

Chapter 2

Computation: Brief History Prior to the 1900s

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Computation, as a human activity, has a long history extending back to such ancient civilizations as Egypt, Sumeria (Babylon), Assyria, Greece, and Rome and the later civilizations of medieval Europe. It was used in commerce, agriculture and astronomy. However, it was not an activity of the common man in the street.

Egyptian mathematics is known partly from studies of the large Rhind papyrus, which is possessed by the British museum (and a small piece of which is in the Brooklyn museum according to Carl Boyer's "A History of Mathematics", John Wiley 1968, which we refer to as a source for some of the history which we summarize below). Despite their conjectured computational prowess in building the quite perfectly shaped pyramids, Egyptian mathematicians subsequently dropped behind their Sumerian colleagues in capabilities. This may have been due to the awkward and inelegant hieroglyphic notation for Egyptian numerals.

Sumerians lived in the region known as Mesopotamia, the fertile valley between the Tigris and Euphrates rivers which is now Iraq. Their principal city Babylon, of biblical renown, gave its name, Babylonia, to their culture and civilization which flourished from about 2000BCE to 600BCE. The Sumerians developed the earliest form of written language. It comes down to our attention in the guise of thousands of preserved clay tablets on which are carved symbols in cuneiform (wedge-shaped) patterns. Some of these symbols are numerals denoting natural numbers (positive integers) and were involved in practical computations for agriculture and business. Many tablets studied by archeologists in records of the Hammurabi dynasties, 1800–1600BCE, exhibit number systems such as the common base 10 numerals and an unusual one utilizing base 60 numerals in their astronomy. Base 10 numerals were used in daily transactions. In fact, the present-day positional notation for decimal numerals, where position of a digit is determined by a power of 10, was in use by the Babylonians. Its facilitation of numerical computations like addition

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is familiar to us. An important symbol in positional notation, the zero, was not initially available but was eventually invented by the Babylonians. Their more complex computations beyond addition included special tables for multiplication. Given this fairly sophisticated state of numerical computation in ancient Babylonia it is surprising that later civilizations did not develop more complex concepts for computations.

As the center of ancient civilization slowly moved toward the Grecian cities and lands on the Mediterranean sea, Babylonian mathematics moved with it. It was taken up by two Greek groups, one led by Thales and the other by Pythagoras. The Pythagoreans practiced various nonconformist cult-like philosophies. Although they developed new mathematics for geometry, they did not do much to advance computation methods. They coined the words “philosophy” to describe “love of wisdom” and “mathematics” to describe “that which is learned”. As this indicates, they regarded mathematics as a much broader intellectual activity which emphasizes love of wisdom rather than practical computational goals. Nevertheless, the Pythagorean motto is said to have been “All is number.”, which may reflect the influence of the Babylonians who attached numerical measures to compute almost everything, from the motions of heavenly bodies to the values of their slaves.

As opposed to the Pythagoreans, the growing society of ordinary Greek citizens was a society of shrewd traders and business men and their needs were satisfied by a fairly low level of computation. They used two numeral notations for the integers, the more primitive one resembling the later Roman system with a special symbol for the number 5. We know the Roman numeral notation is less suitable for computation than the positional decimal notation. Both Greek numeral systems were weak in the way they represented fractions. Decimal positional notation for fractions was rarely used by the Greeks or other societies until the Renaissance.

Around 600–400BCE deductive methods were introduced into mathematics and adopted later by Euclid in his *Elements* books on geometry. This was the age of Plato and Aristotle. Deductive computations were highly prized by the Platonic school. In his book *The Republic*, Plato states that *arithmetic* theory, by which he meant deductive proofs, is superior to computation (called *logistic*) as an intellectual pursuit. The Platonic school grappled with numbers like $\sqrt{2}$ which they proved to be irrational (not a ratio of 2 integers m/n .) (Remember how? Hint: use contradiction after supposing $\sqrt{2} = m/n$. Then $mm = 2 nn$. Then mm has an even number of two factors, whereas $2 nn$ has an odd number, which is a contradiction).

The Greek empire was split into several pieces when Alexander the Great died. In about 300BCE, the Egyptian part was under control of Ptolemy I. He established an outstanding school in Alexandria with a great library, world-class scholars and teachers. Among the latter was the mathematician Euclid who is the author of the famous textbook the *Elements*. The first 13 books, or chapters, of the *Elements* are devoted to plane geometry and the next three to number theory. As taught in secondary schools today the true statements in the geometry books of the *Elements*, called *theorems*, are proved by deduction from a few postulates, or *axioms*. We shall see that the deductive steps make these proofs a kind of non-numerical computation and further, this served as an example of the logical proofs advocated

in the 1900s as a means to derive all of mathematics (see Chap. 3 Appendix G). The Elements were translated into Arabic, then into Latin in the twelfth century and finally in the sixteenth century into various European languages. It has appeared in a large number of editions, a number perhaps only exceeded by the Bible.

