The Smart Cities Lectures

The Course Again: Some Preliminaries

Michael Batty

http://www.spatialcomplexity.info/
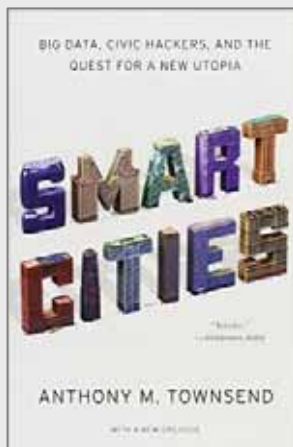
19 April 2017

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I thought I would show you what I and others looked like when I came here 31 years ago in November 1986, I think and gave a talk on fractals and geography, I think. There are some people here who you might recognise

Background Reading Again

The web site http://www.spatialcomplexity.info/ is where the lectures will be placed. I have adopted Anthony Townsend's book *Smart Cities* as good background. You can read a review here: http://www.spatialcomplexity.info/archives/2419
Something to read today, download the following paper
http://link.springer.com/content/pdf/10.1140%2Fepjst%2Fe2012-01703-3

BIG DATA, CIVIC HACKERS, AND THE QUEST FOR A NEW UTOPIA

SMART CITIES

ANTHONY M. TOWNSEND

EPJ ST

Special Topics

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THE EUROPEAN PHYSICAL JOURNAL SPECIAL TOPICS

Regular Article

Smart cities of the future

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Background Listening and Watching

My colleague Dr, Hannah Fray has released 10 radio programmes on BBC Radio 4 which you can download as podcasts from the BBC i-Player site or from the links below. These programmes will tell you a vast amount about the history

Please look at these BBC Podcasts

To STREAM http://www.bbc.co.uk/programmes/b06bq6j1
To PODCAST http://www.bbc.co.uk/programmes/b06bq6j1/episodes/downloads

Picking Up and Repeating What I Said
at the End of Last Week's Lecture

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April 18th 2017

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The Laws of Computing

First there was **Moore's Law**. At the same time, there were rapid developments in networking and in the material of networking. In parallel to miniaturisation, fibre optics was invented.

Computers had begun to be networked from the very beginning but there ARPANET was founded to linked main frames across distance in 1969 and in the 1970s at Xerox Parc local area networking was invented in terms of the Ethernet.

There is much to say about all this but here it is worth noting that as computers get connected together, then they share resources and these increases as the rate of the number of connections of the network. This led to **Metcalfe's Law** – the ***value of a telecommunications network is proportional to the square of the number of connected users of the system (n^2).***

There is also Gilder's Law and Sarnoff's Law and so on. Let me state quickly five of these laws but there are more that relate to miniaturisation, memory, cost, value and so on of ICT.

Moore's Law: formulated by Gordon Moore of Intel in the early 70's - the processing power of a microchip doubles every 18 months; corollary, computers become faster and the price of a given level of computing power halves every 18 months.

Gilder's Law: proposed by George Gilder, prolific author and prophet of the new technology age in 1988 - the total bandwidth of communication systems triples every twelve months. New developments seem to confirm that bandwidth availability will continue to expand at a rate that supports Gilder's Law.

Metcalfe's Law: attributed to Robert Metcalfe, originator of Ethernet and founder of 3COM in the 1970s: the value of a network is proportional to the square of the number of nodes;

Sarnoff's Law: states that the value of a broadcast network is directly proportional to the number of viewers, and believe it or not

Zuckerberg's Law: the information that people share doubles each year

Hardware to Software to Dataware to Orgware to ….

Ok there are many many things we can say about modern computation and to finish this history so far, let me give you a rapid run down of how computing has changed through this process of miniaturisation and networking and

The 1950s and 1960s: ***The mainframe era*** – essentially users delivered by hand their programs to some central large computer which were operated behind closed doors. Programming and operation were completely separate. There was not such thing as software; the term is very hard to source – thinking versus machine operation has something to do with it but it gradually emerged I think in the 1970s and came in with a vengeance once the PC took off.

The 1970s: ***The minicomputer era*** – essentially users has their own small mainframes which were often networked with teletypes or even visual display units in star like fashion around the machine. There was some sense too that users needed to know more about the operating system than before as they had more control.

The 1980s: ***The PC revolution***: with the invention of the microprocessor, small computers became the norm but the end of this decade and the laptop or portable PC came onto the scene. Networks of machines appeared and by the 1990s one was connecting PCs to networks to act as go betweens between data and users and big computation on i and mainframes

The 1990s: ***extensive networking***, continued miniaturisation, the web and the emergence of hand held computers

The 2000s: ***hand held devices – phones, tablets and related devices*** – software and data on such devices and also continual computation

The 2010s+: ***Apps, many different devices***: some specialisation is beginning with respect to computers for different roles

At the same time as computers have become smaller and faster and bigger in terms of memory, special purpose machines continue to be devised – supercomputers, parallel computation on arrays of devices, grid computing

The client-server architecture is now writ large. But in this value chain the value of hardware has fallen – this is Moore's Law in action. What has happened is that the value of Software has risen but it now appears that software is becoming so general that it is different combinations of software that are being devised. Hard to know if software is as important as it was.
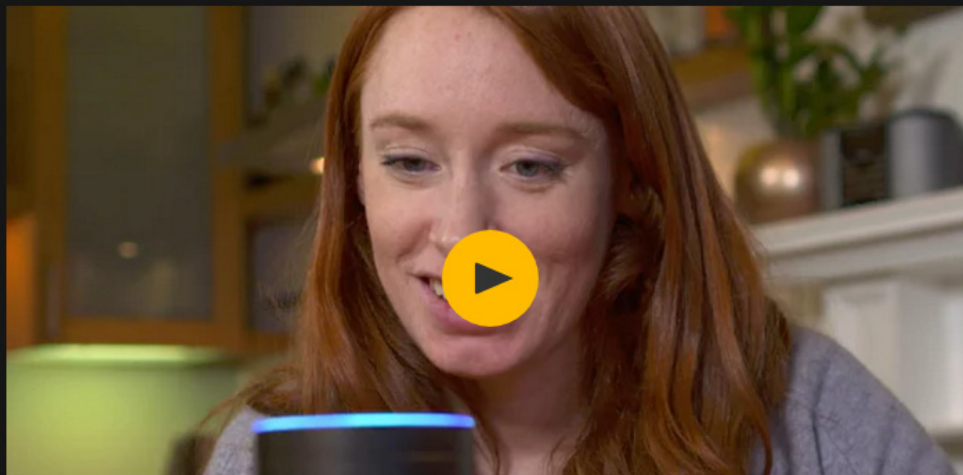
Now if we look at other elements of computing, data and organisation, which we might refer to as dataware and orgware, then these are becoming more important in the value chain – how much more so is tricky to figure but organisation is absolutely key to good operation and integrated data too is key – orgware and dataware will be the keys to the smart city, rather than hardware and software

The next era in this nexus will be clouds of data and programs and access using various kinds of hand-held device –or even voice. Do you have an Alexa? Yet? Well let me show you …..

But before we deal with the kind of data that is now being generated in terms of smart cities, let us take one last look at history and see how all this has emerged. Graphics is key as we will see.

https://www.theguardian.com/lifeandstyle/video/2017/jan/26/alexa-amazon-echo-virtual-assistant-friend-gadget-video

How much can I help you? Alexa's voice recognition skills tested – video

0:00 / 3:39   </> Embed

With voice recognition software being used in household products, Dr Hannah Fry explores how it works – and what the future might bring. She test-drives Alexa, one of the new wave of virtual home assistants that works out what you're saying and attempts to answer your questions. The artificial intelligence housed in the Amazon Echo device can find answers for many of your daily needs. But what are its limitations?

