

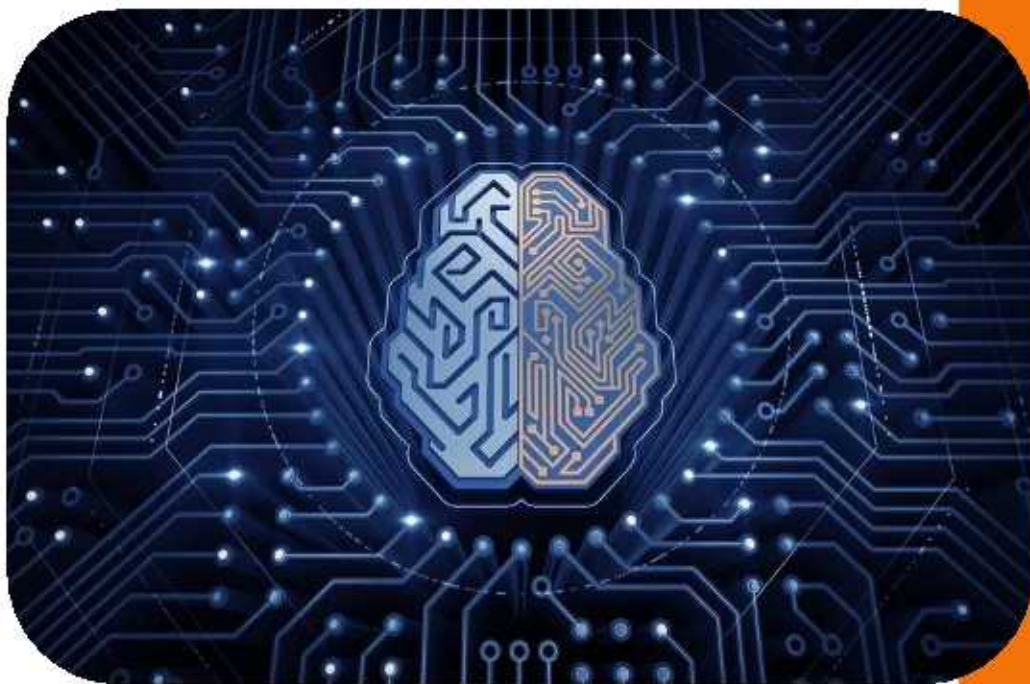
Mathematics, Artificial Intelligence and Us – learning to work together

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What is Artificial Intelligence?



'The ability of a digital computer, or computer-controlled robot, to perform tasks commonly associated with intelligent beings.'