Ancient India and China both had number systems for computation. Chinese numerals were mainly decimal, the individual digits d from 1 to 9 being denoted by a multiplicity of d strokes, or “rods”. A positional notation for the rods allowed the invention of counting boards as primitive computers. The word *abacus* for these devices may originate from the Semitic word *abq*, referring to the sand tray used as a counting board for the rods in other lands as well as China. In Arabia, the abacus had ten balls per position wire. The Chinese had five balls on upper and lower wires separated by a bar. The Chinese were also familiar with computations on fractions and negative numbers. By about 300BCE, the Indian notation of individual ciphers for the digits 1–9 had evolved to the Hindu numerals which we use today and it was recognized that they can be used in all decimal positions.

In about 800AD, a 100 years after the founding of the Muslim empire by Mohammed, there was an awakening in Arab countries to science and mathematics. A university comparable to the one in Alexandria was established in Baghdad. Around 850AD, a mathematician on its faculty named Mohammed ibn-Musa al-Khowarizmi became so well-known for his published works employing Hindu numerals that we now refer to them as being Hindu-Arabic in origin. As a corruption of his name, his rules for operating on these numerals became known as *algorithms*, a word now applied to any computation method specified by a systematic sequence of well-defined rules. Also from his work called *Al-jabrah wa'l muqabalalah* came the modern word *algebra* and knowledge of that subject as of that era was made available in Europe. In Persia, around 1050–1123AD a book on algebra was published by the mathematician Omar Khayyam, better known in the west as a poet. This book treated computation of solutions of quadratic equations and gave geometric solutions of cubic equations, which we now know can be generally solved by purely algebraic formulas.

Europe in the middle ages did not experience great progress in mathematics or computation but relied on classical ancient Greek knowledge. In the Renaissance period, 1400–1600, the main mathematical trend was in algebra. The Italian mathematician Geronimo Cardano, known to us as Cardan, published works on the solution of the cubic and quartic equations actually discovered by others (Tartaglia and Ferrari). In the modern period which followed, Galileo Galilei (1564–1621) and B. Cavalieri (1598–1647) and Johann Kepler (1571–1630) developed mathematics and computation applied to the physical world. Francois Vieta (1540–1603) worked in algebra. John Napier (1550–1617) of Scotland and Henry Briggs (1561–1631) of England created logarithms as a means of computation of multiplication more easily.

The center of new mathematical discovery moved from Italy to France, where it was dominated by Rene Descartes (1596–1650), Pierre Fermat (1601–1665) and Blaise Pascal (1623–1662). Descartes's algebraic notation for his published mathematics created a modern expository style wherein letters at the beginning of

the alphabet denote parameters, letters near the end denote unknown quantities, superscript exponents denote powers and + and – the usual positive and negative quantities.

At this juncture in our brief tour of the history of computation, when we consider Pascal, we come upon an actual computer device (We ignore the abacus as too primitive). Pascal had wide-ranging interests in mathematics and at the age of 18 he planned a computer device which he actually built and of which he sold about 50. It was mechanical in its usage of gears. Again, when we consider the work of the mathematician Leibniz, who is credited along with Newton with the creation of the Calculus, we learn that Leibniz invented a mechanical computer device, called the *stepped reckoner* which was based on a stepped drum mechanism and an intricate gear-work mechanism. Leibniz built a wooden model which he brought to London in 1676. In principle it could perform all four arithmetic operations on integers, whereas Pascal's machine could only add and subtract. According to a Wikipedia encyclopedia article, its design was beyond the mechanical fabrication technology of that time and there were design flaws in the positional carry mechanism (always a challenge in computing machines). These factors made its operation unreliable. However, the stepped wheel device, called a *Leibniz wheel*, was employed in many computer devices for 200 years, even in the 1970s in the Curta hand-held calculator. Mechanics was the chief mode of fabrication of computing machines in the ages before electronic devices. Leibniz, a polymath, lived before the advent of electric motors and therefore his was a brave hand-operated attempt to mechanize computation. According to Wikipedia, there is a 16 digit prototype which survives in Hannover. It is about 67 cm (26 in.) long and consists of two parallel parts, an accumulator which can hold 16 digit results and an eight digit input section having eight dials and a hand crank which is turned to cause operations to be performed.

Leibniz, like mathematicians of his era, was also a physicist. As such he developed a theory of kinetic energy (mass times velocity squared) discovered by his mentor Huygens. Leibniz believed kinetic energy was a more fundamental physical quantity than momentum (mass times velocity), which Descartes and English scientists regarded as the fundamental quantity. Leibniz proposed a conservation of (total) energy law but it was based on metaphysical grounds rather than engineering facts. Among Leibniz's other discoveries was the principle of separation of variables for solving certain partial differential equations. Further, he used determinants long before Cramer did. Despite his accomplishments in theory, he was also an advocate of applied science and invented many devices such as wind-driven propellers and water pumps, mining machines, hydraulic presses, lamps, and clocks. His stepped wheel computer was only one of his mechanical inventions.