SMART CITIES ARE ABOUT INFORMATION, HARDWARE AND SOFTWARE: DATA and TECHNOLOGY

The Wired City: Computable City: Information Infrastructure

Michael Batty

http://www.spatialcomplexity.info/
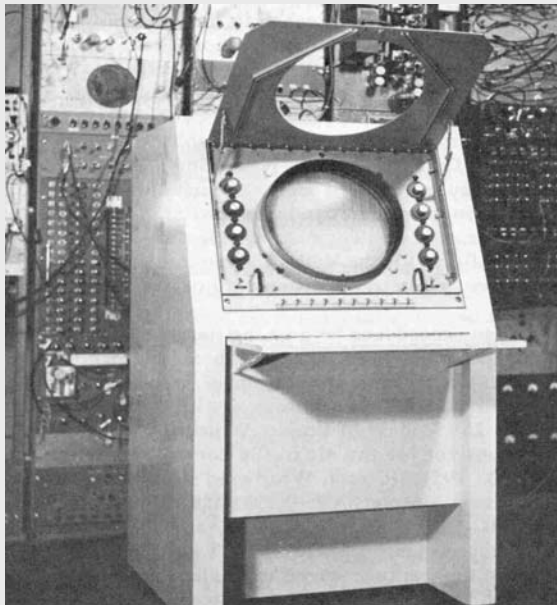
April 18th 2017

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1. Two More Keys to the Smart City:

   a. How We Access Computers: Graphical User Interfaces GUIs
   b. The Convergence of Technologies: IT → ICT

2. Where the Wires Are, Telecoms, Broadband, G3, G4

3. Early Smart Cities: Networking: Wiring Industry, Technopoles, Science Hubs and Parks

4. Singapore: The Intelligent Island; and Malaysia: The Multimedia Super Corridor

5. The Internet: Arpanet to The Web: The Information Divide

7. The Impact of Technology on Distance and Time: Another Key to the Wired World and the Smart City

8. A Theory of the Smart City

Two More Keys to the Smart City: How We Access Computers: *The Graphical User Interface GUI*

Graphics began almost as soon as computers were invented between 1940 and 1950; essentially to connect up components, oscilloscopes were used to interrogate the worked of the machine as these were based on probing using an electron beam, they presented an early form of graphics

Somewhat ironically for our field, the person who wrote the book **Urban Dynamics** in 1969, Jay Forrester, led the Whirlwind computer project at MIT after the war – a defence related project to do with missiles – and in 1950 he went on the Ed Morrow show, **See it Now** and demonstrated the first computer graphic – a bouncing ball on an oscilloscope. There are other stories for example in Wilkes lab in Cambridge UK.

I am now able to show you the clip from the Ed Morrow show. When I last gave this talk it was not online but it is from the MIT video collection so here it is. Here is the oscilloscope on which it was played too.

See It Now: Jay Forrester and Whirlwind

During a 1951 episode on Edward R. Murrow's *See It Now* television series, Professor Jay Forrester debuted MIT's Whirlwind computer. As project director, Forrester demonstrated the computer's combat information systems for the US Navy. View this video in its entirety at the From the Vault collection.

I also want to show you *Whirlwind at MIT* and also a clip from Ed Morrow's iconic show from the early 1950s about networks
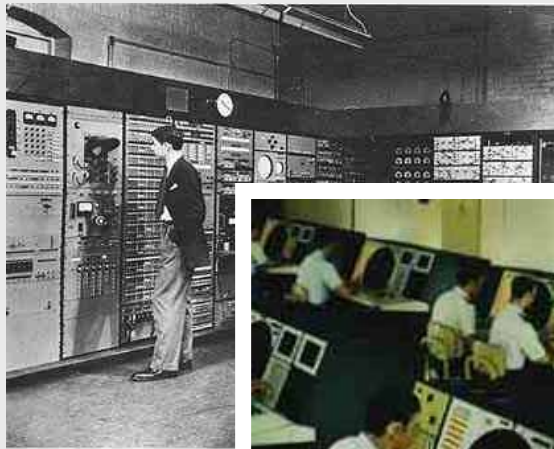
MIT Whirlwind   close

1951

- MIT's Whirlwind debuted on Edward R. Murrow's "See It Now" television series. Project director Jay Forrester described the computer as a "reliable operating system," running 35 hours a week at 90-percent utility using an electrostatic tube memory.

        Start of 1945
        project:
    Completed: 1951

But lest we think that it was America that produced graphics then is worth showing a Russian clip of how they programmed an animated cat *Kittie* in 1967 – using a symbol mapping kind of animation. The movie was produced by Nikolay Kostantinova

This kind of animation was also used in our own field to animate the *Growth of East Lansing Michigan* by Alan Schmidt at Harvard computer graphics lab in the same year – long before we began to directly associated screen memory with graphics

I will show you the two clips before we go and stalk about how graphics really was driven by miniaturisation on the one hand and the fact that many many more people had access to machines due to the PC revolution from 1980 on.

The earliest computer movie I found in

I can't show you the movies here but you can get them on YouTube

And now I will try and show Alan Schmidt's movie of the growth of East Lansing from the mid-1850s to the late 1860's

Ok, graphics which did not get going until miniaturisation reached the point were we could produce cheap personal computers – the PC – depended intimately on Moore's Law

Before then graphics was done either by producing frames from a computer as hard copy **SYMAP** or but tracing out an image on a display tube by electron beam and then capturing the image with some sort of copier – often by taking a photograph. The great insight which came a little earlier in the 1970s was to associate the computer screen with memory and it was at Xerox Parc that the really path breaking work on interaction with computers was done. The story is well known that at Xerox Parc they intend most things that have become commonplace – the mouse, windows, ethernet, hypertext. The story was that Steve Jobs pinched all the stuff for the Apple Mac …but PCs were stuck in the command line mode

But most PCs were truly stuck in the command line mode really until the mid 1990s with the development of Windows 3.1. This is the way we interacted which was painful – here is an example of an early command line driven system – an urban model for Melbourne which was accessed through a graphics terminal where command line and graphics were quite separate in terms of the memory – you can actually see this – 1982 -
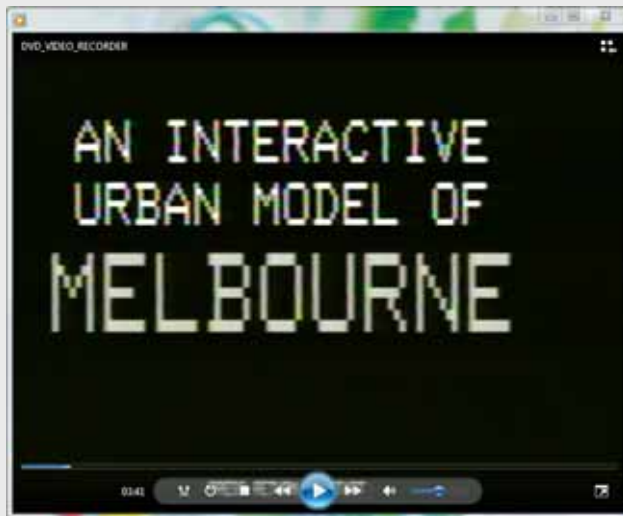
If you go to www.complexcity.info, you can find this movie and others that show early computer graphics and land use models

