HISTORY OF COMPUTER HARDWARE AND SOFTWARE DEVELOPMENT

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Summary

The stored-program electronic digital computer first appeared in the 1940s and, from a machine designed to perform calculations, quickly evolved into an information processing and communications machine that became indispensable to business, science and many individual people. This article investigates how changes and improvements in computer technology have led to the evolution of the electronic digital computer from a machine filling an entire room, costing several million Euros and able to perform only simple arithmetic operations to the powerful and versatile laptops, PCs and supercomputers we know today.

Developments in four broad sets of technologies, often overlapping, paved the way for the development of today's computers, and contributed to what we now call Information and Communication Technologies (ICT). These technologies are: Technologies to aid Calculation, Technologies for Automation and Control, Technologies for Information Processing and Information Management, and Communication Technologies.

1. Introduction

To most people today, computers are just electronic devices that offer a means of accessing the Internet and World Wide Web, a way to read your e-mail, an aid to running a business and a way to facilitate writing using a word processor. To most of us computers do not normally conjure up the picture of a fast calculator, which was the purpose for which they were initially designed: the first electronic computers were essentially large calculating machines. Even using the word *computer* to refer to an electronic machine is fairly new. Before World War II this term was generally applied as a job title to the *human clerks* (often young women) who performed routine computations for business, government and research purposes. These people were the *computers* of this period.

The stored-program electronic digital computer first appeared in the 1940s and, from a machine designed to perform calculations, quickly evolved into an information processing and communications machine that became indispensable to business, science and many individual people. Advances in technology meant that computers became cheaper, smaller and much more capable. In the late 1960s the idea of a household having its own computer was unthinkable, but the advent of the Personal Computer

(PC) ten years later changed all this until today almost every business, and many homes, have their own PC.

2. What is a Computer?

What we now call a *computer* can be more formally described as a *Stored Program Electronic Digital Computer* and in this article that is what I will use this term to mean. But apart from the human computers mentioned earlier, until the 1960s there were two different types of computer: Analogue Computers and Digital Computers. Whereas a digital computer stores its data and performs its operations using digital (numeric) representation (usually using binary numbers), an analogue computer does this by analogy using quantities like electronic voltages, volumes of liquid or fractions of the turn of a wheel. This article is concerned primarily with digital computers as analogue computers have now all but disappeared from the scene, but we will give some consideration to the use of analogue computers before the 1940s.

The dictionary defines a computer as "*an electronic device which is capable of receiving information (data) and performing a sequence of logical operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals*" [1].

The key here is that a computer must be *programmable* and so able to perform various operations under the control of different programs – it must be able to do more than just a single thing. An electronic device that automatically performs one or more fixed set of operations – like that of a washing machine, an electric bread maker, an espresso coffee maker, an automatic car wash or a car engine management system cannot be called a computer. To be what we know as a general purpose computer the device must be capable of performing various different general sets of operations under the user's control: it must be programmable, and the program must be able to be stored in the device; hence the name 'stored program computer'. A stored-program digital computer stores its program (instructions) as well as its data in internal memory and typically makes use of what is known as 'von Neumann architecture' (- see Section 3.1.5.3).

2.1. Conceptual Structure of a Computer

Although they do not normally look quite like this, conceptually a computer can be considered to consist of the following components:

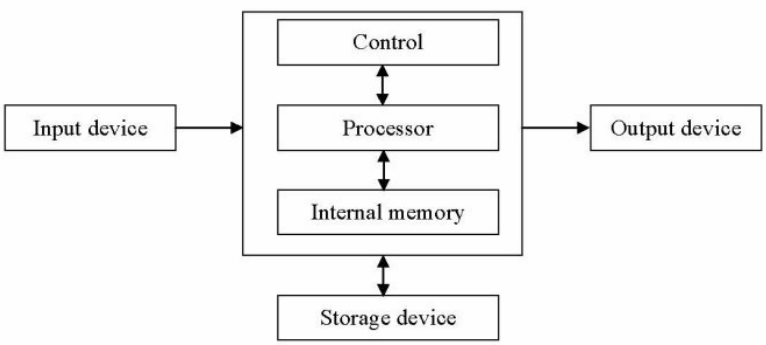

Figure 1. Conceptual Structure of an Electronic Digital Computer

In this article we will see how changes and improvements in each of these components has led to the evolution of the electronic digital computer from a machine filling an entire room, costing several million Euros and able to perform only simple arithmetic operations to the powerful and versatile PCs and supercomputers we know today. We will see how the evolution of these devices over the years has contributed greatly to the way that computer hardware, software and applications have developed.

