Are Models becoming smarter than Modellers?

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SIDRA SOLUTIONS

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CELEBRATING 20 YEARS

Presentation theme

Are Models becoming smarter than Modellers?

- Models in software applications are becoming increasingly more sophisticated.
- Artificial Intelligence becoming visible in all areas of our lives.
- Is this making modellers smarter or are they left behind?
- How is all this affecting the use of models, interpreting outputs, handling uncertainties in model results and translating model outputs into practical solutions?

and

- How is all this affecting our profession? Is there a disruption / threat from technology?

Previous presentation at NZMUGS 2017

This is based on my keynote speech titled

Are smart models leading to dumb modellers?

presented at the New Zealand Modelling User Group 2017 Conference held in Christchurch.

Presentation plan

- The road traffic / transport system we are modelling
- Models
  - General Discussion
  - Experiment vs Theory
  - Complexity vs Simplicity
  - Uncertainty and Reliability
  - Calibration
  - Big Data
- Modeller
  - General Discussion
  - Understanding and improving model outputs
  - Lessons from Artificial Intelligence

With recommended reading, some quotes and internet links.

Artificial Intelligence in our daily lives

Meeting Alexa

…

Apparently over a million people asked Amazon's Alexa to marry them in 2017 and it turned them all down.
https://bit.ly/2BsjV3E

Digital voice assistants like Amazon's Alexa are applications of artificial intelligence (AI) that are increasingly part of our daily lives.

They rely on natural language generation and processing and machine learning, forms of artificial intelligence, in order to effectively operate and perform better over time.
https://bit.ly/33ReGab

Artificial Intelligence is becoming visible in all areas of our lives.

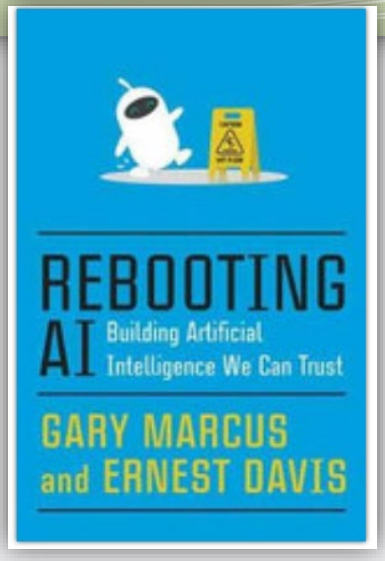
Self-driving vehicles

Another AI application which is much talked about, and is of great interest to the traffic engineering / transport planning profession, is the self-driving vehicle.

Discussion on this is included in a recent book which presents a general critical review of the current state of AI.

I'll quote some aspects of this book later in this presentation due to their relevance to my discussion of models and modellers.

MARCUS, G. and DAVIS, E. (2019). REBOOTING AI – Building Artificial Intelligence We Can Trust. Pantheon Books, New York. https://nyti.ms/2m4QQXP



Examples of other AI applications affecting us

- **GPS navigation**

  https://bit.ly/33Mhjd3

- **Automotive industry**

  https://bit.ly/2o3oOgJ

- **War drones (autonomous weapons)**

  https://bit.ly/2MVNoZe

Questing arising from Artificial Intelligence considerations

All this brings to my mind questions like:

- How much intelligence is there in the models we are using in our profession?
- How would models with increasing intelligence affect modellers?
- Do we have wish to have Expert Systems capabilities (decision-making abilities of a human expert) in our models?
- Any threats / disruptions to our profession?
- Are there any lessons to learn from artificial intelligence methods?

The road traffic / transport system we are modelling

We are modelling a complex system (1)

Understanding the characteristics of the road traffic / transport system we are modelling:

- Multiple conflicting objectives
  - Diversity of road users: cars, buses, light rail, freight vehicles, bicycles, pedestrians.
  - Diversity of areas of concern: safety, operations, environment, economy.

The best solution for one group of road users or one area of concern is not the best solution for another.

We are modelling a complex system (2)

Understanding the characteristics of the road traffic / transport system we are modelling:

- High variability of travel demands and operating conditions
  (hourly, daily, weekly, yearly changes – even changes within an hour can have significant effect).
- Non-linearity
  Sensitivity and uncertainty of operating conditions increase at a high rate when demand approaches and exceeds capacity of the system.
- Human element
  Adapting to varying conditions, e.g. effect of traffic conditions on aggressive vs relaxed behaviour (adding to variability).
- Diversity of transport and traffic engineering / planning / control practices and emergence of new practices over time add to the complexities.

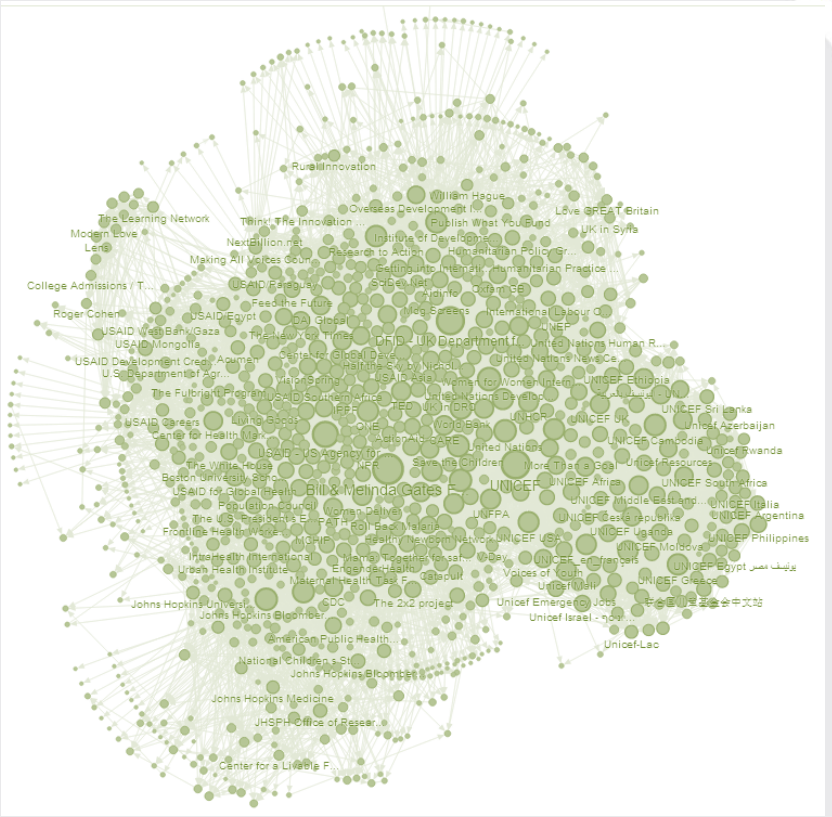
Complex Systems

A complex system is any system featuring a large number of interacting components.

Complex systems are systems whose behaviour is intrinsically difficult to model due to the dependencies, relationships, or interactions between their parts or between a given system and its environment.
https://bit.ly/32xIp7v

Examples: Earth's global climate, the human brain, social and economic organizations, an ecosystem, a living cell, the entire universe.

