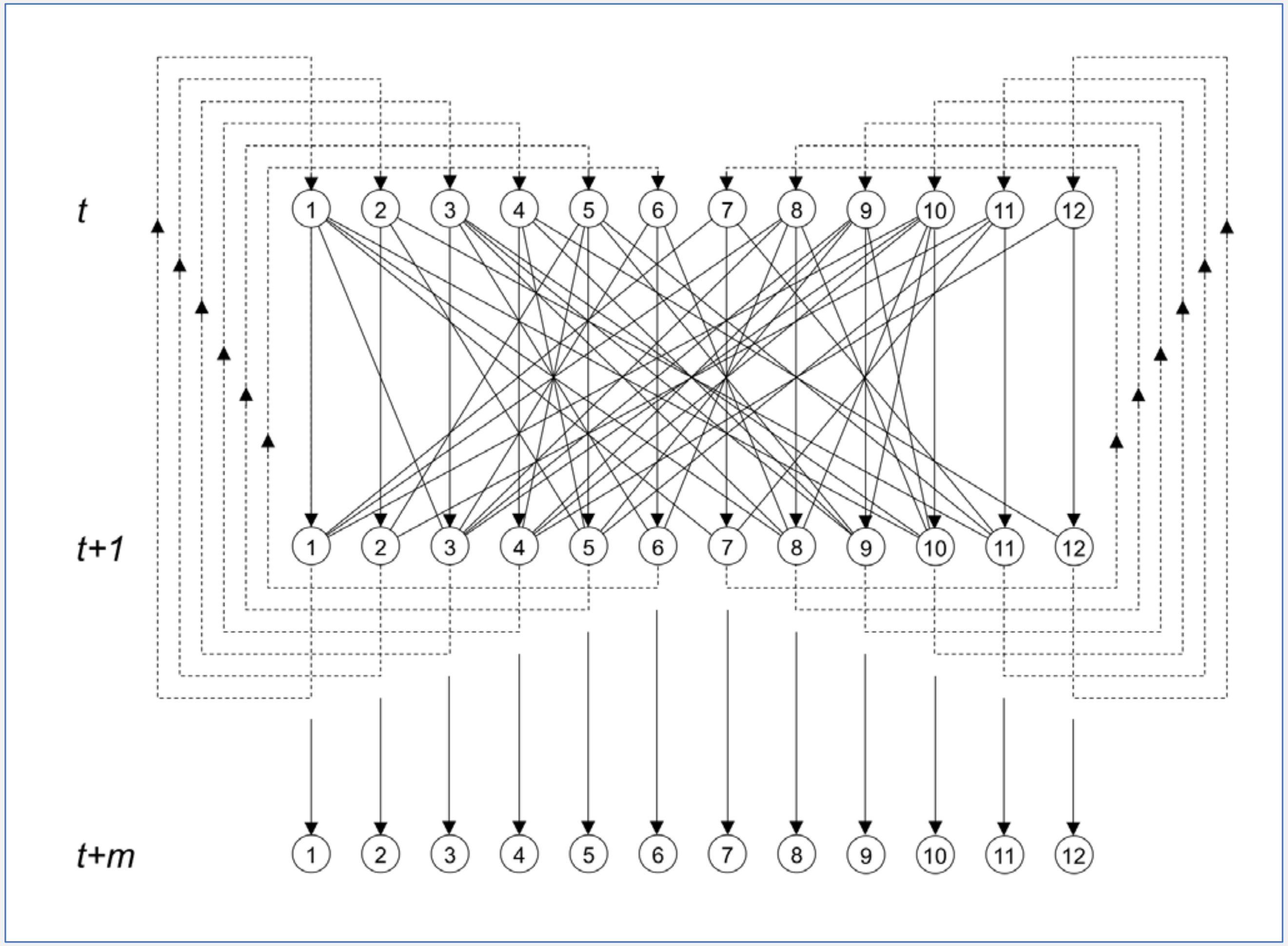
$$a_i(t+1) = \sum_{j=1}^{n} W_{ij} a_j(t)$$

$$a_i(t+1) = b_i(t) + \sum_{j=1}^{n} W_{ij} a_j(t)$$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Key Factors Affecting Residential Development