'To make a machine do what humans do using intelligent / cognitive capacities

Perceive – rich, complex and subtle information

Learn – within an environment

Abstract – to create new meanings

Reason – to plan and decide

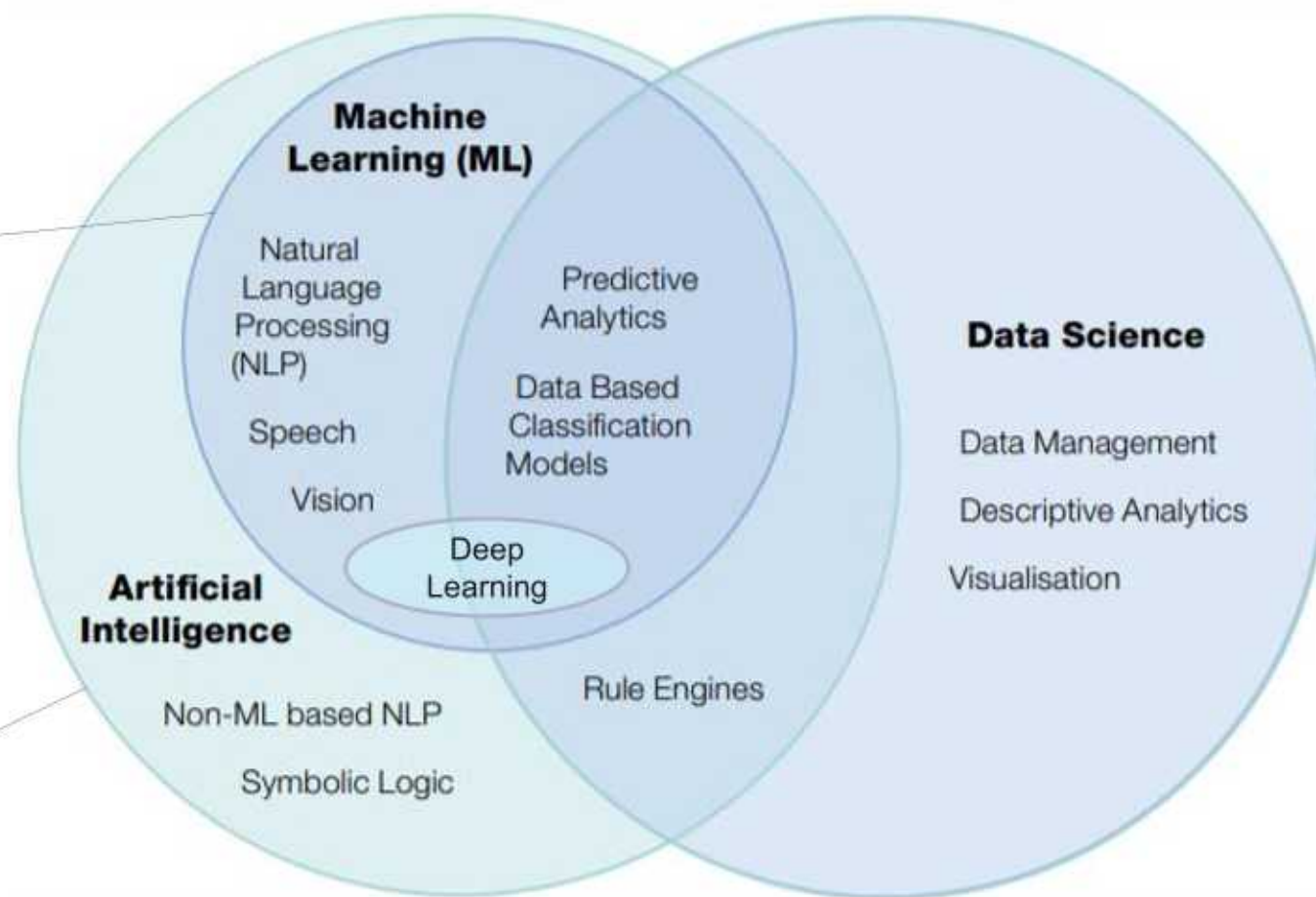
Act – to achieve rational goals.'

'Theories and techniques developed to allow computer systems to perform tasks normally requiring human or biological intelligence.'

Artificial Intelligence, Machine Learning or Data Science?

- Algorithms that help machines improve through supervised, unsupervised and reinforcement learning
- Subset of AI and Data Science

