FOUNDATIONS OF COMPUTING P/T

TUTORIAL 1

SOME OF THE IDEAS BEHIND COMPUTING

The modified extract below is taken from:
http://www.cs.unm.edu/~luger/ai-final/chapter1.html

It is from the book *Artificial Intelligence: Structures and Strategies for Complex Problem Solving* by George Luger
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Everyone wants to know...

Quotation from the ancient Greek writer, ARISTOTLE, the opening sentence of the *Metaphysics*:

> 'Hear the rest, and you will marvel even more at the crafts and resources I have contrived. Greatest was this: in the former times if a man fell sick he had no defense against the sickness, neither healing food nor drink, nor unguent; but through the lack of drugs men wasted away, until I showed them the blending of mild simples wherewith they drive out all manner of diseases. . . .'

A second quotation, this time from the ancient Greek dramatist AESCHYLUS, from his work *Prometheus Bound*:

> 'It was I who made visible to men's eyes the flaming signs of the sky that were before dim. So much for these. Beneath the earth, man's hidden blessing, copper, iron, silver, and gold--will anyone claim to have discovered these before I did? No one, I am very sure, who wants to speak truly and to the purpose. One brief word will tell the whole story: all arts that mortals have come from Prometheus.'

Prometheus speaks of the fruits of his sins against the Greek gods of Olympus: his purpose was not merely to steal fire for the human race but also to enlighten humanity through the gift of intelligence or 'nous' : the rational mind. This intelligence forms the foundation for all of human technology and ultimately all human civilization. The work of Aeschylus, the classical Greek dramatist, illustrates a deep and ancient awareness of the extraordinary power of knowledge.

Though Prometheus's action freed humanity from the sickness of ignorance, it also earned him the wrath of the god Zeus. Outraged over this theft of knowledge that previously belonged only to the gods of Olympus, Zeus commanded that Prometheus be chained to a barren rock to suffer the ravages of the elements (i.e. all weathers) for eternity. The notion that human efforts to gain knowledge constitute an offense against the laws of God or nature is deeply ingrained in Western thought. It is the basis of the story of Eden and appears in the work of Dante and Milton. Both Shakespeare and the ancient Greek tragedians portrayed intellectual ambition as the cause of disaster. The belief that the desire for knowledge must ultimately lead to disaster has persisted throughout history, enduring the Renaissance in the Middle Ages (Leonardo da Vinci etc.), the Age of Enlightenment (eighteenth century ideas preceding the French Revolution), and even the scientific and philosophical advances of the nineteenth and twentieth centuries. Indeed, rather than dispelling this ancient fear of the consequences of intellectual ambition, modern technology has only made those consequences seem likely, even imminent.[…]

Let us go back to consider the genius of Aristotle, or as Dante in the Divine Comedy refers to him, "the master of them that know". Aristotle wove together the insights, wonders, and fears of the early Greek tradition with the careful analysis and disciplined thought that were to become the standard for more modern science.

For Aristotle, the most fascinating aspect of nature was change. In his Physics, he defined his "philosophy of nature" as the "study of things that change". He distinguished between the matter and form of things: a sculpture is fashioned from the material bronze and has the form of a human. Change occurs when the bronze is moulded to a new form.

The matter/form distinction provides a philosophical basis for modern notions such as symbolic computing and data abstraction. In computing (even with numbers) we are manipulating patterns that are the forms of electromagnetic material, with the changes of form of this material representing aspects of the solution process. Abstracting the form from the medium of its representation not only allows these forms to be manipulated computationally, but also provides the promise of a theory of data structures, the heart of modern computer science. **Question 1**

In his *Metaphysics*, beginning with the words "All men by nature desire to know", Aristotle developed a science of things that never change, including his cosmology and theology. More relevant to computing, however, was Aristotle's epistemology or analysis of how humans "know" their world, discussed in his *Logic*. Aristotle referred to logic as the "instrument" (organon), because he felt that the study of thought itself was at the basis of all knowledge. In his *Logic*, he investigated whether certain propositions can be said to be "true" because they are related to other things that are known to be "true". Thus if we know that "all men are mortal" and that "Socrates is a man", then we can conclude that "Socrates is mortal". This argument is an example of what Aristotle referred to as a 'syllogism' using the deductive form *modus ponens*. Although the formal axiomatization of reasoning needed another two thousand years for its full flowering in the works of Gottlob Frege, Bertrand Russell, Kurt Gödel, Alan Turing, Alfred Tarski, and others, its roots may be traced to Aristotle. **Question 2**