- Accessibility to Existing Urban Services
- Costs of Spatial Congestion
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- Areas of Acceptable Micro-Climate
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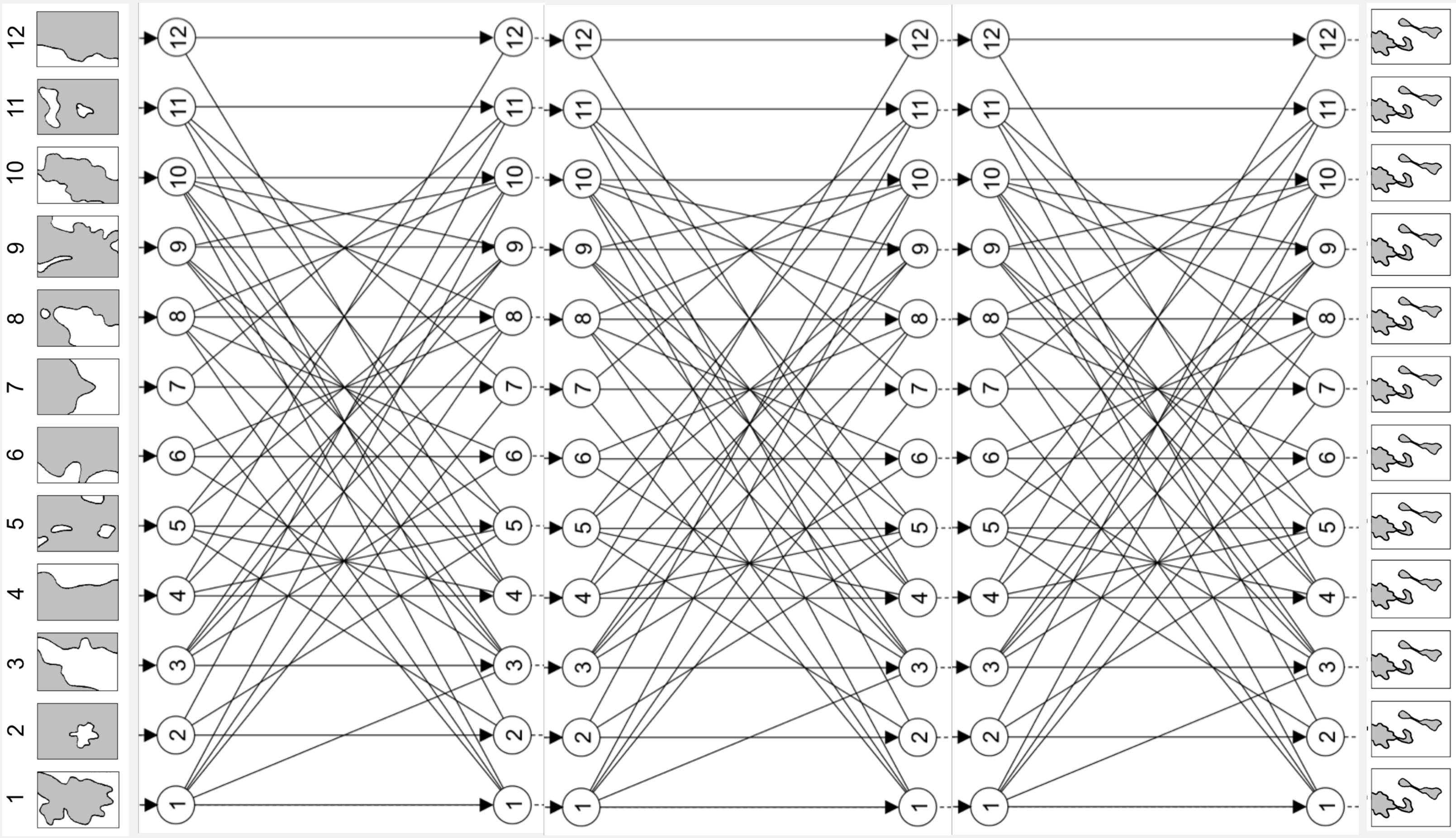
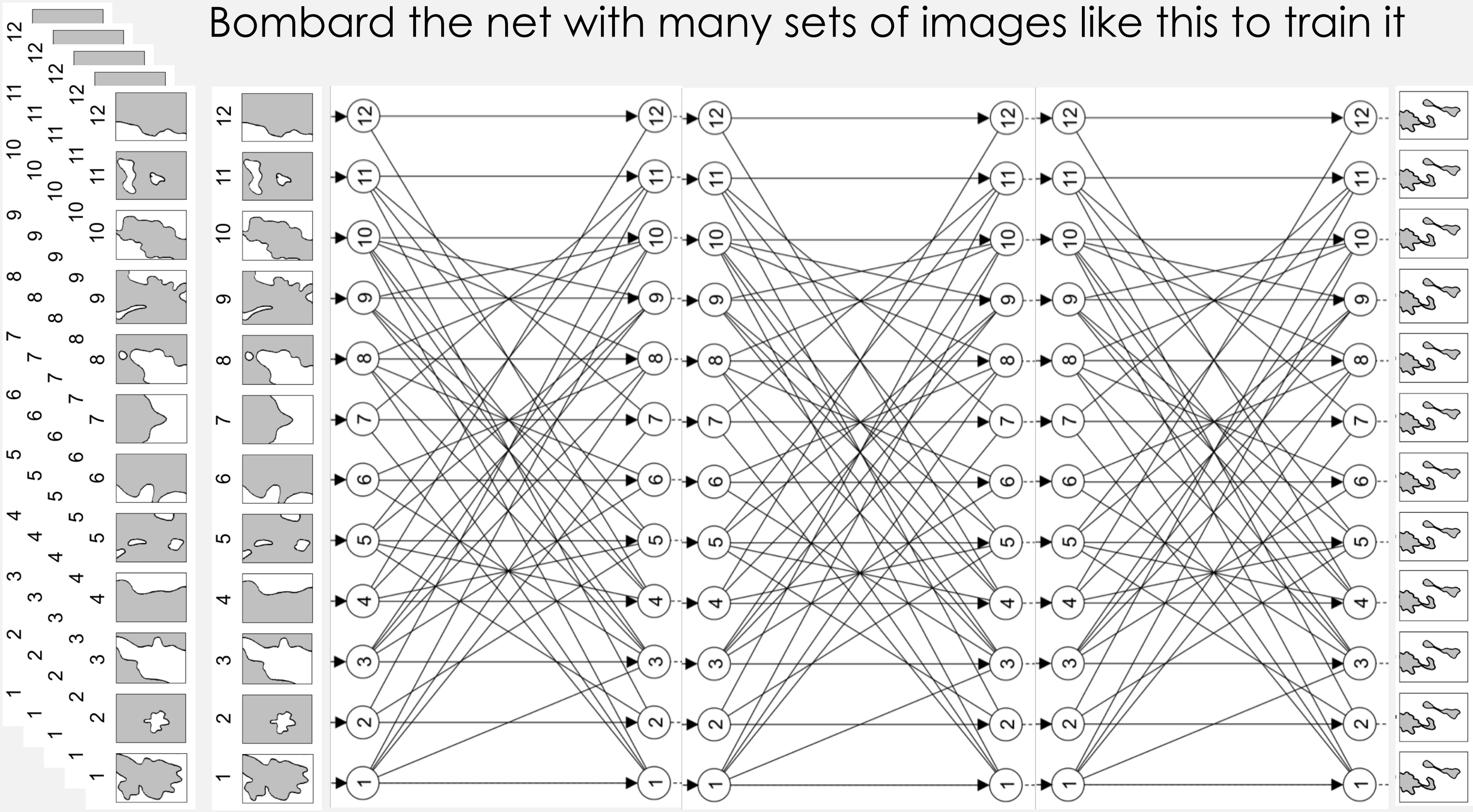
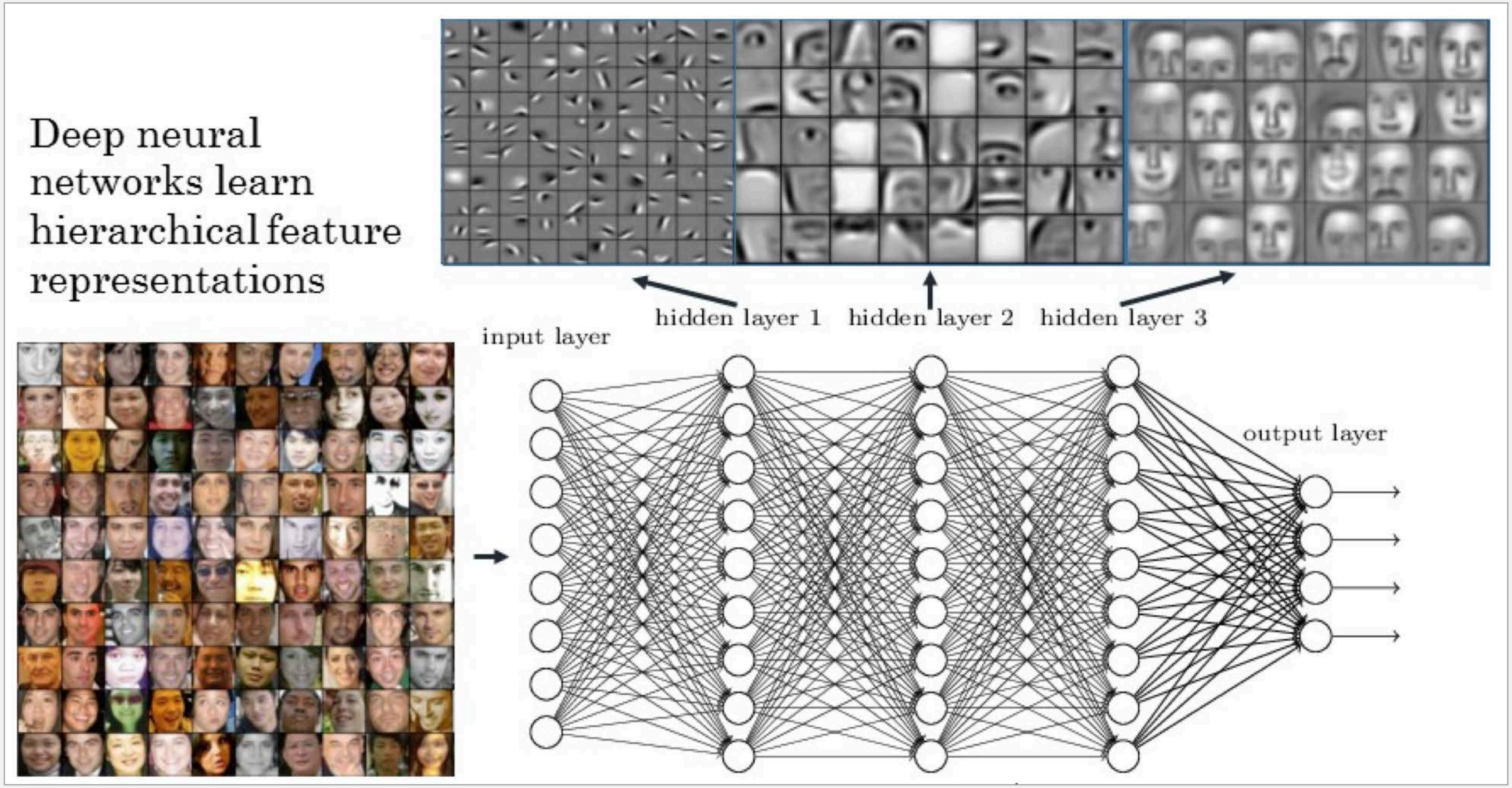