In the 1980s, the development of the user interface was very fast and the Macintosh, a whole generation of workstations such as those from Sun and SG were introduced with graphical user interfaces but it wasn't really until Windows 95 that things really began to take off. It took a long time too to see the interface in the way I am showing it today on this powerpoint – and there are rapid developments all the time, of course now on phones and tablets and so on

However what was clear was that the web – the world wide web which was essentially a graphics interface to the internet – is the first browsers were essentially graphic. Of course there were access software before **Mosaic** which was the first effective interface like **Gopher** but the decision to make it graphic was key – I don't quite know why – not sure it was to do with Tim Berners Lee. More likely Larry Smarr at NCSA.
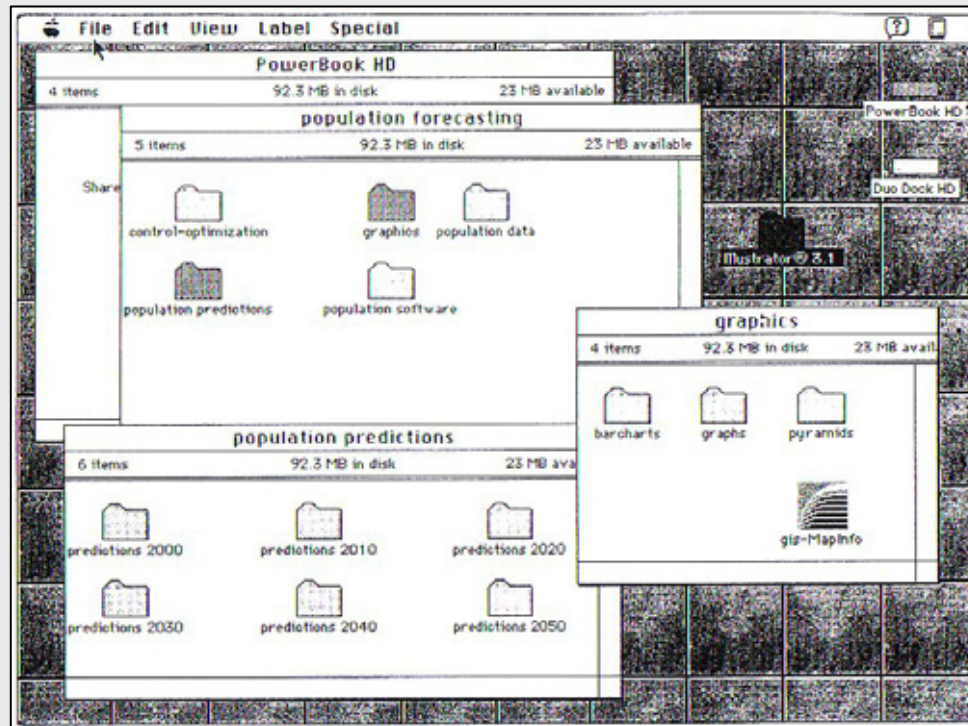
A Desktop PSS for Population Forecasting
on a Mac circa 1993 ↑

A Web-based Feed of Real Time Traffic Data
In San Diego circa 1995 →
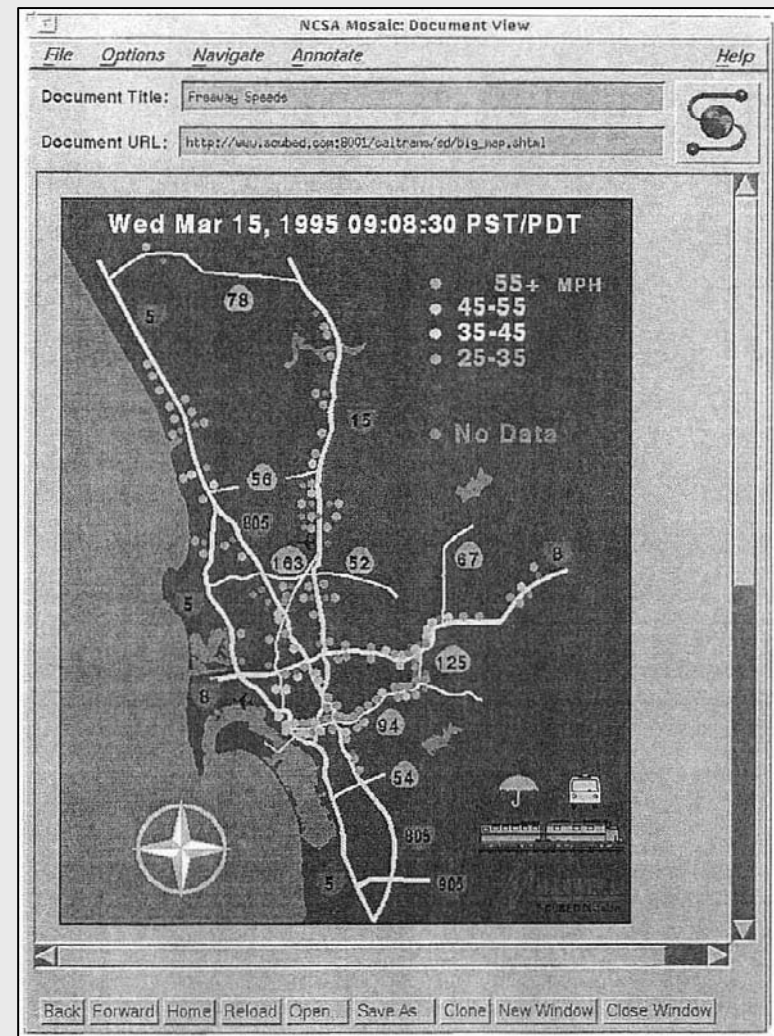
If we look briefly now at the web and its graphics, then the essential distinction between web 1 and web 2 – web 1 is really passive – read, while web 2 is more interactive – read and write – to use TBL nomenclature

Web 3 is more like using a degree of intelligence in interacting with the web – it has not got a very clear definition but some say that it is the web with AI or rather the semantic web

Anyway the key issue is that the web is completely graphic – that is the predominant way of access and in essence the mouse and keyboard are also being displaced in hardware terms by touch screen

3D graphics, and animation are now taken for granted – massive developments but progress with good HCI is slow and problematic

There is now a key move from the desktop to the web – a kind of enfranchisement where it is essential to have graphics – another component of modern computing and this of course is central to the idea that new styles of computing will be participatory – as we see in information systems in the city – and this of course will be the essence of the smart city.

What is now happening is quite hard to comprehend. I think we are a bit close to it all - too close to it – a lot of these developments seem to be slowing down in terms of interfaces and this focus is now on very simple Apps on phones and these is likely to be some critical merger with TV. The thesis about productivity gains is an issue here and we will return to is later – the real gains are where we make new things possible but graphics is only making most things a bit better

Our Second Key to the Smart City: ***The Convergence of Technologies: IT → ICT***

My second major point is by now quite obvious to us all but is was barely anticipated –obvious in hindsight of course – but it required miniaturisation and new materials based on the notion that computers would converge with other technologies, with people and with their activities.

The first convergence is linkage of computers and communications and there are two modes: *the first mode*: software and data are linked across the <u>desktop</u> with the user providing the momentum for this; *the second mode* is software and data linked across the <u>net</u> and this is part and parcel of the client-server architecture that now dominates.