Is it possible to make simple models of complex systems?



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Models

- General Discussion
- Experiment vs Theory
- Complexity vs Simplicity
- Uncertainty and Reliability
- Calibration
- Big Data

Models - General Discussion

(Models implemented via computer software)

Model Benefits

Models help with (contribute to):

- problem solving and decision making
- improved communication:
  (speaking the same language)
- expert discipline:
  (no simple recipes)
- perception and understanding
  of the “real system”:
  describing vs explaining

Are models more sophisticated now?

- Technological developments have contributed to model use: faster processing allowing more scenarios to be analysed, better visualisation, more detailed and "dynamic" models, and so on.

  Do such functionality improvements necessarily mean smarter models?

- Is increased model complexity to do with the areas the modellers are required to address?
- Is the ability to do much more than before overwhelming the modellers?
- Is perception of "complexity" all relative?
- Does complexity mean "sophistication"?

The model and the modeller

The following has been our motto in model development:

- No model is perfect - know its limitations
- The user must UNDERSTAND
  (black box solution NOT desirable)
- A model is only a Professional TOOL

Will development of artificial intelligence challenge this?

“Reality” and “Modelling”

We should understand “Modelling” as a basic human brain process. We try to simplify the complex world around us, we try to describe (“how?”), explain (“why?”) and we try to predict the future.

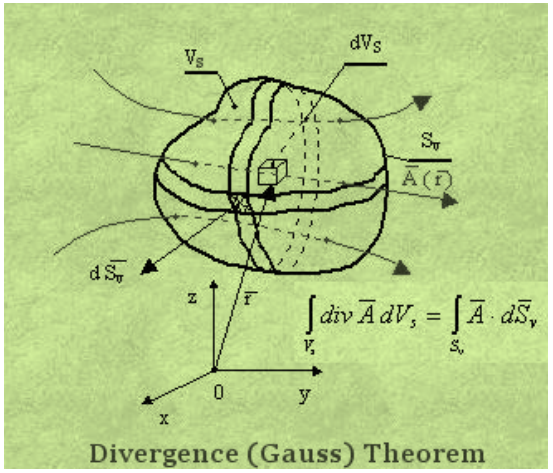
> “There is no … theory-independent concept of reality. …
> We make models in science, but we also make them in everyday life.
> Model-dependent realism applies not only to scientific models but also to the conscious and subconscious mental models we all create in order to interpret and understand the everyday world.
>
> HAWKING, S. and MLADINOW, L. (2010).
> The Grand Design. Chapter 3 (What is Reality?).
> *Bantam Books, New York*.

What is a good model?

A good model probably has the following characteristics:

- Detailed and realistic but as simple as possible:
  Making the model more complex does not necessarily make the accuracy of its estimates better.
- Clarity of model assumptions (documentation).
- A balanced use of experimental and theoretical elements.

Models - Experiment and Theory



Divergence (Gauss) Theorem

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Experiment vs Theory

Contrasting models as “empirical vs theoretical" represents a simplistic view since most models have basis in traffic behaviour theory and are empirical at the same time.

Immanuel Kant (1724 – 1804):
“Experience without theory is blind, but theory without experience is mere intellectual play.”

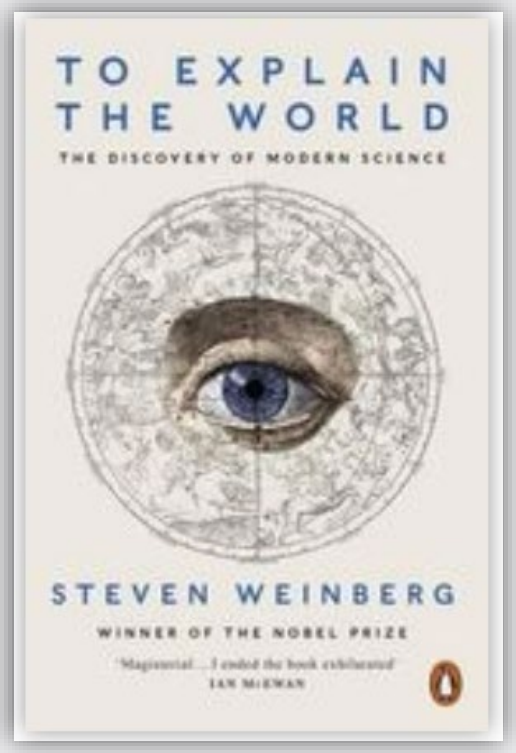
KEHLMAN, D. (2006). **Measuring the World.**
English Edition translated by C. B. Janeway. Pantheon Books.

A novel of life-long conflict between Alexander Von Humboldt (1769 – 1859) and Carl Friedrich Gauss (1777 –1855) who were both concerned with the measurement of the world: Humboldt constantly took readings during his vast journeys - the height of every mountain, the line of the equator, … while Gauss conceived space as a mathematical reality …

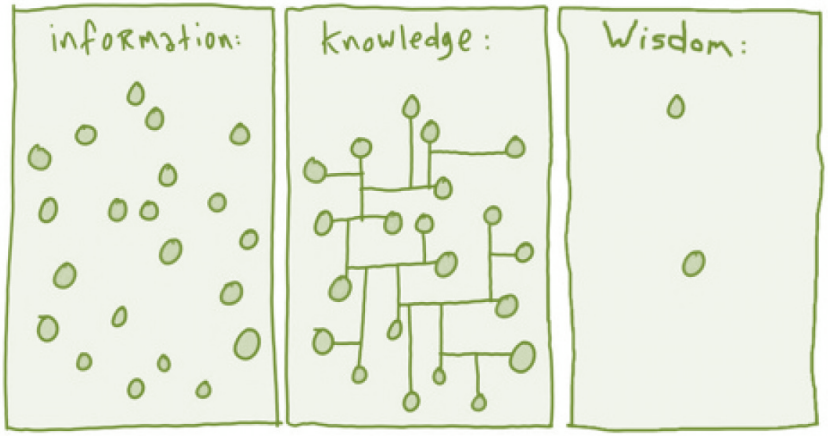
Explaining vs describing

Steven Weinberg. **To Explain the World – The Discovery of Modern Science**. Penguin Books. 2016.

> **"The great success of Newton was in *explaining* the motions of planets, not merely describing them. Newton did not explain gravitation, and he knew that he had not, but that is the way it always is with explanation – something is always left for future explanation."**



Models - Complexity vs Simplicity

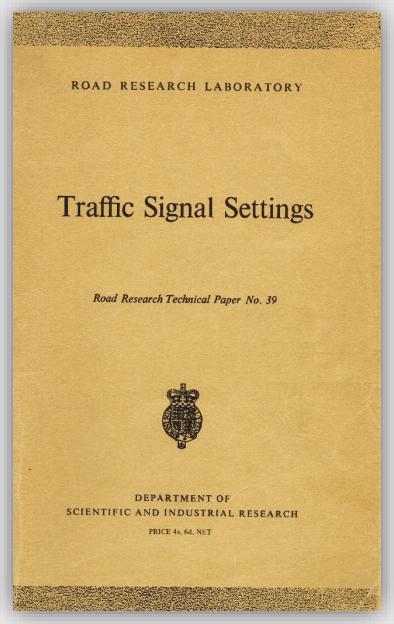


Perception of “complexity” is relative

Is “smart model” a perception of new more complex aspects of the model that we don’t understand well at this stage?