Renaissance thought, building on the Greek tradition, initiated the evolution of a different and powerful way of thinking about humanity and its relation to the natural world. Science began to replace mysticism as a means of understanding nature. Clocks and, eventually, factory schedules superseded the rhythms of nature for thousands of city dwellers. Most of the modern social and physical sciences found their origin in the notion that processes, whether natural or artificial, could be mathematically analyzed and understood. In particular, scientists and philosophers realized that thought itself, the way that knowledge was represented and manipulated in the human mind, was a difficult but essential subject for scientific study. **Question 3**

Perhaps the major event in the development of the modern world view was the Copernican revolution, the replacement of the ancient Earth-centered model of the universe with the idea that the Earth and other planets are actually in orbits around the sun. After centuries of an "obvious" order, in which the scientific explanation of the nature of the cosmos was consistent with the teachings of religion and common sense, a drastically different and not at all obvious model was proposed to explain the motions of heavenly bodies. For perhaps the first time, our ideas about the world were seen as fundamentally distinct from that world's appearance. This split between the human mind and its surrounding reality, between ideas about things and things themselves, is essential to the modern study of the mind and its organization. This breach was widened by the writings of Galileo, whose scientific observations further contradicted the "obvious" truths about the natural world and whose development of mathematics as a tool for describing that world emphasized the distinction between the world and our ideas about it. It is out of this breach that the modern notion of the mind evolved: introspection became a common motif in literature, philosophers began to study epistemology[1] and mathematics, and the systematic application of the scientific method rivalled the senses as tools for understanding the world.

In 1620, Francis Bacon's *Novum Organun* offered a set of search techniques for this emerging scientific methodology. Based on the Aristotelian and Platonic idea that the "form" of an entity was equivalent to the sum of its necessary and sufficient "features", Bacon articulated an algorithm for determining the essence of an entity. First, he made an organized collection of all instances of the entity, enumerating the features of each in a table. Then he collected a similar list of negative instances of the entity, focusing especially on near instances of the entity, that is, those that deviated from the "form" of the entity by single features. Then Bacon attempts - this step is not totally clear - to make a systematic list of all the features essential to the entity, that is, those that are common to all positive instances of the entity and missing from the negative instances. **Question 4**

It is interesting to see a form of Francis Bacon's approach to concept learning reflected in modern AI algorithms for Version Space Search. An extension of Bacon's algorithms was also part of an AI program for discovery learning, suitably called Bacon (Langley et al. 1981). This program was able to induce many physical laws from collections of data related to the phenomena. It is also interesting to note that the question of whether a

[1] The theory of knowledge

general purpose algorithm was possible for producing scientific proofs awaited the challenges of the early twentieth century mathematician Hilbert (his Entscheidungsproblem) and the response of the modern genius of Alan Turing (his Turing Machine and proofs of computability and the halting problem); see Davis et al. (1976).

Although the first calculating machine, the abacus, was created by the Chinese in the twenty-sixth century BC, further mechanization of algebraic processes awaited the skills of the seventeenth century Europeans. In 1614, the Scots mathematician, John Napier, created logarithms, the mathematical transformations that allowed multiplication and the use of exponents to be reduced to addition and multiplication. Napier also created his bones that were used to represent overflow values for arithmetic operations. These bones were later used by Wilhelm Schickard (1592-1635), a German mathematician and clergyman of Tübingen, who in 1623 invented a Calculating Clock for performing addition and subtraction. This machine recorded the overflow from its calculations by the chiming of a clock. **Question 5**

Another famous calculating machine was the Pascaline that Blaise Pascal, the French philosopher and mathematician, created in 1642. Although the mechanisms of Schickard and Pascal were limited to addition and subtraction - including carries and borrows - they showed that processes that previously were thought to require human thought and skill could be fully automated. As Pascal later stated in his *Pensées (Thoughts)* (1670), "The arithmetical machine produces effects which approach nearer to thought than all the actions of animals".

Pascal's successes with calculating machines inspired Gottfried Wilhelm von Leibniz in 1694 to complete a working machine that became known as 'the Leibniz Wheel'. It integrated a moveable carriage and hand crank to drive wheels and cylinders that performed the more complex operations of multiplication and division. Leibniz was also fascinated by the possibility of an automated logic for proofs of propositions. Returning to Bacon's entity specification algorithm, where concepts were characterized as the collection of their necessary and sufficient features, Liebniz conjectured a machine that could calculate with these features to produce logically correct conclusions. Liebniz (1887) also envisioned a machine, reflecting modern ideas of deductive inference and proof, by which the production of scientific knowledge could become automated, a calculus for reasoning. **Questions 7**