This is a shift from moving people to information or to people with information versus moving information to people – face to face contacts - moving is more than just information, it involve people and activities – the electronic cottage is essentially a myth; it never took account of networking and it didn't anticipate the power of wireless, thought to be dead technology in general until its resurrection for connectivity

- second convergence is TV, video, phones, and of course computers where networking is assumed

- third convergence – computers in mechanical devices which is happening extensively at a low level

- fourth convergence – computers into places – the smart city

- fifth convergence – computers inside people. – implications for space and interaction are profound.

We will come back to all this at the end of the talk today when we talk about how ICT is affecting distance and time as this is key to the smart city.

But we should also flag the fact that ICT and natural systems, particularly biological systems are converging. This is a very controversial area – it is no accident that just as Shannon was doing his famous work on coding and people like von Neumann were building the first computers, the other essential insight into coding was developed: DNA and the genetic code which was discovered by Watson and Crick in 1953. I think there will be some profound developments in this domain in the near future – there already are and this may be where the momentum will drift.

Where the Wires Are, Telecoms, Broadband, G3, G4

Ok we have done a lot on the essential background but we need to say something very quickly about where all this hardware is embedded and to do this I will give you a quick summary.

The location of the hardware, the wires and the wireless are also key to delivering information but it is hard to figure all this out because everything is so bottom up

Essentially most of our connectivity still is sitting in front of a computer and interacting directly but as I type this slide, I keep going back to the web – because I am connected – wirelessly in the office in the hotel at University, and I search for information on the web. So basically although probably 70% of my interaction now is me and the computer, some 30% is me, the computer & the net.

This is important as it is growing fast and the ratio of desktop to net will fall. When I first wrote this slide it was 80/20, now I reckon 70/30, and probably next year 60/40.

Ok let me show you three things – where the wires are – some of them – where the wireless is – some of it and then something about how data is transmitted and where the data centres are.

First let me look at the big wires between continents like the north Atlantic cable. There is a very nice interactive map of this and let us see if we can pull it http://www.cablemap.info/

This was first done for the electric telegraph – read Tom Standage's book – but these cables are being put in everywhere. I need to tell you my experience outside my flat in central London where the street is dug up at least 15 times a year
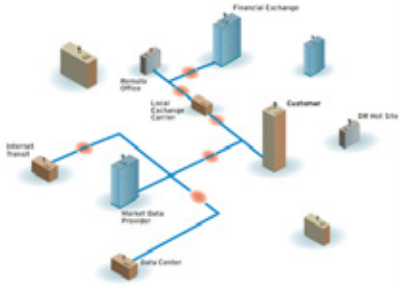
Wireless requires repeaters – wireless towers to capture the data and then transmit it on – remarkable really radio waves compared to fibre optics – generally wired is much faster still and can also take massive amounts of data in the cables – under sea cables back to the idea of the telegraph and telephone http://atlantic-cable.com/Maps/index.htm

The way data is communicated is that it is broken up into packets and packets are switched and make use of redundancy of the network – assembled at the other end – I think this is how it works – it always seems to work – indeed one of the major issues about electricity is that is it so robust but I expect this must be the case if it is everywhere

The last point about the wires involve data centres – You have probably heard about the big Google data centre in Oregon where they are taking over a whole town (in terms of jobs that is I guess) – there are many of these big server factories and farms and big switches for the internet –

Let me show a couple of pictures and then also point you to a very interesting Google web site that tells you the story and we will load it and see

Telehouse west in London…………………in Amsterdam

http://www.google.com/about/datacenters/gallery/#/

https://www.youtube.com/watch?v=avP5d16wEp0

Early Smart Cities: Networking: Wiring Industry, Technopoles, Science Hubs and Parks

Let me say something very briefly about how people thought of smart cities as soon as it became possible to develop wide area networks in the mid to late 1980s. Combined with a lot of hype about fibre optics – but remember the internet was not yet invented – as such – then the idea was to network places and putting in the fibre was the key issue. It still is and in fact the biggest concentrations of wired stuff and probably wireless is in big cities