" Since **a theoretical calculation of delay is very complex** and direct observation of delay on the road is complicated by uncontrollable variations, it was decided to use a method whereby the events on the road are reproduced in the laboratory by means of some machine which simulates behaviour of traffic …”

F. V. Webster (1958)



Simple model for a complex system?

- "Everything should be made as simple as possible, but not simpler."

  Albert Einstein (1879 –1955)

- A paper on neural modelling:

  "Nevertheless, most theorists think that a good model includes only the details needed to help answer a specific question. Indeed, one of the most challenging aspects of model building is working out which details are important to include and which are acceptable to ignore.

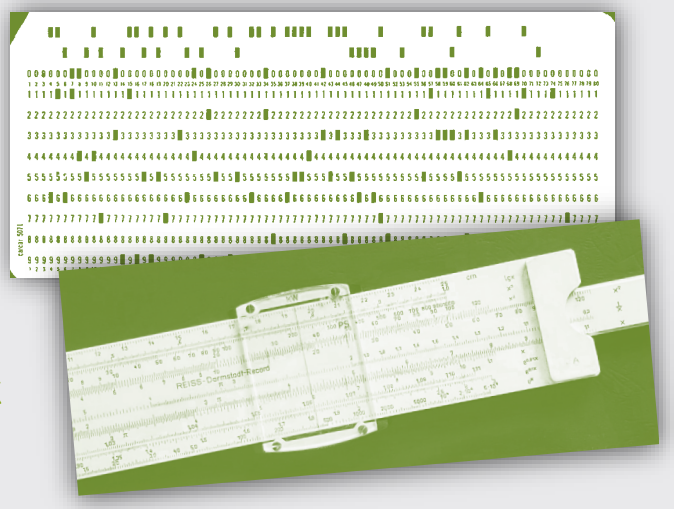
  CHI, K. R. (2016). Neural modelling: Abstractions of the mind. *Nature* 531, S16–S17, doi:10.1038/531S16a. =true
  https://go.nature.com/2Jb1fKi

Have the models been getting smarter?

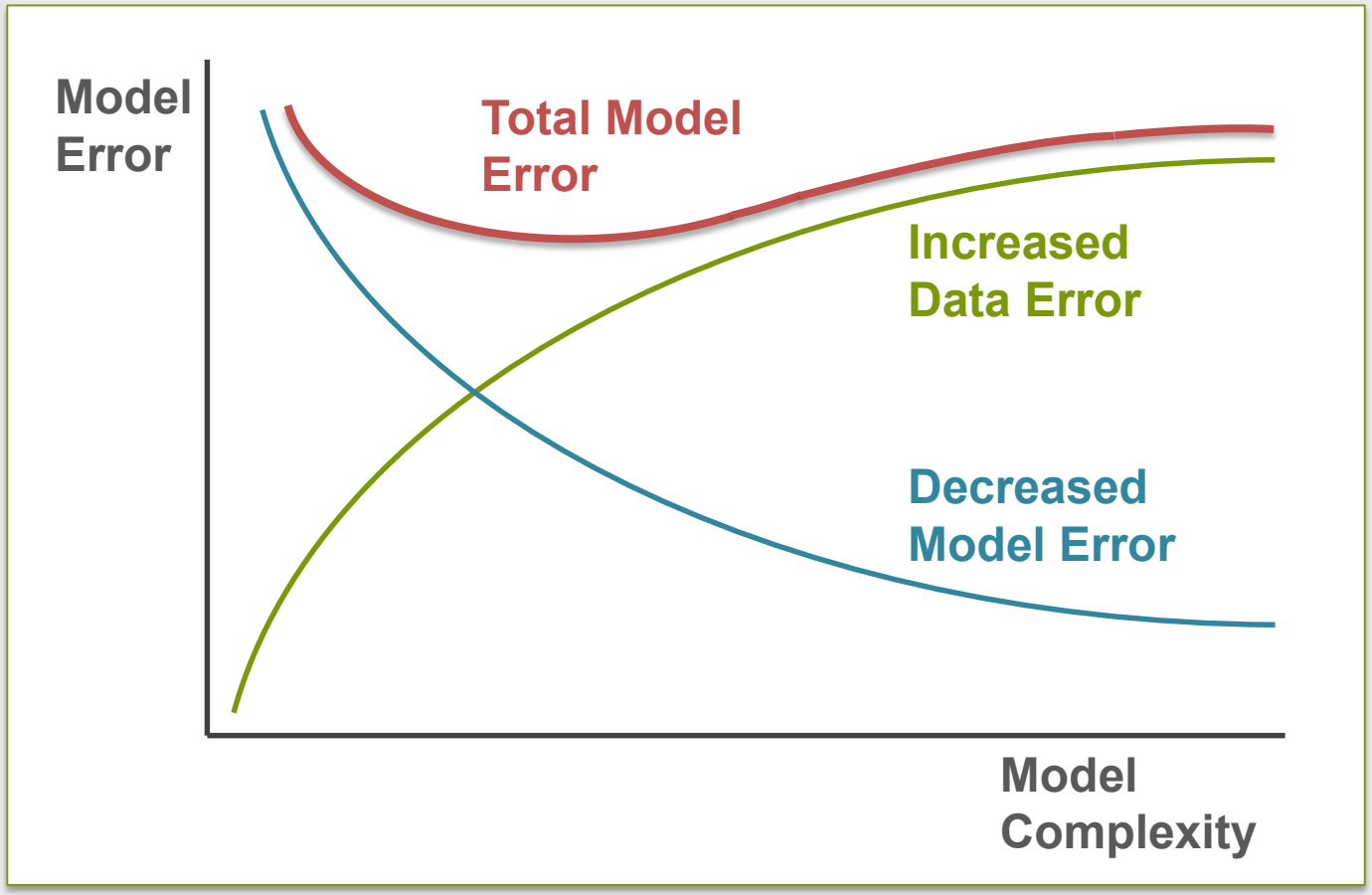
Have the fundamentals of models been getting better or have the technological developments allowed computers to offer more powerful functionalities but models are still too simplistic?

Examples:

- US HCM is based on lane groups and uses non-iterative techniques - remaining from manual / slide rule calculation days.
- Sophisticated looking software uses link-based network models without queue spillback.
- Travel demand models based on simplistic speed-flow functions with constant capacities.
- Observing travel demand very difficult or too expensive.