These historical examples of computing machines were the only notable ones until the year 1822 when the Cambridge mathematics professor Charles Babbage, a polymath like Leibniz, invented a mechanical computer, called the Difference Engine. This was a special-purpose computer for computing polynomial values by finite differences, polynomials being good approximations to the functions needed to calculate astronomical tables, the main objective. Babbage had difficulty

obtaining funding to build a Difference Engine. A few difference engines were built by one Per Scheutz in about 1855. The second Difference Engine built had 8,000 parts, was 11 ft long and weighed 5 t.

Understandably, a general-purpose computer called the *analytical engine* was later designed by Babbage in 1837 and he worked on its development until his death in 1871. It was never built, for political and funding reasons. But many of its design features were implemented in modern computers. Its data and programs were input by punched cards in the manner already employed in controlling Jacquard looms. Output of intermediate results was also on punched cards and final output was to be by printer. Ordinary base-10 arithmetic was used internally. There was a memory of capacity of 1,000 50-digit numbers. Analogous to the *central processing unit (CPU)* in a modern computer, the mill (*arithmetic unit*) had its own internal built-in operations, *microcoded* by pegs inserted in a drum. The programming language was similar to a modern *assembly language*. It provided for *loops* and *conditional branching* (see Chap. 4 on Software). An Italian mathematician whom Babbage had met while traveling in Italy wrote a description of the programming language in 1842 and it was translated into an English version in 1843. This was read by Ada King, Countess of Lovelace, Byron's daughter, who was herself a gifted mathematician. She added to the English version and actually wrote specific programs. For this reason she has been called the first programmer and a recent language was named ADA in her honor. Babbage died in 1871, unable to get funding to build his analytical engine. In 1910, his son reported that a part of the engine (the mill and printer) had been built and used successfully and he proposed to build a demonstration version with a small memory having 20 columns with 15 wheels in each. Closely related electromechanical (relay) machines were later worked on by George Stibitz at Bell Laboratories and Howard Aiken (the MARK I) at Harvard. Aiken attributed much of the MARK I design to Babbage's Analytical Engine design (see Chap. 5 on the Hardware side of Computer Science for the modern history of computing machines).

It is of some interest to remark that many of the key players in the history of Computer Hardware, Pascal, Leibniz, Babbage, Turing and von Neumann were equally adept at theory and were in fact polymaths of genius stature. They contributed to many other disciplines.

Babbage was the Lucasian Professor of Mathematics at Cambridge (the Chair once held by Newton), was a founder of the Royal Astronomy Society, worked in cryptography (like Turing) where he broke what is known as Vignere's autokey cipher to aid the British military, invented the "cowcatcher" device to clear the track in front of railway locomotives, invented a medical ophthalmoscope which was later re-discovered by Helmholtz, and, again like Turing, exhibited several eccentricities. For example, having read the poet Tennyson's lines "Every moment dies a man, Every moment one is born", Babbage contacted the poet to point out "if this were true the population of the world would be at a standstill. . . in truth the rate of birth is slightly greater than death. . . so your lines should read "Every moment dies a man, Every moment 1 1/16 is born." which is sufficiently accurate for poetry." Babbage is commemorated in several ways: the crater on the moon called the Babbage Crater, the Charles Babbage Institute at the University of

Minnesota, the Babbage lecture hall at Cambridge, and a railway locomotive named after him by British Rail. His programming colleague was Ada Augusta Byron, the only legitimate child of the great poet George Gordon, Lord Byron. Her mother took her away as a child from Byron and raised her to study math and science. She married William King who became Earl of Lovelace and she became Countess Lovelace. They had three children. As noted above, she translated into English the French version of the article on the Analytical Engine written by the Italian engineer Manabrea (who later became a prime minister of Italy). She added many of her own notes and wrote a program for the engine to compute Bernoulli numbers. She died in 1852 and is buried next to Lord Byron.

From the preceding brief account of the early history of computation, we learn that, except for a few explicit examples such as the invention of logarithms by Napier and Briggs and the rather primitive computers invented by Babbage, Leibniz and Pascal, in modern civilizations the ideas involved in computation were not developed much beyond their ancient forms. By contrast with its rather sparse history prior to 1936, the almost all-pervasive presence of computation in today's world is a consequence of the recent and rapid growth in only the last 75 years of the *hardware* and *software* sides of the modern subject known as *Computer Science*. If modern man wishes to understand and cope with the world he lives in, he should have some working knowledge of Computer Science. This book is intended to impart such knowledge. To keep this knowledge accessible and within reasonable and readable bounds, the book does not attempt to give a complete account of the development of Computer Science nor an encyclopedic coverage of it. Rather it presents the main ideas of Computer Science in a hopefully comprehensive and coherent fashion. It does this at several levels, one given in expository sections at a rather intuitive and easily understood level not requiring prior advanced education and other levels in sections, usually Appendices, requiring some advanced prior education, say at a college level. The reader is advised to journey through the various chapters at a leisurely pace and choose to skip over the advanced sections and Appendices at first and perhaps return to them in a second more strenuous reading. Our authors wish you Bon Reading Voyage.



<http://www.springer.com/978-1-4614-1167-3>

Computer Science

The Hardware, Software and Heart of It

Blum, E.K.; Aho, A.V. (Eds.)

2011, X, 470 p., Hardcover

ISBN: 978-1-4614-1167-3