Not particularly in high tech concentrations where hardware and software is being developed but in places where it is being used – financial centres. Here is a map of the UK in terms of internet hubs in the late 1990s
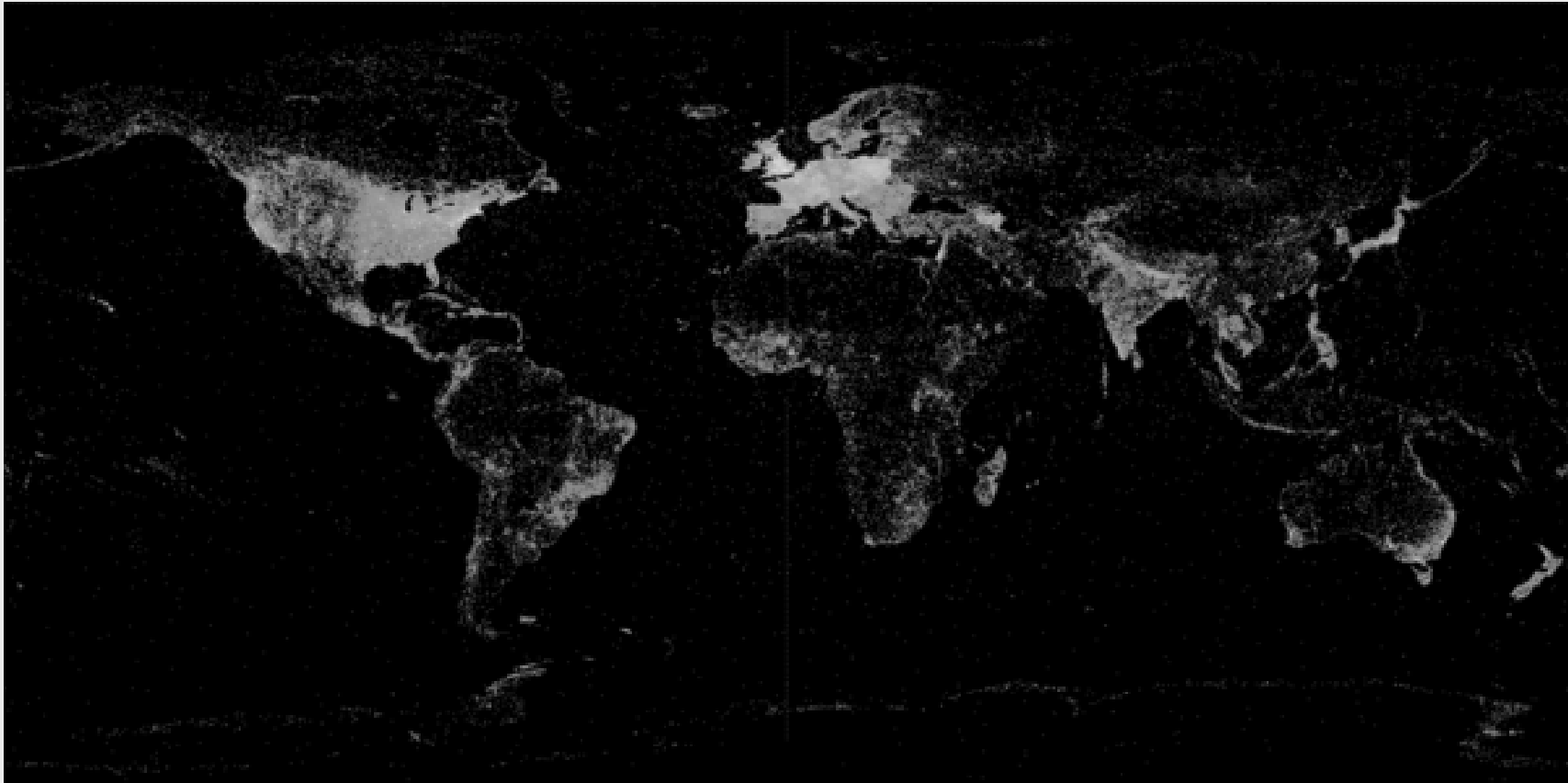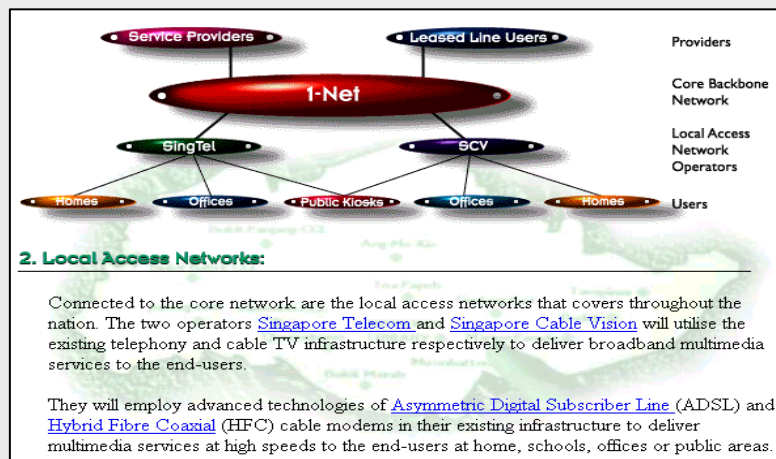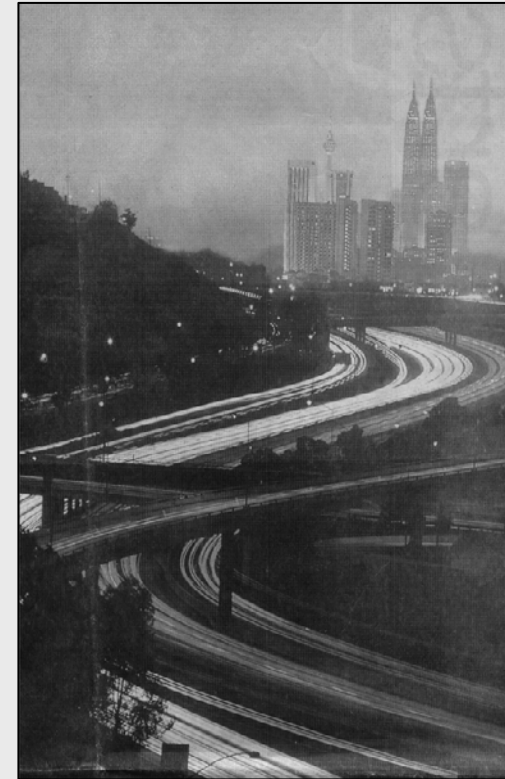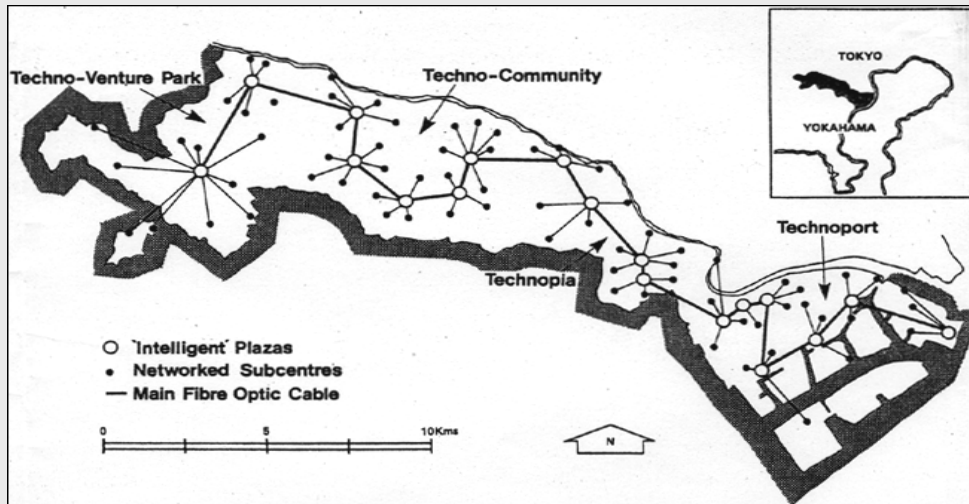
Internet Hubs:
England circa 1998

The NY stock exchange above and the London stock exchange below. Note how traders are now gone as a physical force – it is all electronic trading
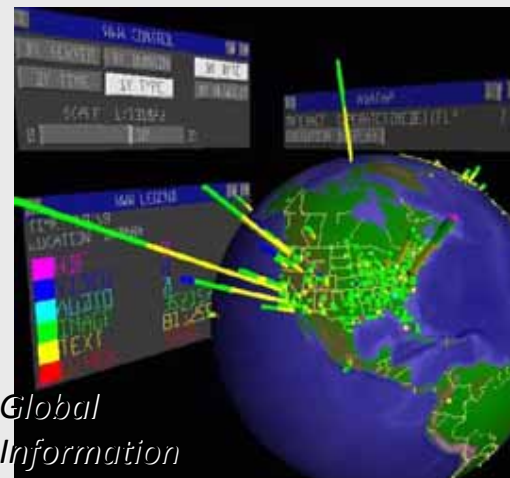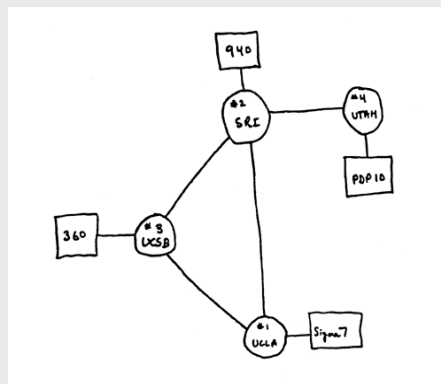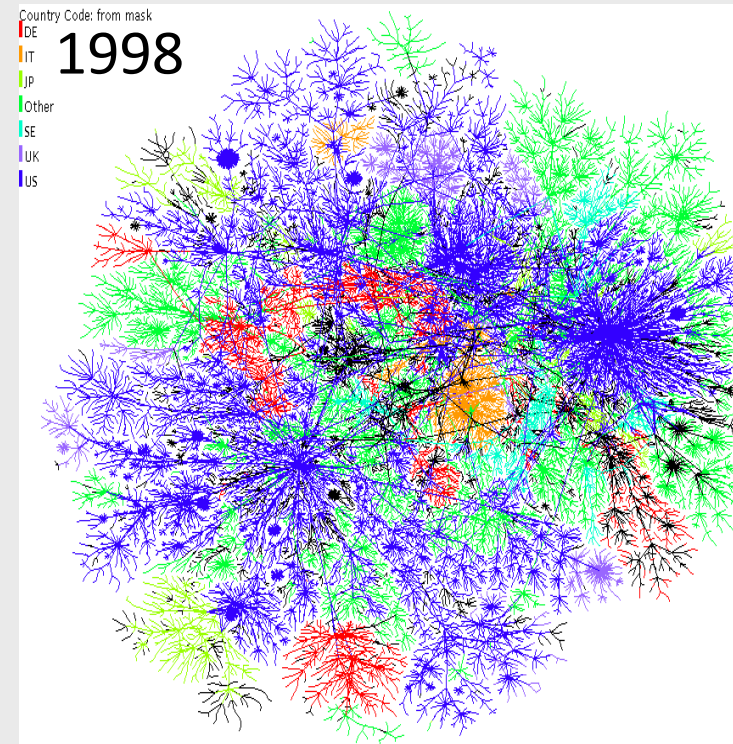
I can't find a good map of computer IT/ICT concentration per se but these are Wiki points – there are many maps like this that tend to show use rather than hardware