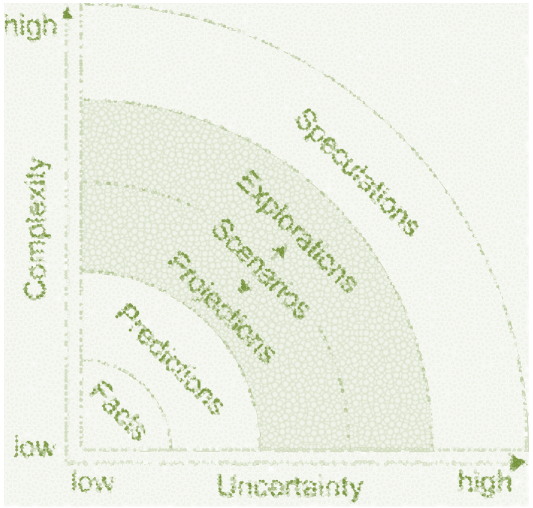


Model Complexity vs Model Error



Alonso 1968;
Richardson and Ampt 2001

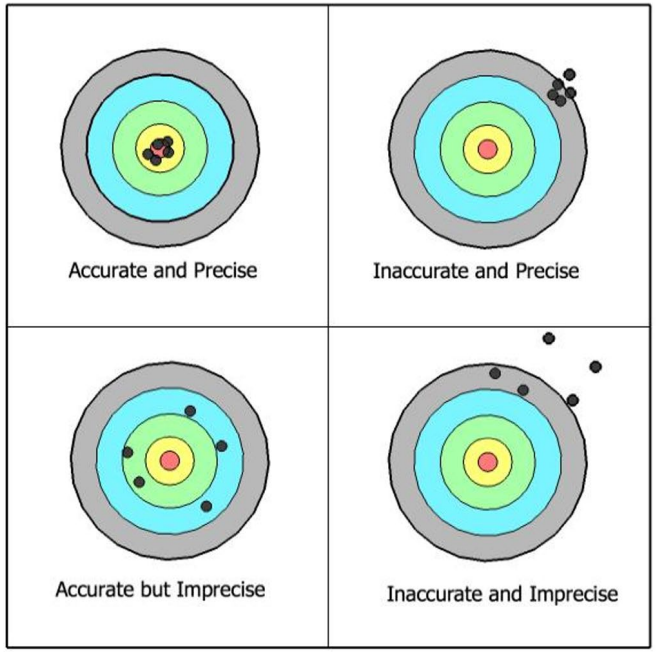
Models – Uncertainty and Reliability



Uncertainty: Accuracy and Precision

Accuracy and precision

- Sometimes pursuing **precision** may lead to **inaccuracy**
- It is better to be approximately right than precisely wrong



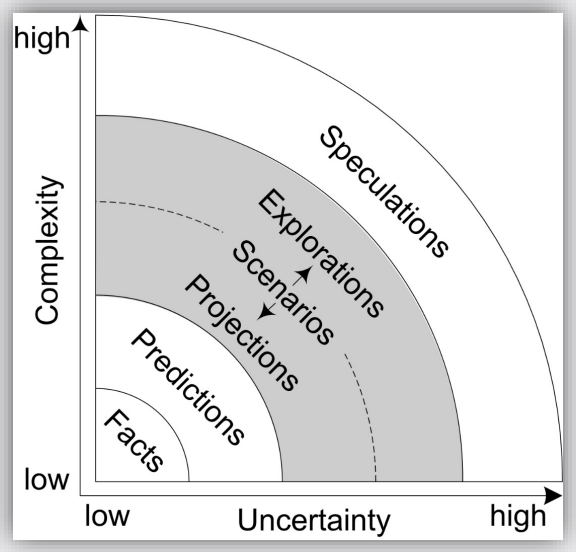
WILLUMSEN, L. (2017). Modelling for an uncertain future. Presentation at the *Transport Modelling Interactive Forum, AITPM 2017 Conference*, Melbourne, Australia.

This presentation includes discussion of "future uncertainty".

Uncertainty and complexity

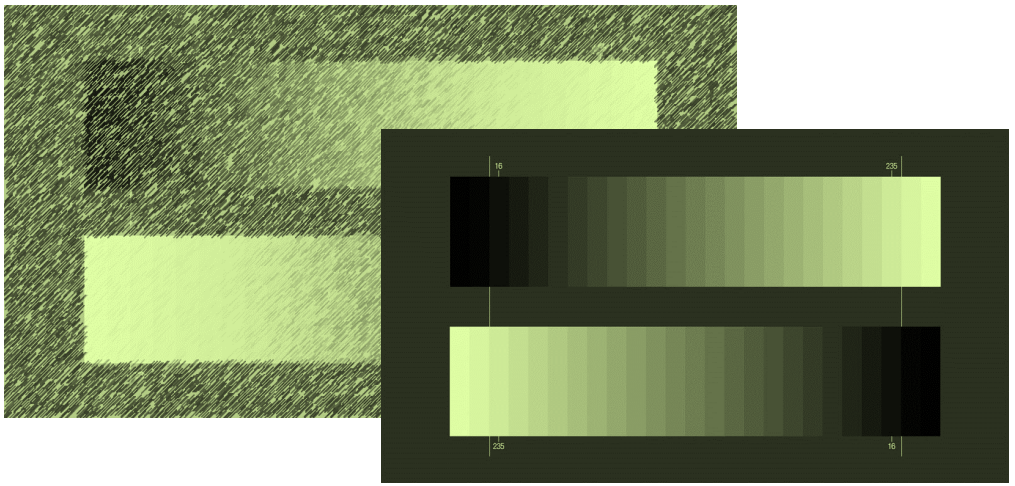
Scenario-based approaches are particularly useful when addressing the considerable uncertainty about future trajectories in complex systems. Here, uncertainty may arise from a system's complexity itself, or may be related to determining future developments. …

Often this makes it necessary to reduce the complexity of systems before analysing them, either by looking only at parts of a system or by focussing on a very concrete focal question in the scenario process.



ZUREK, M. B. and HENRICHS, T. (2007). Linking scenarios across geographical scales in international environmental assessments. *Technological Forecasting & Social Change* 74, pp 1282–1295. https://bit.ly/2J7IM14

Models - Calibration



Model calibration – a general principle

Principles for software model calibration:

- **Understand the key parameters**
- **Adjust basic parameters to allow model adjustment for changing conditions**

Model calibration - difficulties

Diversity and variability of traffic conditions including driver behaviour, vehicle characteristics, road geometry and demand volumes are such that, while model calibration is an essential necessity, it is a **difficult task** partly because of the **difficulty of identifying relevant parameters** in a model of a **complex system**.

Deep understanding and reasoning based on **causality**, **abstraction** and **theory** are needed rather than **deep statistical analysis**.

This will be revisited in discussing the relevance of good **artificial intelligence principles to modelling and modellers**.