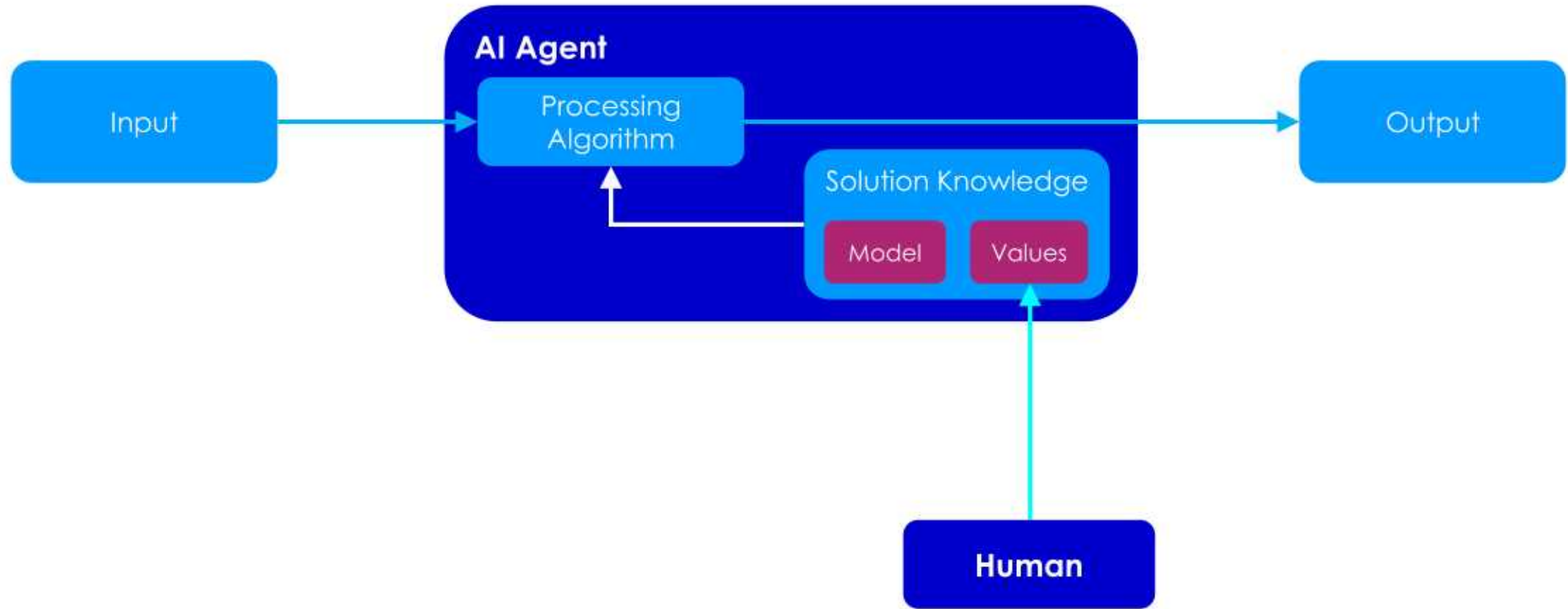
- Technology for machines to understand / interpret, learn, and make 'intelligent' decisions
- Includes machine learning among many other fields