Artificial Intelligence and Smart Cities

- Imagine there were only 12 factors that determined urban development, things like accessibility, topography etc..
- If we had many, many towns and relevant sets of 12 factors for each, these factors are images, and we could throw them at our neural net and we could train the net to produce a unique set of weights that would produce the most relevant combination of factors that would determine the most likely town form.
- This is a great challenge. I wonder if there is a student out there on the MSc course who might like to have a go at doing this sort of thing for a dissertation next year

Bombard the net with many sets of images like this to train it




Deep neural networks learn hierarchical feature representations
input layer
hidden layer 1
hidden layer 2
hidden layer 3
output layer

Where Do We Go From Here: Truly Intelligent Cities?

- There are some very big open questions about AI in general and about their application in cities in particular. Cities are complex, they evolve from the bottom up. At the end of the day, AI helps automate relatively mundane tasks
- One question is can they ever do more than this? My own view is they cannot, but an equally important questions is whether or not they can actually produce things that we don't know about systems that we invent. I think not
- But they probably can make an enormous impact on natural systems and the physiology of our own human systems. We are at the beginning of such work and I don't think this is going to come from automation of mobility or anything like that. More likely it will be a return to strong AI of the kind that was important at the beginning.

Thanks

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12 January 2021

Some of my publications on this area since 1995