Models - Big Data

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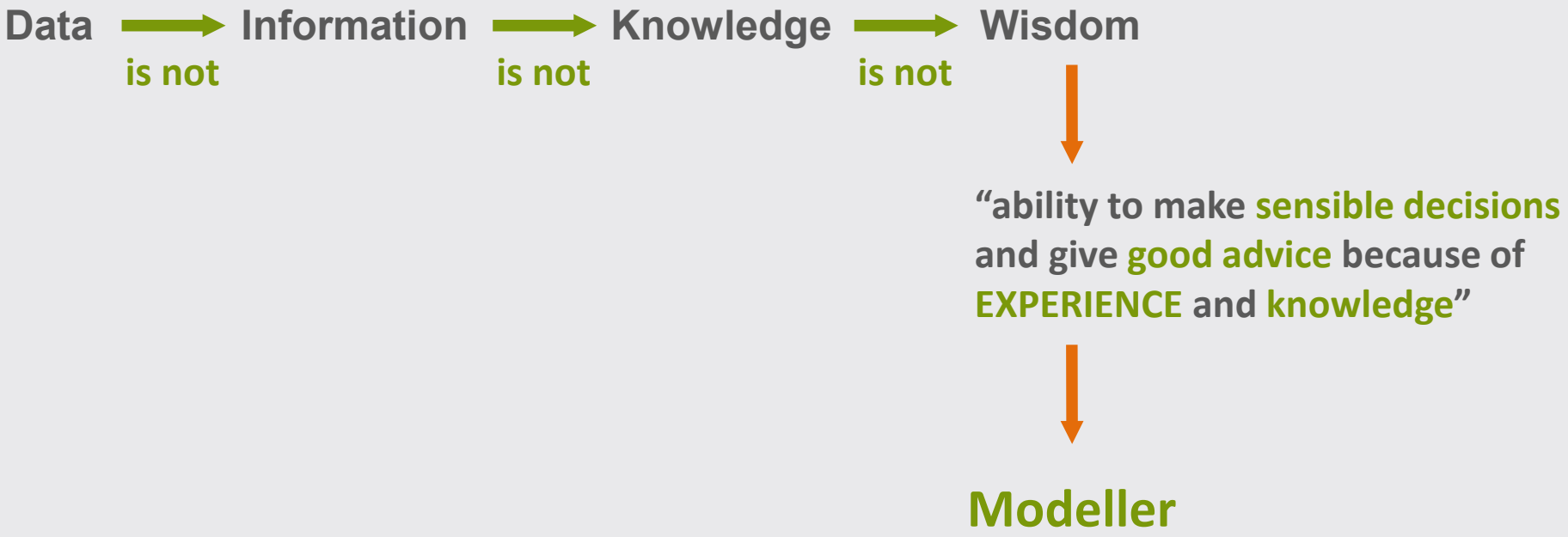
Big data – usefulness?



Better use of Big Data

Can we extract information from big data that can that can be more useful in traffic / transport modelling?
https://bit.ly/1FSZacQ

While statistical information that can be extracted from big data can have a great positive impact on modelling techniques, would there be a danger in losing the perspective of the theoretical (conceptual) basis of modelling techniques used?

Statistical analysis of big data may be useful for some purposes but it should be possible to extract information from big data that can help with improved model concepts and algorithms. For example, could it help with determining travel demand data for small and large road networks, or facilitate modelling of all-day traffic rather than morning and evening peak periods.

Modeller

- General Discussion
- Understanding and improving model outputs
- Lessons from Artificial Intelligence

Modeller - General Discussion

Smart Modeller

What is a good / smart / wise modeller?

- Importance of knowledge and experience
- Understanding the model
  - Model concepts
  - Model assumptions
  - Input data limitations
- Model as a tool
- Signs of a good model user
  - creates research topics
  - gives feedback to software developers

Dependence on technology

Bargiela (2000)

"It is paradoxical however that the development of more natural interfaces leads to unnatural adaptations or changes in the user. In the progressively tighter coupling of user to interface, the user evolves as a cyborg. "

BARGIELA, A. (2000). Strategic directions in simulation and modelling. Paper invited by the Conference of Professors and Heads of Computing. Department of Computing, The Nottingham Trent University, Nottingham, UK.

A cyborg, short for "cybernetic organism", is a being with both organic and biomechatronic body parts.

https://bit.ly/2qyn3ZN

Modeller - Understanding and improving model outputs

- Understanding the model
- Some fundamental flaws in traffic / transport modelling practice

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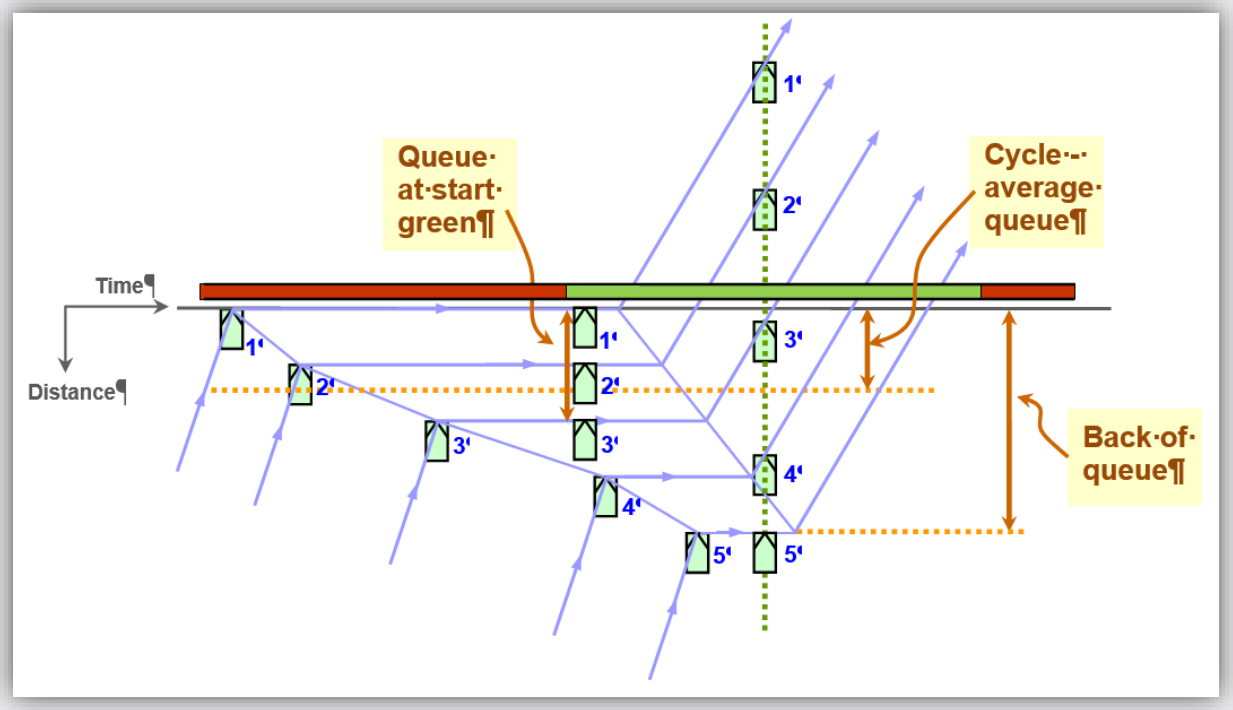
Understanding the model to question model results

- Understand the fundamentals of the model so that you can question the results and make choices about scenarios and decisions considering uncertainties
- Understand the assumptions of the model
- Understand the parameter DEFINITIONS and measurement methods. This is important in:
  - Comparison of output from different models (software)
  - Calibrating a given model using real-life data
  - Consistency in assessing alternative treatments

  (compare apples with apples)

Queue Length – An example for importance of DEFINITIONS

There are many useful definitions of queue length as shown here.
Average queue and percentile queue apply to each of these.