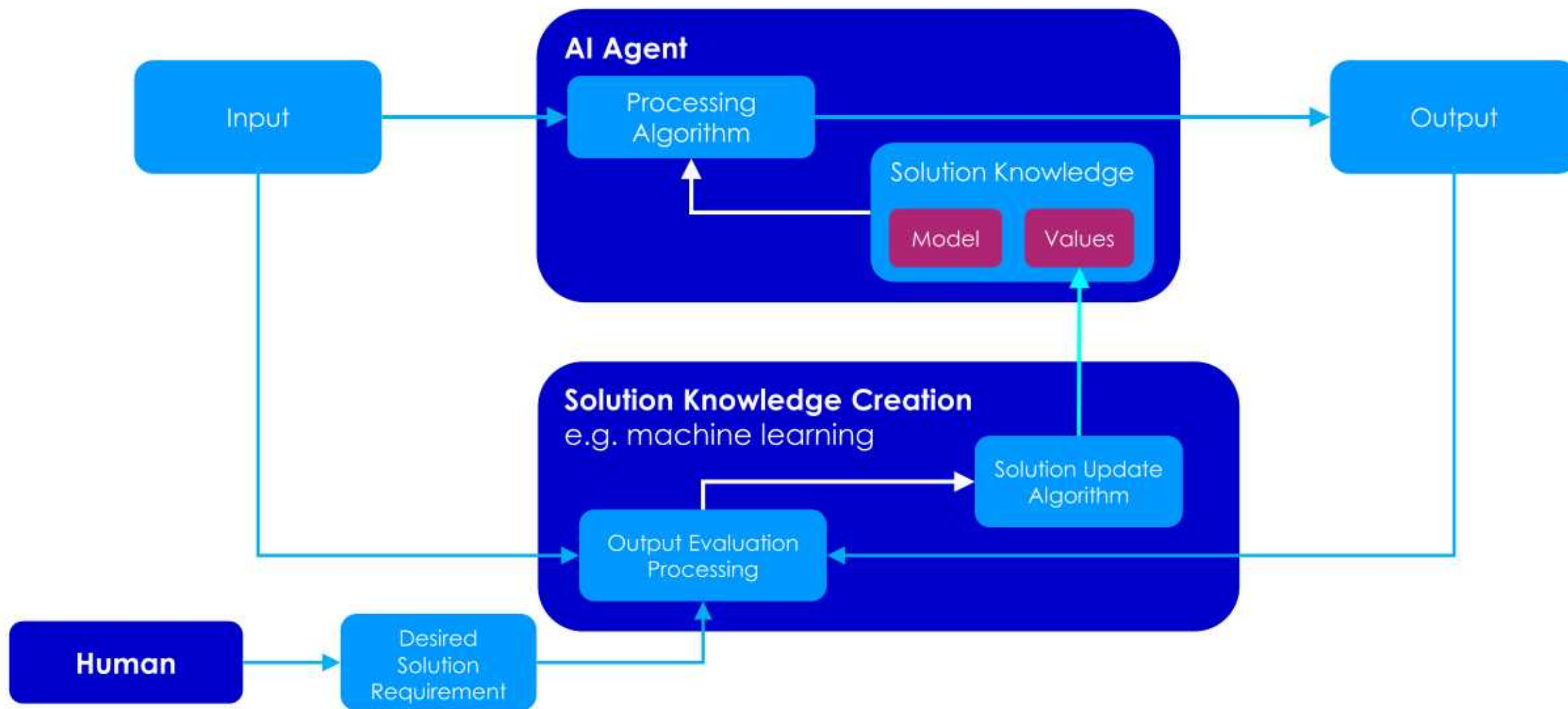
- Collection, preparation and analysis of data
- Leverages AI/ML, research, industry expertise, and statistics to make business decisions

Dstl AI Biscuit Book –
[The Dstl Biscuit Book WEB.pdf \(publishing.service.gov.uk\)](#)

Relationship between AI and Machine Learning



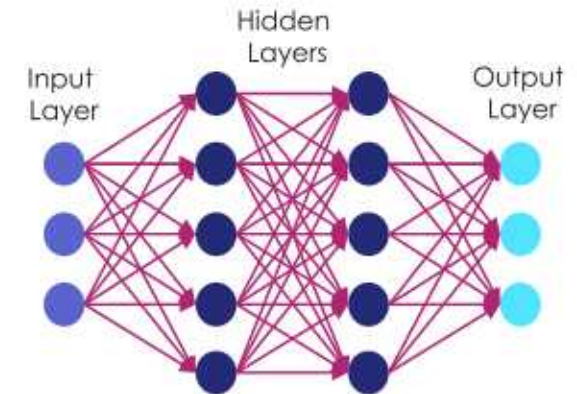
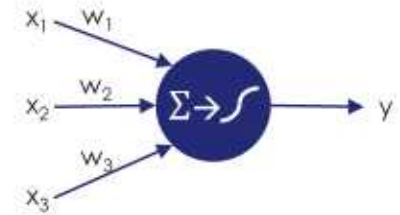
Relationship between AI and Machine Learning



How mathematics helped in the development of AI - Example

Perceptron to Multi-Layer Perceptron (MLP)

- > 1958 – Perceptron first implemented – capable of learning linearly separable functions
- > 1969 – “Perceptrons” book – impossible for a perceptron to learn XOR function → First AI winter
 - Thought that MLP networks would suffer from the same limitation
 - MLPs difficult to train due to multiple layers of perceptron nodes
- > 1970s – Backpropagation published
 - Chain rule of calculus, partial derivatives of the error function are back propagated through the network to tune the weights
- > 1982 – Backpropagation first applied to MLPs
- > 1985 – Experimental analysis of backpropagation → Active period of MLP research starts



How is Mathematics used by AI

> Operational phase

- Problem representation
 - E.g. reward function in Reinforcement Learning, data labelling in classification tasks, error functions
- Input representation
 - Numerical inputs to AI
- Processing to produce answers
 - E.g. data point similarity in classification tasks
- Output representation
 - Numerical outputs from AI
 - E.g. MLP outputs are numbers

> Training phase

- Same uses as for Operational phase

+

- Automated training – machine learning
 - Error calculation
 - Adjustment of parameters which learn the solution
 - E.g. back propagation for MLPs adjusting the weights
 - Hyper parameter tuning
 - E.g. number of layers, number of nodes in each layer, learning rate, etc.

