Knowledge Representation

and

Reasoning

Symbols and Thought

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Knowledge and Reasoning – The Core of Intelligence

What does the agent **know**[*]
and

what **else** does the agent **know** as a **consequence** of what it knows?

[*] We are concerned with explicit declarative knowledge
and not implicit procedural or tacit knowledge

Representation

Semiotics: A symbol is something that stands for something else
Examples.

- The "number" seven can be represented in many different ways.
- Road signs – curves, pedestrian crossing, schools, U-turns, eating places…

All languages, both spoken and written, are semiotic systems

Biosemiotics: How complex behaviour emerges when
simple systems interact with each other through signs.

For example, pheromone trails left by ants

Recap from SMAI

Reasoning

The manipulation of symbols in a *meaningful* manner.

Maths is replete with *algorithms* we use –

- Addition and multiplication of multi-digit numbers

- Long division

- Solving systems of linear equations

- Fourier transforms, convolution…

Perception is an Internal Process

"I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we locate them are concerned, and that they reside in consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated"
    —Galileo Galilei, *The Assayer* (published 1623).

"Philosophy is written in this grand book, the universe ...
It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures;....

Galileo showed that geometry could be used to represent and reason about motion.

Galileo Galilei
Born15 February 1564
Pisa, Duchy of Florence, Italy

Source: http://en.wikipedia.org/wiki/Galileo_Galilei

Recap from SMAI

Thomas Hobbes: The Grandfather of AI

It was the English philosopher Thomas Hobbes (1588-1679) who first put forward the view that thinking is the manipulation of symbols.

Galileo had said that all reality is mathematical in the sense that everything is made up of particles, and our sensing of smell or taste was how we reacted to those particles.

Hobbes extended this notion to say that thought too was made up of (expressed in) particles which the thinker manipulated.
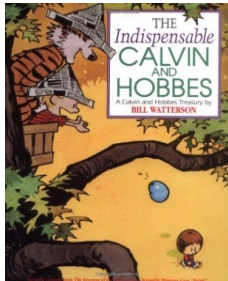
Hobbes was influenced by Galileo. Just as geometry could represent motion, thinking could be done by manipulation of mental symbols.
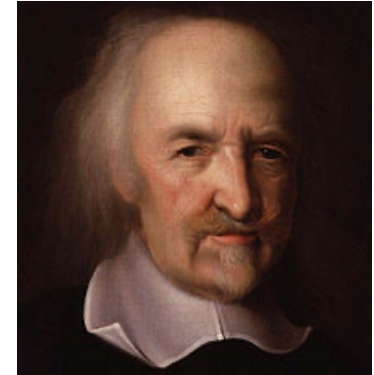
John Haugeland, AI: The Very Idea, 1985

Recap from SMAI

Reasoning = Computation

In *De Corpore* Hobbes first describes the view that reasoning is computation early in chapter one. "By reasoning", he says "I understand computation. And to compute is *to collect the sum of many things added together at the same time, or to know the remainder when one thing has been taken from another*. To reason therefore is the same as *to add* or *to subtract*" (Hobbes 1655, 1.2).

Stanford Encyclopedia of Philosophy
http://plato.stanford.edu/entries/hobbes/

Thomas Hobbes
Born 5 April 1588
Westport near Malmesbury, Wiltshire, England

Bill Watterson named the character Hobbes after him.

Recap from SMAI

Thoughts = Symbols

René Descartes (1596 –1650)

Animals are wonderful *machines*.
Human beings are too,

except that they possess a *mind*.

Galileo: Motion → Geometry
Decartes: Geometry → Algebra

Everything is "applied math"

… even "thought"

Decartes: Thoughts themselves are symbolic representations

Born 31 March 1596
La Haye en Touraine,
Kingdom of France

Recap from SMAI

Dualism: Mind and Body

Decartes: A symbol and what it symbolizes are two different things

algebraic manipulation = thinking   subject of thought

mind   ≠   world

What makes a notation suitable for symbolizing?
What makes a suitable notation actually symbolize?