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First principles and rules of thumb

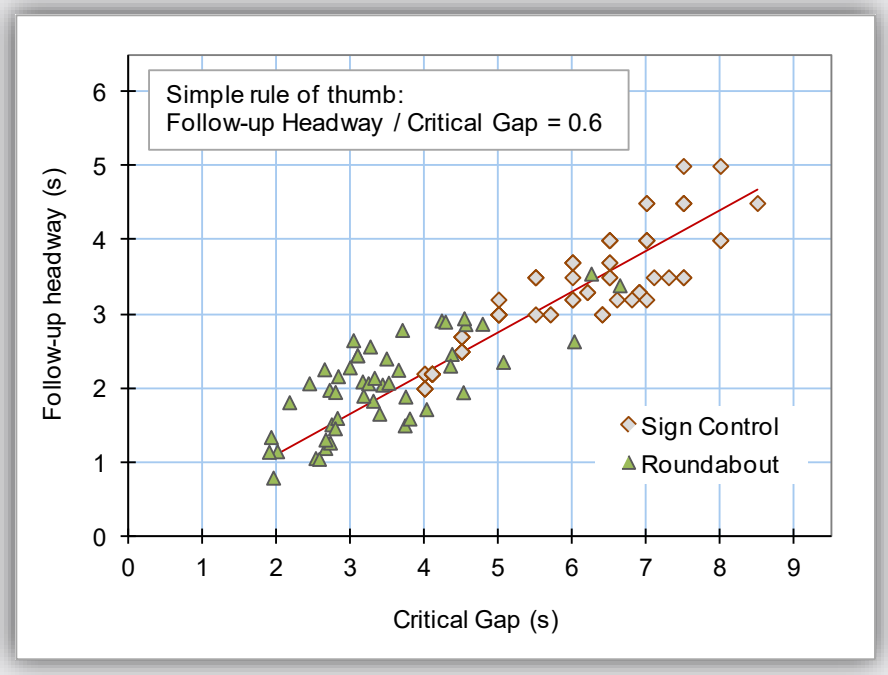
- Be able to think in terms of the "first principles" in interpreting complicated looking software results. Simple rules of thumb help.
- Appreciate that many different mathematical constructs are possible to model the same phenomenon, and many different approaches (techniques) are possible to model the same reality (think less about the "right model" and the "wrong model")

A useful rule of thumb: an example

Gap acceptance parameters representing driver behaviour:

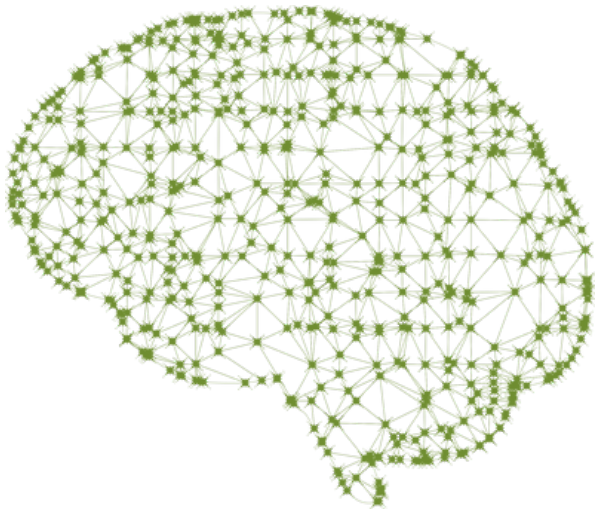
Follow-up Headway / Critical Gap ≅ 0.6

How do we interpret this?



Austroads – SIDRA Standard model data for **two-way sign control** and the Australian **roundabout** data

Modeller – Lessons from Artificial Intelligence

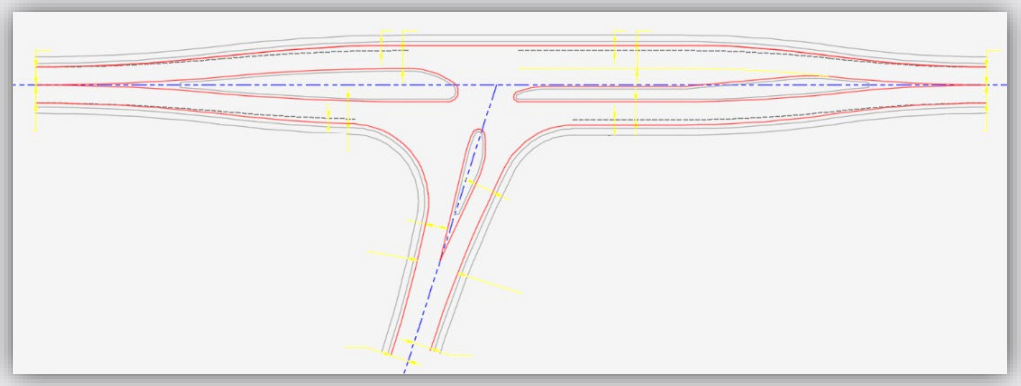


Fully automated design?

Would you like a fully automated design of an intersection or network by software (model)?

Could an AI-based software modelling tool (involving all steps from data collection to automated output) make the choices and decisions expected of "wise" modellers?

Or should a model remain simply as a tool for human decision making?

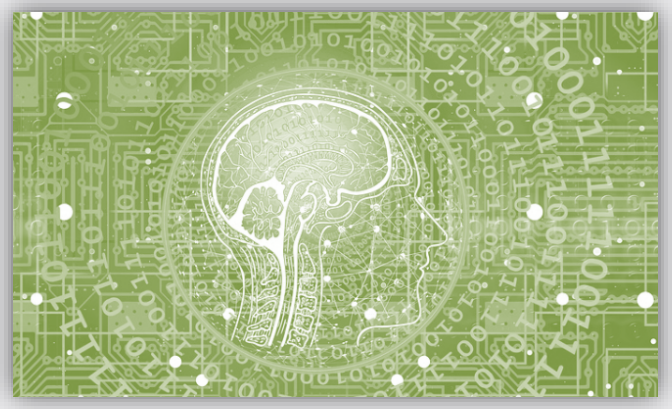


Artificial Intelligence (AI)

Artificial intelligence (AI) is intelligence exhibited by machines, in contrast to the natural intelligence displayed by humans.

Capabilities generally classified as AI include successfully understanding human speech, strategic game systems, autonomous cars, intelligent routing in content delivery networks, military simulations, and interpreting complex data.

https://bit.ly/1SVAO6t



Will computers take over the world?