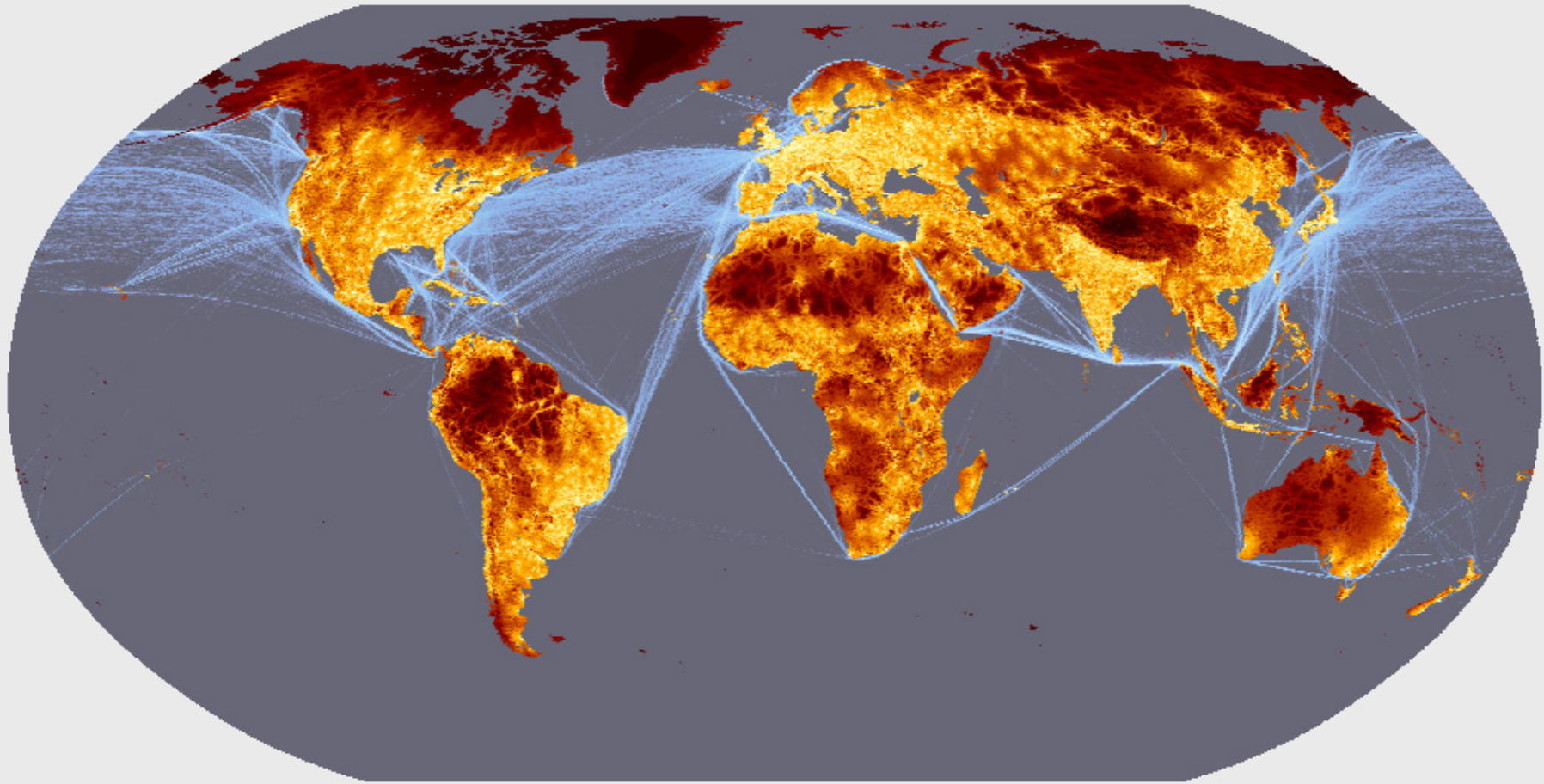# Singapore: The Intelligent Island; Malaysia: The Multimedia Super Corridor, Kawasaki Japan 1989
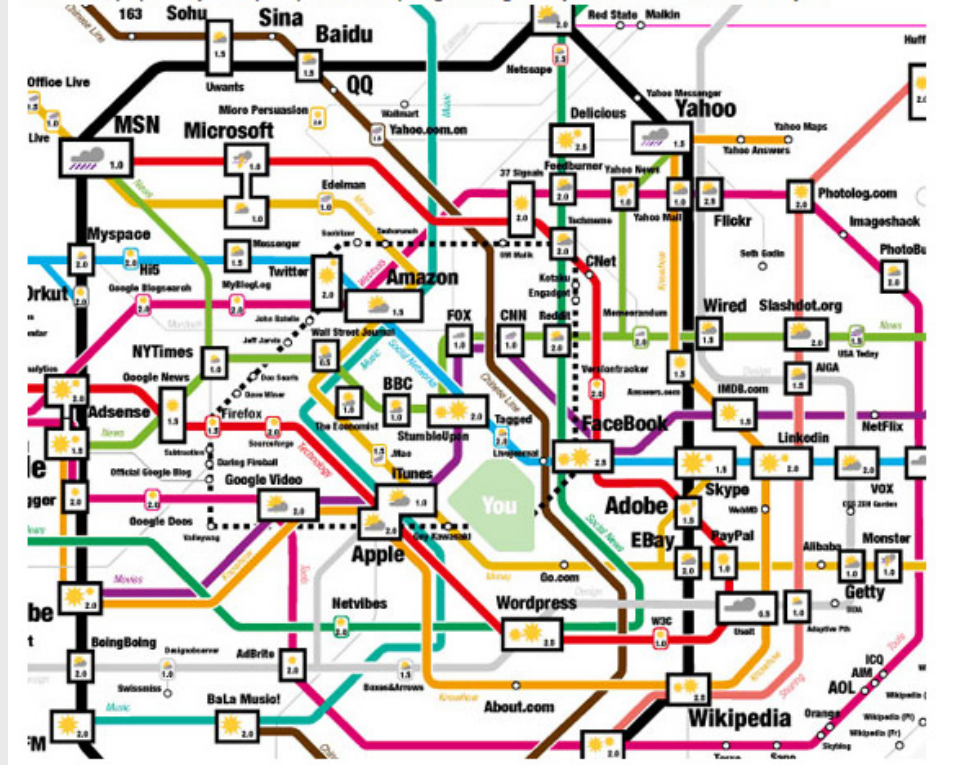
The Internet: Arpanet to The Web