How can thought and matter interact?

mind-body problem

Recap from SMAI

The Paradox of Mechanical Reason

IF
Reasoning is the manipulation of meaningful symbols according to rational rules
THEN
Who is manipulating the symbols?

It can be either mechanical or meaningful but how can it be both?

How can a mechanical manipulator pay attention to meaning?

faculty of will?

transcendental ego?

or

the *humunculus*? A little man?

For some more recent thoughts on this question see
Hofstadter: *Godel, Escher, Bach*
Hofstadter & *Dennet: The Mind's I*
Hofstadter: *I am a Strange Loop*

John Haugeland, AI: The Very Idea, 1985

Recap from SMAI

Physical Symbol Systems

Symbol : A perceptible something that stands for something else.
- alphabet symbols, numerals, road signs, musical notation

Symbol System: A collection of symbols – a pattern
- words, arrays, lists, even a tune

Physical Symbol System: That obeys laws of some kind, a formal system
- long division, an abacus, an algorithm

Recap from SMAI

The Physical Symbol System Hypothesis

"A physical symbol system has the **necessary** and **sufficient** means for general intelligent action."

— Allen Newell and Herbert A. Simon

The ability to manipulate symbols - Symbolic AI / Classical AI

Good Old Fashioned Artificial Intelligence (GOFAI)

– John Haugeland in *AI: The Very Idea*

Recap from SMAI

Symbols

Communication is commonplace amongst living creatures.
- birds have a wide variety of songs
- whales communicate across long distances in the seas
- dogs wag their tails and bark at strangers

Humankind is the only species that *consciously* uses symbols to represent information.
- ants leave pheromone trails for others to follow
- many mammals mark their territory by leaving chemical markers

The earliest humans known to engrave symbols on clay were the Sumerians in ancient Mesopotamia, which is often known as the cradle of civilization.

The first engravings were pictographs, but soon evolved into more abstract entities like symbols from an alphabet.

Cuneiform

"First developed around 3200 B.C. by Sumerian scribes in the ancient city-state of Uruk, in present-day Iraq, as a means of recording transactions, cuneiform writing was created by using a reed stylus to make wedge-shaped indentations in clay tablets.

Cuneiform as a robust writing tradition endured 3,000 years. The script—not itself a language—was used by scribes of multiple cultures over that time to write a number of languages other than Sumerian, most notably Akkadian, a Semitic language that was the lingua franca of the Assyrian and Babylonian Empires."

Ancient Gilgamesh tablet
NBC news

It was replaced by alphabetic writing sometime after the first century A.D.

The World's Oldest Writing

Alphabets, Words, Sentences

The breakthrough came when symbols were not only employed as images representing objects and events like a hunt, but abstract entities like sounds.

A set of symbols forms an alphabet.

Alphabetic symbols could now come together to form words, and words could form sentences.

The spoken word became the written word.

Different natural languages evolved in many regions of the world.

The common theme was writing.

Computing Machines

- The earliest machines were mechanical non-symbolic machines

- They did not *represent* symbols explicitly. They used gears to *count* numbers

- Babbage's Difference Engine did use symbols in the *punched card input*

- With electronics the design of the machine itself became more and more digital

- Now we take it for granted that the digital computer operates on 1s and 0s

- Our primary concern is to lift the machines up to our languages. Thus groups of 0s and 1s form higher level symbols, whose meaning is easily decipherable by us

- Language and logic preceded computers

- Our quest is to impart both to machines

Mechanical Arithmetic

Blaise Pascal (1623 –1662) invented the mechanical calculator using lantern gears in 1642. He went through 50 prototypes before presenting his first machine to the public in 1645.

Called *Arithmetic Machine, Pascal's Calculator* and later *Pascaline*, this calculating machine could add and subtract two numbers directly and multiply and divide by repetition.

Pascal received a Royal Privilege in 1649 that granted him exclusive rights to make and sell calculating machines in France. By 1654 Pascal had sold about twenty machines, but the cost and complexity of the Pascaline was a barrier to further sales, and production ceased in that year.