When we asked this question in the near past, we would say NO.

- Hardware was bulky.
- Computing was slow.
- Memory was insufficient
- Communications were poor.

Now we have mobile phones, internet, Google, Apple, Twitter, Facebook, LinkedIn, Research Gate …

and consider the current status of work, social interactions, media, war …

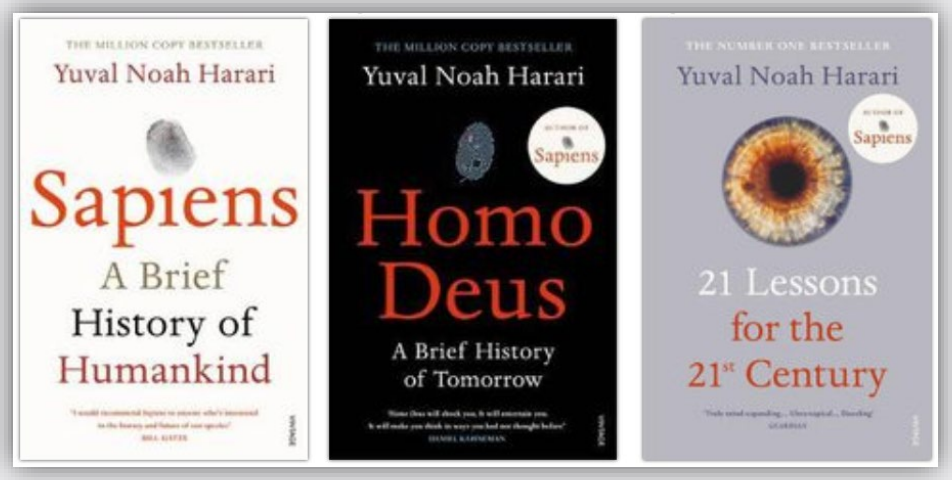
Haven't computers taken over the world?

Future of professions (1)

In Chapter 2 ("Work") in his book titled "21 lessons for the 21st century " in his series of three books after "Sapiens" and "Homo Deus", Harari states:

> "It is generally agreed that machine learning and robotics will change almost every line of work. … However, there are conflicting views about the nature of change and its imminence. "

HARARI, Y.N. (2018). 21 Lessons for the 21st Century. Jonathan Cape, London.

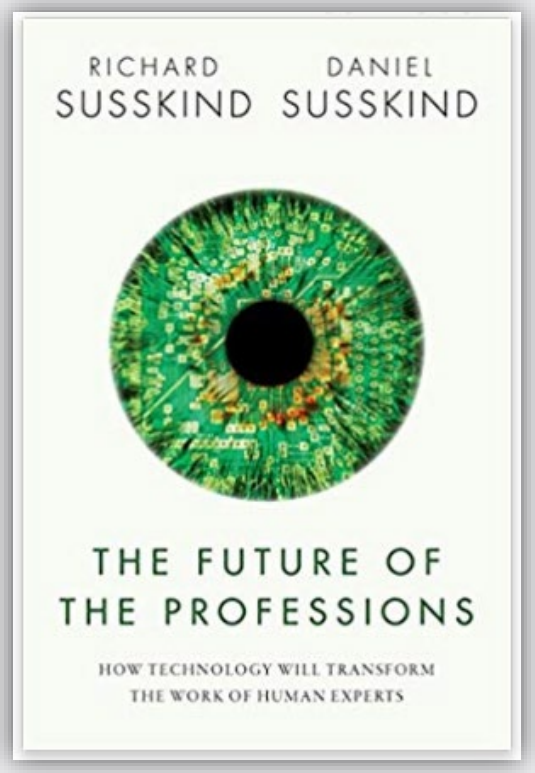


Future of professions (2)

In the "The Future of Professions" written by father and son discussing "How technology will transform the work of human experts", Richard Susskind and Daniel Susskind suggest :

> "In the medium term, during 2020s, this will not mean unemployment but retraining and redeployment. In the long run, however, … there will be a steady decline in the need for flesh and blood professionals. "

SUSSKIND, R. and SUSSKIND, D. (2015). The Future of Professions - How Technology Will Transform the Work of Human Experts. Oxford Press, Oxford.

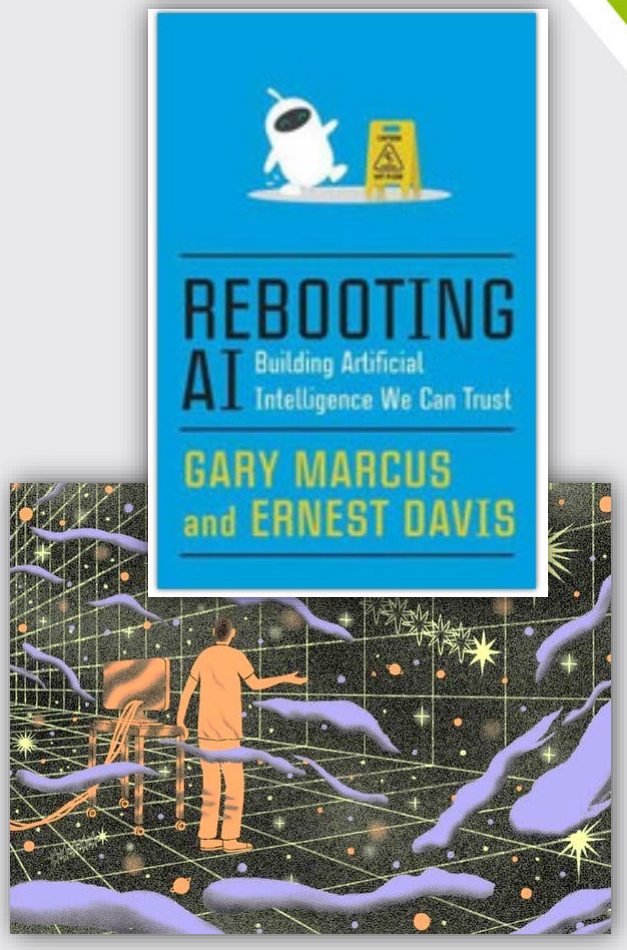


"Artificial Intelligence We Can Trust" (1)

The following recent book presents an excellent critical review of AI, pointing out its shortcomings, and gives suggestions toward better AI. The discussions have a lot of relevance to modelling principles. I'll summarise a few points.

MARCUS, G. and DAVIS, E. (2019). REBOOTING AI – Building Artificial Intelligence We Can Trust. Pantheon Books, New York.

Article "How to Build Artificial Intelligence We Can Trust" by the authors of the book (New York Times, 6 Sep 2019) https://nyti.ms/2m4QQXP



“Artificial Intelligence We Can Trust” (2)

Marcus and Davis discuss media overreporting abilities of AI, emphasise the need for deep understanding, adoptability to new and unusual circumstances, abstraction and generalisations, reasoning.