1972

1998

Global Information

Smart Cities Lectures: The Chinese University of Hong Kong, April 2017

Financial Concentrations : High Frequency Trading
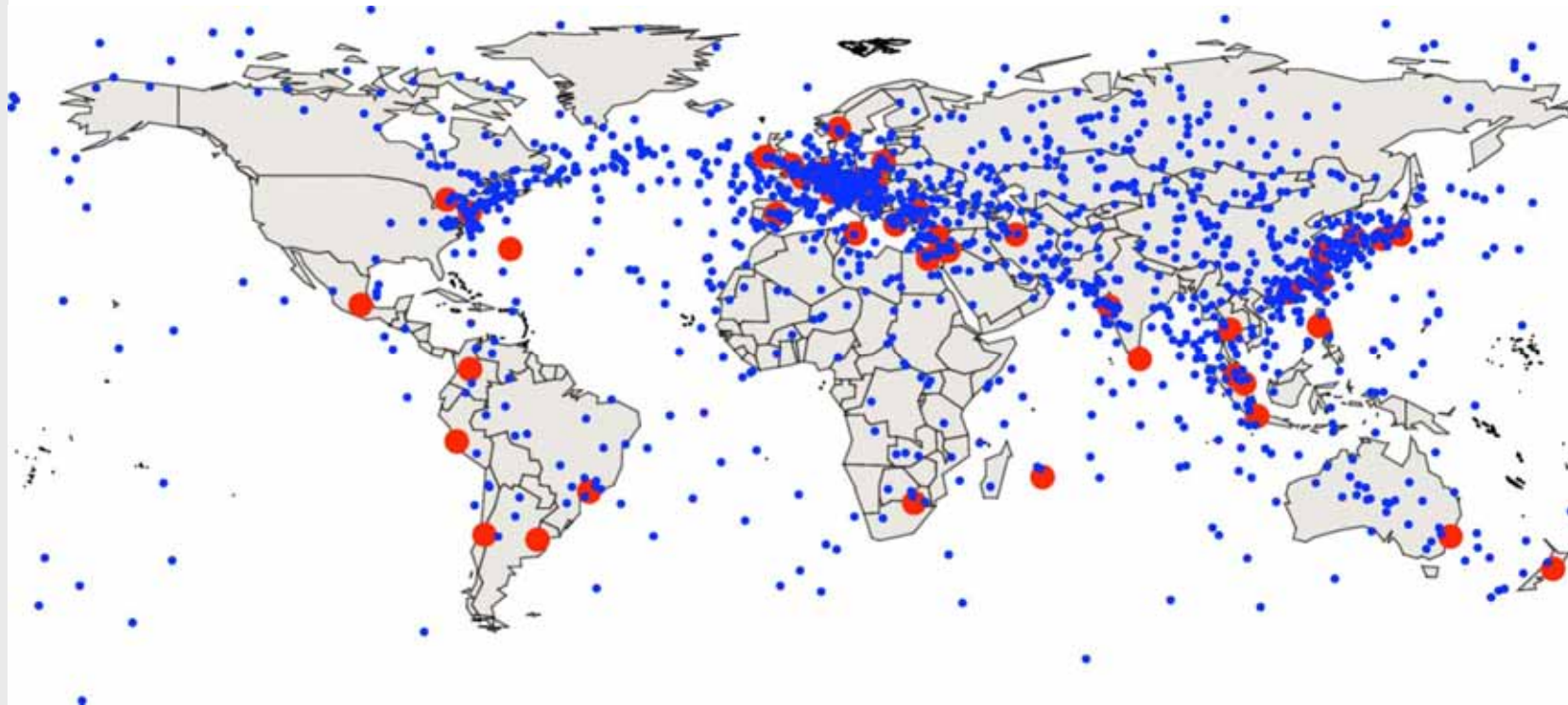
The Information Divide

I need to flag the fact that all these things are part of the smart city and the fact that smart cities are global in this sense. In some respects we should have maps of the use not the actual ownership and this is a key point. We will not say any more other than flag the divide as a recurring issue
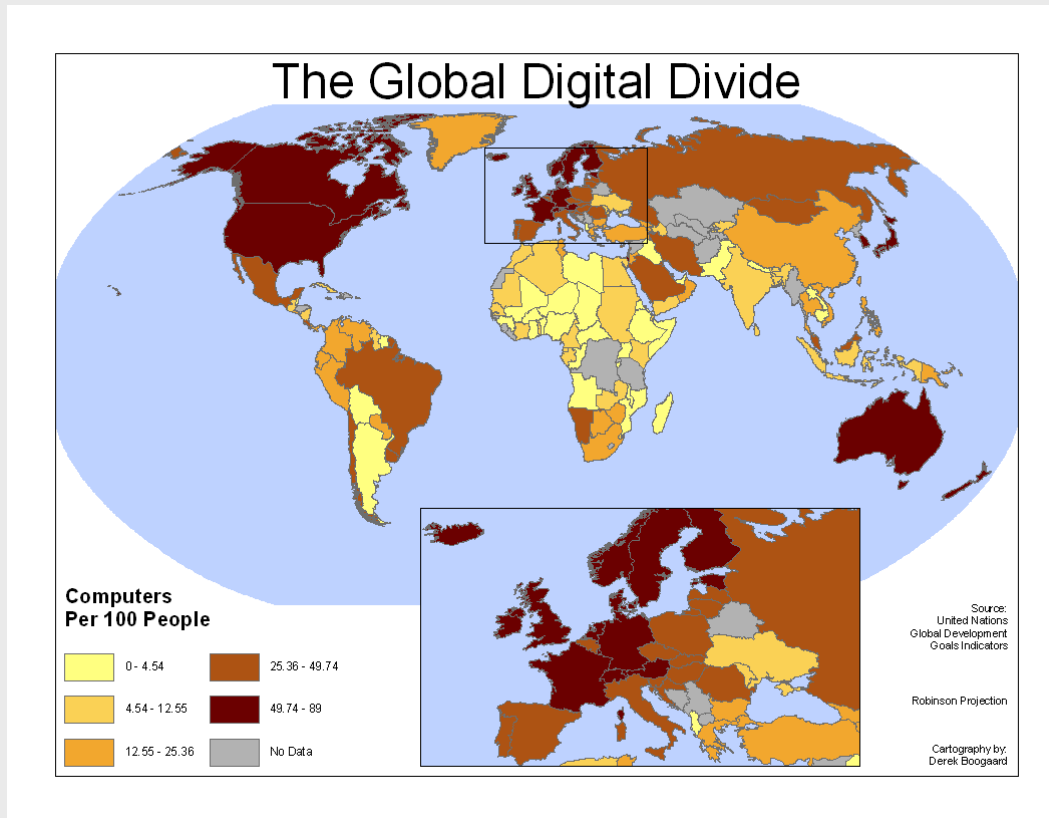
The Impact of Technology on Distance and Time: Another Key to the Wired World and the Smart City

Ok – a long talk – but let me focus on my last theme because as geographic scientists and urban researchers we are clearly interested in space.

Clearly each wave of technology through the industrial revolutions has meant change in the way we interact – in particular the distances over which we can interact and also the speed of that interaction

First came the internal combustion engine and steam and this led to railways and then to automobile – so average distance that some one could travel increased dramatically from say 5 or 6 miles to 10s of miles, and the time taken decreased

Then came electricity and the telegraph and the phone with very long distances being possible in terms of communication, not physical travel so this was an information medium

The computer and ICT has accelerated all this and in fact it has led to almost continual communication

Air travel has led to global movement but in general we are still restricted by how long it takes to drive – however there are strange and insidious things going on with travel. It is hardly the death of distance but there are strange transformation going on with respect to locational decision-making and it is this that we need to get a handle in in terms of the smart city.