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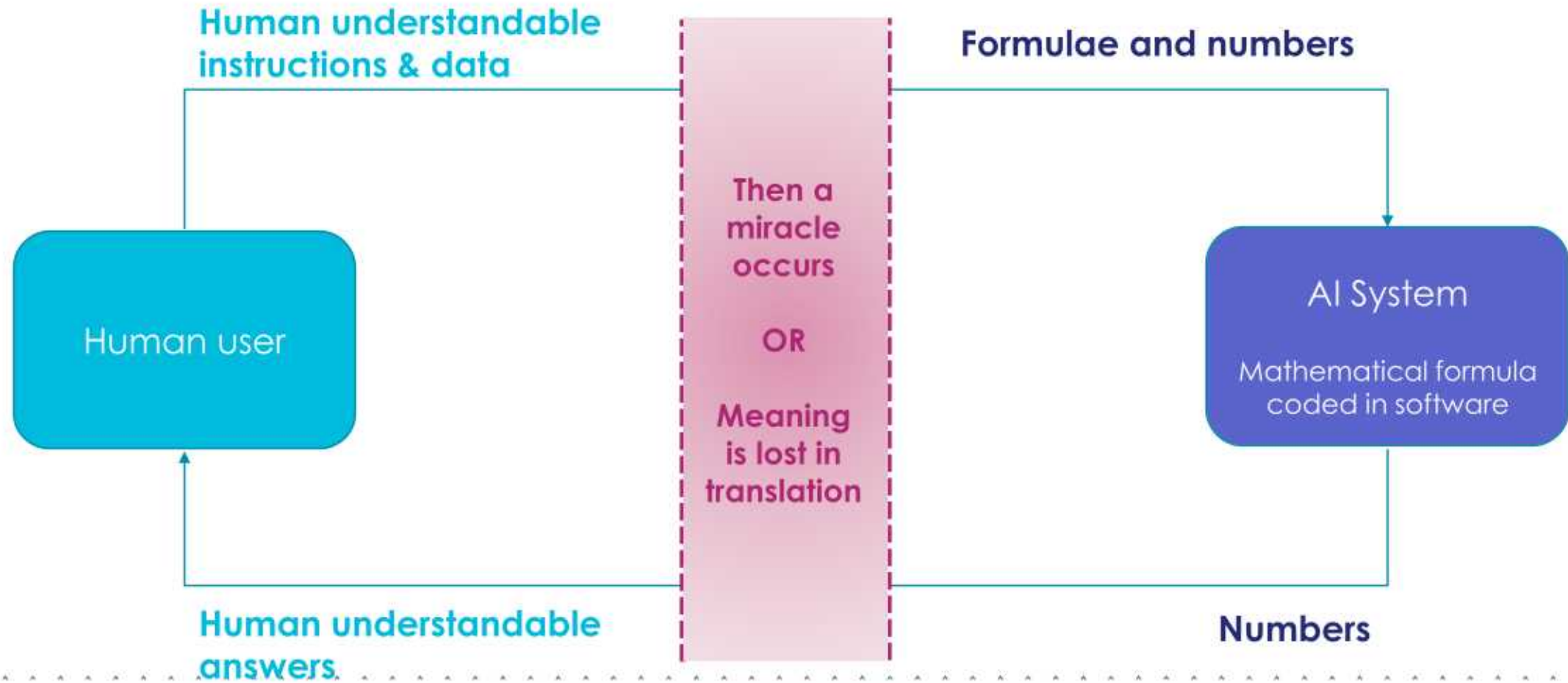
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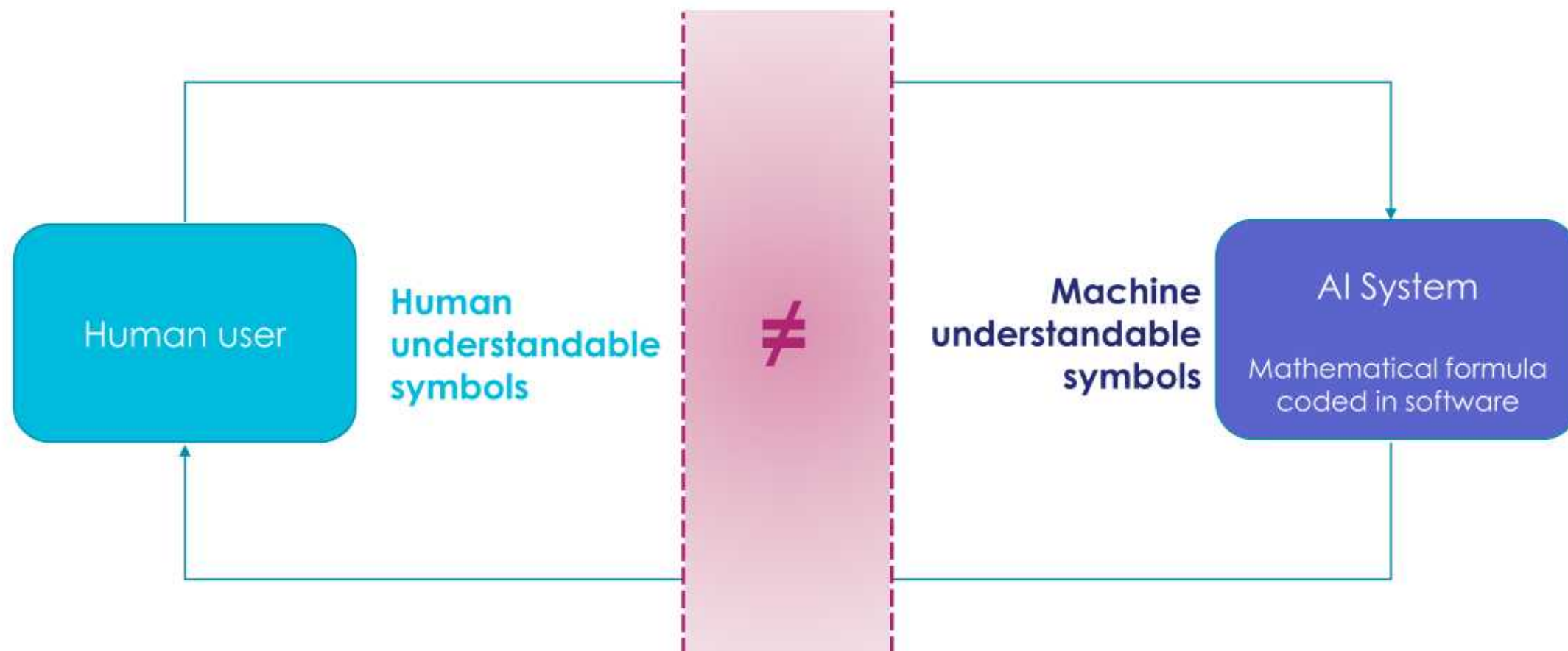
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Mathematics enables us to automate AI processing
Current AI is software which manipulates numbers