> “We need to stop building computer systems that merely get better and better at detecting statistical patterns in data sets (deep learning) and start building computer systems that … innately grasp three basic concepts: time, space and causality."
>
> "We can stick with today’s approach to A.I. and greatly restrict what the machines are allowed to do (lest we end up with autonomous-vehicle crashes and machines that perpetuate bias rather than reduce it). Or we can shift our approach to A.I. in the hope of developing machines that have a rich enough conceptual understanding of the world that we need not fear their operation.“

Insights from the Human Mind (1)

In Chapter 6 of their book, Marcus and Davis discuss 11 aspects of about how "Human Mind" works. I'll summarise some of these in this and the following four slides.

The discussions indicate the principles that modellers (practitioners), model (software) developers and researchers should pay good attention to.

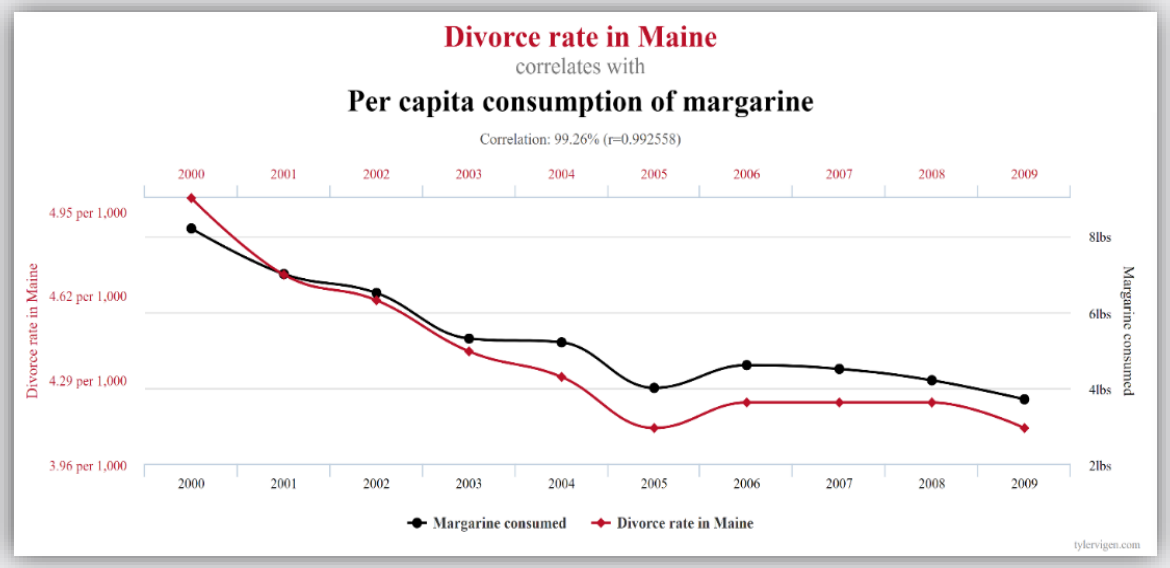
- Abstraction and generalisation play an essential role in cognition. Much of what we know is fairly abstract. A rich collection of abstract relations are used to strip very complex situations down to their essentials, giving enormous power in reasoning broadly about the world.

- Concepts that are embedded in theories are vital to effective learning. General intelligence needs to embed the facts that it acquires into richer overarching theories that help organize those facts.

Insights from the Human Mind (2)

- **Causal relations are a fundamental aspect of understanding the world. We use approximations; we know things are causally related eve if we don't know exactly why. However, the route to causal knowledge is fraught with trouble as almost every cause leads to correlations but a lot of correlations are not causal.**

From: Spurious Correlations by Tyler Vigen



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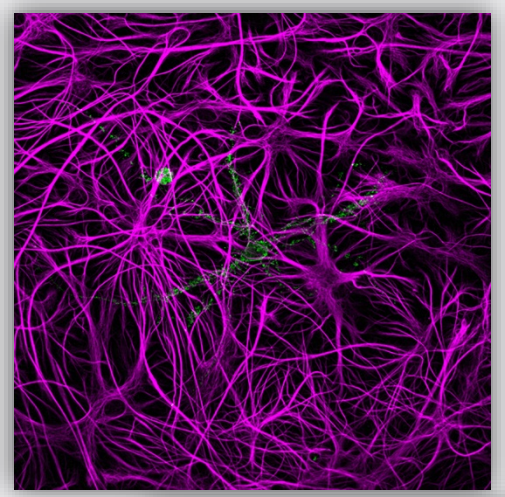
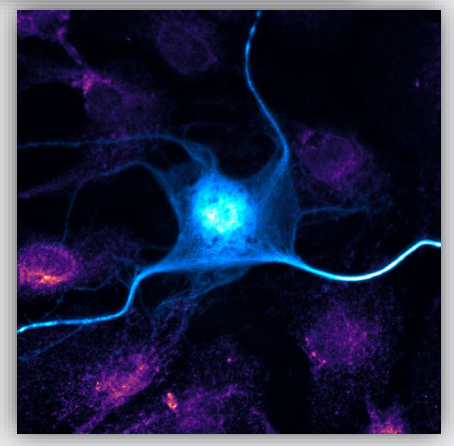
Insights from the Human Mind (3)

- Human brain has 150 distinctly identifiable areas and a vast and intricate web of connections between them. Truly intelligent and flexible systems are likely to be full of complexity much like brains.
- Cognitive systems are highly structured. Neuroscience indicates a complex picture, in which hundreds of different areas of brain each with a distinct function coalesce in different patterns to perform any one computation.
- Cognition makes extensive use of internal representations like beliefs, desires and goals. Without a rich cognitive model, there can be no robustness.





Insights from the Human Mind (4)

- **Complex cognitive structures are not blank slates. How much of the structure of mind is built in and how much of it is learned? The evidence from biology, psychology and neuroscience is overwhelming: nature and nurture work together, not in opposition.**

  Humans are likely born understanding that the world consists of enduring objects that travel on connected paths in space and time, with a sense of geometry and quantity, and the underpinnings of an intuitive psychology. It is also very likely that some aspects of language are also prewired innately.

- **We keep track of individual people and things. Our world of experience is made up of individual things that persist and change over time, and a lot of what we know is organised around particular entities, their properties, individual histories and idiosyncrasies.**

Insights from the Human Mind (5)

Marcus and David concluded:

> "Once AI can take advantage of these lessons from cognitive science, moving the paradigm revolving around big data to paradigm revolving around both big data and abstract causal knowledge, we will be in a positions to tackle one of the hardest challenges of all: the trick of endowing machines with common sense."

Are Models becoming smarter than Modellers?

In addressing the question "Are Models becoming smarter than Modellers?", I wanted to extend the discussion from the present to the future and to raise questions more than give answers so that you can try to answer this difficult question.

We would probably agree that models are becoming smarter and that models are not smarter than modellers (yet) but I wanted you to think whether models will be smarter than modellers, and possibly so much smarter that models will be modellers.

Presenter

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End of Presentation

Thank you!

Rahmi Akçelik
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