Productivity gains have slowed in fact due to the fact that most of what is now happening is improvement not massive disruptive change – we will continue to speculate here….

There are many references but look at

http://www.spatialcomplexity.info/technicity and read, peruse

Andrew Blum (2012) **Tubes: A Journey to the Center of the Internet**, Ecco, New York.

George Dyson (2012) **Turing's Cathedral: The Origins of the Digital Universe**, Vintage, New York.

Dava Sobel (1997) **Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time**, Walker and Company, reprint, New York

Tom Standage (2007) **The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers**, Walker and Company, reprint, New York.

A Theory of the Smart City

Let me take one step back but at the same time propel us forward.

Having developed a lot of background, we are now ready to think about smart cities and what the real focus is now. Essentially computers and their communications can be applied to any and every aspect of the city but the _idea of the smart city is narrower than the application of all digital computation to cities._ In fact here we will take a broad view beginning by making a key separation between using ICT in cities for

a) _Routine purposes_ – how to operate the city, manage it, and design the city in the very short term, and

b) _Strategic purposes_ - how we understand and plan for the city in the much longer term

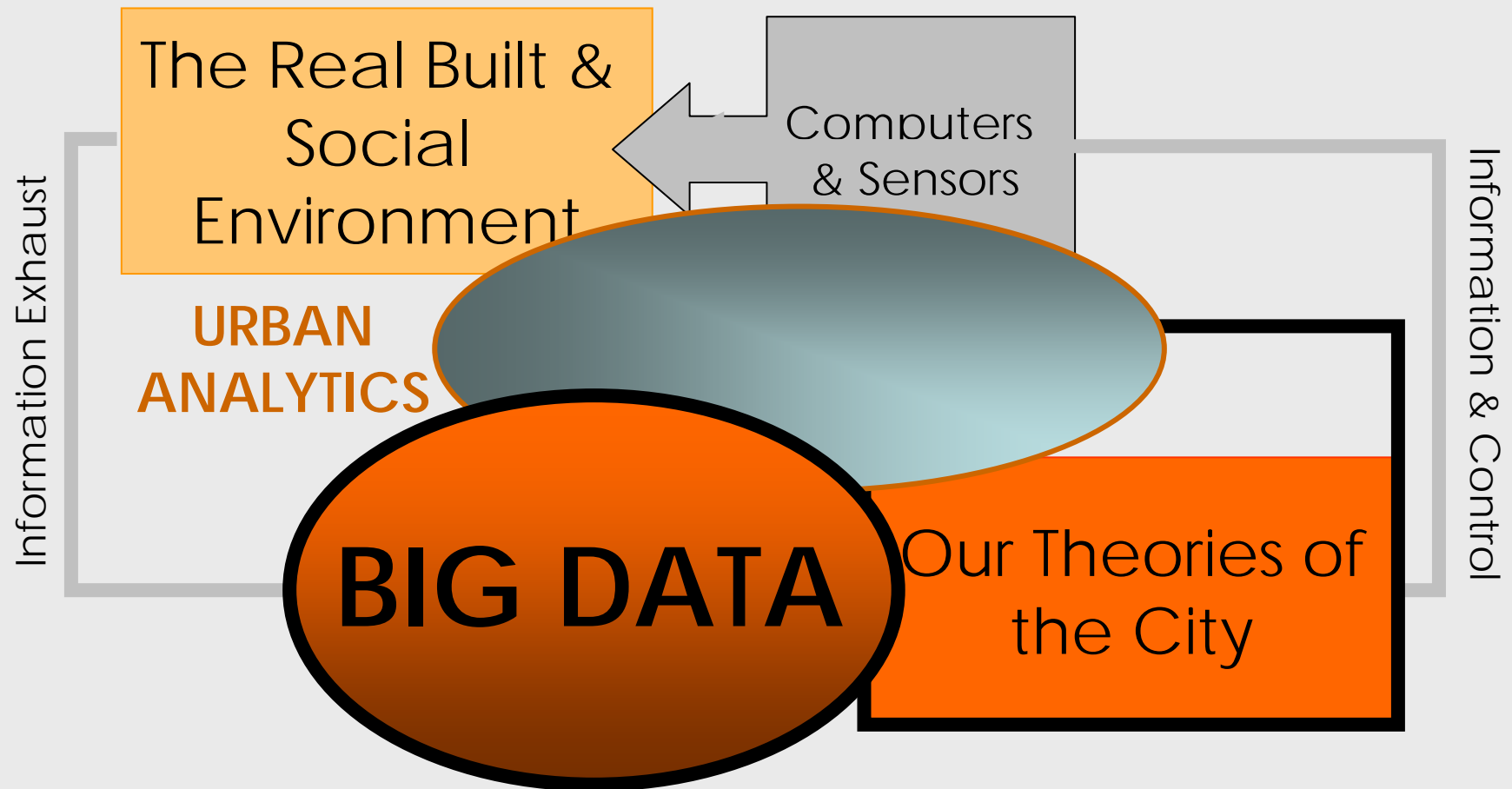So *temporal* rather than *spatial* is a key organising distinction.

In fact there is a tendency for our methods and models and data to be clustered around the short term, fine spatial scale and the longer term, coarser spatial scale. So for example, the operation of routine movements and communications in the short term – second by second, minute by minute and so on – tends to be an the more individual level while our focus on the long term tends to be related to aggregates of such movements which pertain to bigger scale times and locations.

So we have a class of models and methods that pertain to short term fine scale and a different class that pertain to long term coarse scale. Important to note that both classes of models have existed for a long while but the more routine are being reinvigorated through modern ICT

So urban operations research models for emergency services, police, fire, crime and so on are examples of the more routine while transportation planning models, land use and housing market models are examples of the longer term more strategic.

We are tending these days in the smart cities movement to call models and methods 'analytics' while the other feature is data – and in this context 'big' and 'open' data have become significant. Essentially this is because computers are being embedded into the physical fabric of the environment – not only are we using models to manage and plan and improve the environment, computers are being used to control it and it is these that are generating streams of real time data – this is big data where time is the key dimension.

In this sense we might portray our focus on smart cities as follows

The Real Built & Social Environment

Computers & Sensors

URBAN ANALYTICS

BIG DATA

Our Theories of the City

Information Exhaust

Information & Control

Now we can position our focus on the smart city across this set of domains. But before we do so and move to thinking about communications, let us focus on different definitions of the term smart city.

Generally the big IT companies define smart cities as digital technologies meaning software services being embedded or used in cities – this covers all aspects of our figure but in fact it tends to be nearest the routine built environment end of the spectrum

In the history of smart cities, the notion of the **wired city** came first and these were close to the 1980s conceptions of cable and Telephone services in cities. Then this concept was broadened into the **intelligent city** and some times this was notated as the **information city**. Castells was key in this.

In parallel to this as cities were being modelled in terms of their physical form, the **virtual city** came on stream – with cities being pictured as virtual realities. These grew out of 3D mapping and CAD, and thence virtual environments became significant in which the user could interact with the virtual city itself.

These virtual environment were in distinction to other models of cities that were more abstract and in a sense still remain on the edge of these conceptions.

As we proceed we will fill in the history and the picture of the contemporary smart cities movement; and in the next talk, we will begin with thinking about cities in terms of communications.