Human interaction with AI



Human interaction with AI



This is true for all software, so why the concern about AI?

Concern about AI in Defence and Security

> Will AI systems behave as desired when required?

- AI systems will only be deployed if humans have confidence in them, trust them, and are safe and secure

> Why this question?

- Everything is becoming more connected, complex, informed and faster
- Technology exceeding human capabilities so AI is becoming necessary
- AI systems are becoming prevalent in society and being proposed for controlling critical systems
- System complexity increasing → Emergent behaviours (some good, some bad)
- Humans don't understand the system any more (or know someone who does 😊)
- Media reporting focuses on negative aspects → Fear that humans will lose control of AI

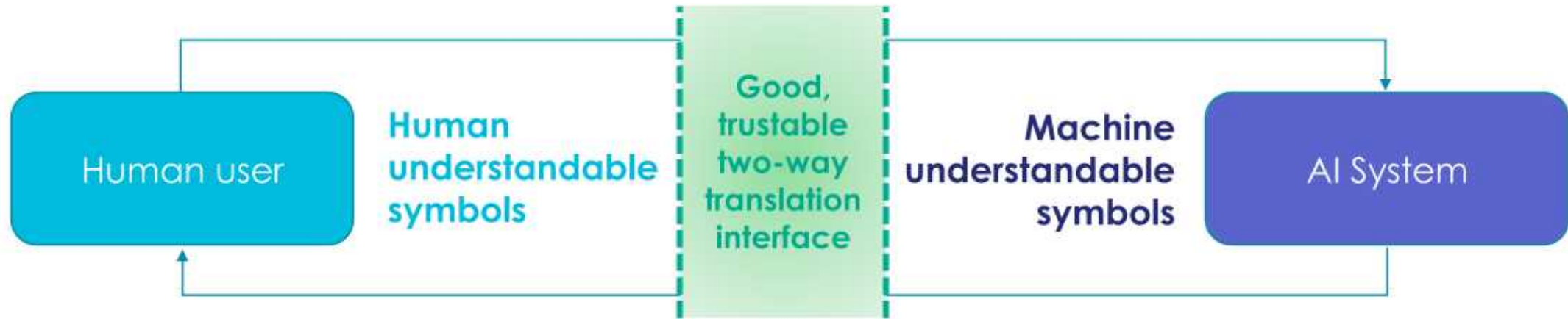
> All leads to a human lack of trust in AI systems

Why the lack of trust in AI?

	Withdrawing money from a cash machine	Controlling an autonomous vehicle
Human conscious input	Request to withdraw money and amount of money	Destination location
Subconscious input	None	Get me there safely Don't break any laws Follow the rules of the road
Assumptions	Cash machine will provide cash securely and accurately	Software knows how to drive and is safe and secure
Machine input	Bank account details – from bank card inserted into the cash machine	Sensors on the vehicle
Software processing	Check account for sufficient funds If sufficient funds then: Provide cash Update bank account fund value	Too much to write on this slide
Software output	Instruct cash machine to present money to user	Vehicle control parameters e.g. speed, steering, breaking, etc.
	<i>Straightforward representation understandable by human and computer</i> <i>Testable assumptions</i>	<i>Complex input and processing</i> <i>Difficult to represent in a way understandable by human and computer</i> <i>Assumptions are difficult to test</i> <i>Large amount of subconscious processing performed when a human drives</i>

A reason - Complexity of the task and of the input

Mathematics, AI and Us - Working together



> Interface complexity depends on the level of capability on either side of the interface

- Human capability ranges from AI user to an AI expert
- AI capability ranges from AI supporting the human user while under human control, to AI operating autonomously without human control (note human always provides task instruction)
- Interface can be a human expert, software or AI

> Computational mathematics can provide and test / verify the interface irrespective of form

Mathematics, AI and Us - Computational Expertise



> Computational expertise on each side must be balanced

- If the level of expertise on one side goes down, the expertise on the other must go up

> AI's usefulness lies in compensating for human limitations – cognitive or physical

- Humans are limited by biology
- AI is limited by maths and processing power
- Mathematics makes AI possible, and AI has the potential to keep humans safe

> Application of mathematics is constantly evolving based on human need and processing devices

- Abacus to microprocessor to supercomputer to quantum computer
- Mathematics, computing and AI have influenced the evolution of each other

> Mathematics is the solution for humans to trust and fully work with AI fully

> The challenge now is: how does mathematics need to evolve to enable such a future?



Thank you

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