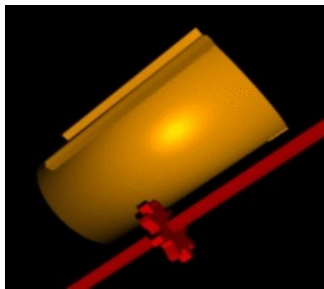Born: 19 June 1623
Clermont-Ferrand,
Auvergne, France

Source: http://en.wikipedia.org/wiki/Pascal%27s_calculator

Recap from SMAI

The Stepped Reckoner

Gottfried Wilhelm von Leibniz (1646 –1716) was a German mathematician and philosopher. He started to work on his own calculator after Pascal's death.


First he invented the Leibniz wheel or stepped drum in 1673, which was used for three centuries until the advent of the electronic calculator in the mid-1970s.

http://en.wikipedia.org/wiki/Gottfried_Leibniz

The Stepped Reckoner was a digital mechanical calculator invented by Leibniz around 1672 and completed in 1694. The machine performs multiplication by repeated addition, and division by repeated subtraction with 8 digit numbers.
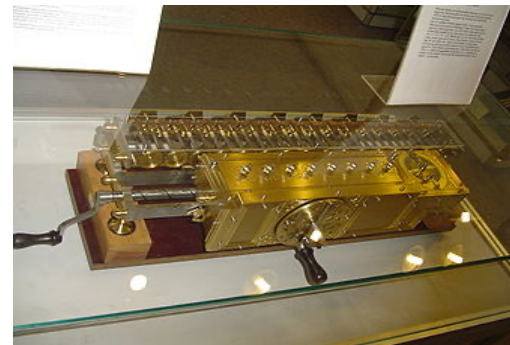

Source: http://en.wikipedia.org/wiki/Stepped_Reckoner

Born: July 1, 1646
Leipzig,
Electorate of Saxony,
Holy Roman Empire

Recap from SMAI

The Analytic Engine

The Analytical Engine was a proposed mechanical general-purpose computer designed by Charles Babbage

It was first described in 1837 as the successor to Babbage's Difference Engine. The Analytical Engine incorporated an arithmetic logic unit, control flow in the form of conditional branching and loops, and integrated memory, making it the first design for a general-purpose computer that could be described in modern terms as Turing-complete.

Source: http://en.wikipedia.org/wiki/Analytical_Engine
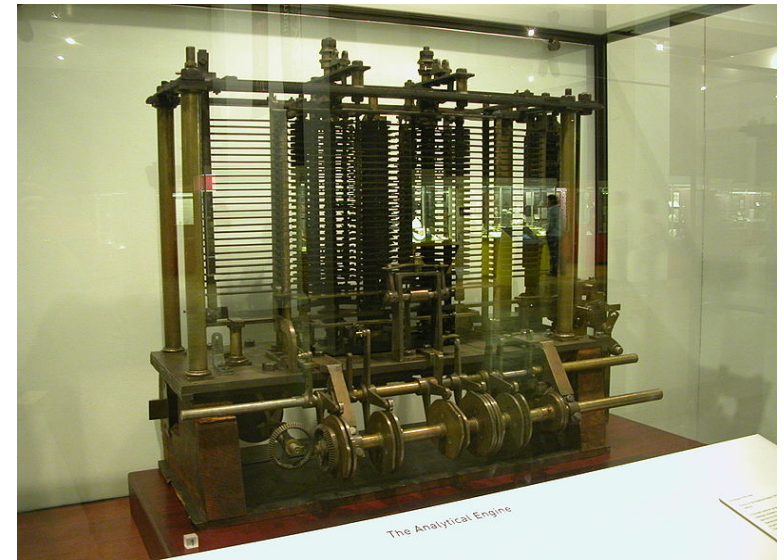
Trial model of a part of the Analytical Engine, built by Babbage, as displayed at the Science Museum (London)

Recap from SMAI

Next

LOGIC