- The input device offers a means of entering both data and instructions (programs) into a computer. Input devices over the years have included paper tape, punched cards, keyboards, mouse, touch screen and voice.
- The output device lets you see the results of whatever the computer has processed. Output devices have included paper tape, dot matrix printers, line printers, plotters, display screens, video projectors, laser printers, inkjet printers and sound.
- Control and processing devices (sometimes called the Central Processing Unit or CPU) use electronic components made up from values, transistors or integrated circuits and, as the name suggests, control and perform the actual processing or 'computing'.
- Internal memory is used by the computer to temporarily store both data and programs during its operations (- a von Neumann concept). These memory devices have included magnetic cores, William's tube CRT devices, mercury delay lines and integrated circuits.
- Storage devices allow the computer to retain large amounts of data for longer periods. They have included paper tape, magnetic tape, magnetic drums, magnetic (hard) disk, floppy disks, CDs, DVDs and memory sticks.

As its name suggests, a digital computer operates on and stores its data in binary, or base-2 (0-1), rather than decimal, or base-10 (0-9) format. A single binary digit is known as a bit while a collection of 8 bits is called a byte. A word is typically the amount of data transferred at one time between the processor and the memory of a computer. Modern computers usually have word sizes of 16, 32 or 64 bits but this varied considerably from one system to another in the past and comprised any of 8, 9, 12, 16, 18, 24, 32, 36, 39, 40, 48, 60 or 64 bits depending on the computer.

But it was not just computer hardware that evolved during this period as computers needed to be made usable by the development of programming languages, operating systems, user interfaces, techniques for storing data and new applications. Each of these aspects of the computer has also made huge strides and helped to determine the nature and uses of the machines we have today.

3. Technologies that Contributed to the Early History of Electronic Digital Computer

We often think of computing beginning with the machines built in the 1940s, but the history of computing goes back much further than this and can be traced back to earlier technologies that performed many of the tasks now performed by computers. Most histories look at the computer's ancestry in terms of calculating machines, but in this article I will suggest that this is just one strand in the history of technology leading to what we now call a computer. Developments in four broad sets of technologies, often

overlapping, paved the way for the development of today's computers, and contributed to what we now call Information and Communication Technologies (ICT). These technologies are:

1. Technologies to aid Calculation
2. Technologies for Automation and Control
3. Technologies for Information Processing and Information Management
4. Communication Technologies

In addition to these technological influences, from the 1940s other influences, including military usage of computers, the US space program, decreases in hardware costs, reduction in physical size and large changes in business needs provided feedback that propelled the already evolving design of computer hardware and software towards further rapid development.

3.1. Technologies to Aid Calculation

People have needed to perform calculations since the dawn of history and this probably became critically important when people began trading with each other. There were two types of calculation which had to be handled: one involved counting and the other measuring – for example, early humans had to count livestock and measure cloth. The earliest calculating devices were those provided naturally; figures for counting and the forearm for measuring [2].

3.1.1. Ancient Calculating Devices

While the use of the fingers was adequate for very simple arithmetic this was inadequate for representing large numbers and performing complex calculations. Evidence suggests that as early as 2,400 BC a calculating device was invented in ancient Babylon. Marks representing numbers were made on a dust-covered board.

Further developments led to counting boards on which moveable markers were arranged to represent numbers. An abacus is used for addition in much the same way as the counting boards.

Another ancient calculating device is the Antikythera mechanism, an astronomical device for modeling the heavens and designed to calculate astronomical positions. It was built by the ancient Greeks in about 100 BC [3] and its construction involved many gear wheels and appeared to have been built on theories of astronomy and mathematics developed by Greek astronomers. It could perhaps be thought of as an early mechanical analogue computer.

3.1.2. Calculating Devices from the Middle Ages

In the early 1600s, the Scottish mathematician John Napier made a major contribution to the history of computation with the invention of logarithms. Napier's logarithms made it possible to perform multiplication easily by addition of the logarithms of the numbers, and division by subtraction. Tables of logarithms are still used today. In about

1614 Napier produced a system of small rods with appropriate markings on them that were a mechanical aid to computation. These rods came to be called Napier's bones. The device consisted of a number of these rods each marked with the digits 1 to 9, with their multiples in columns underneath them.

In about 1630 William Oughtred arranged two of Napier's logarithm rods along an ordered scale to form the first slide rule. The user could multiply and divide numbers very quickly by simply sliding one scale past the other and reading off the answer. A slide rule is in fact a compact set of logarithm tables. Slide rules were commonly used in science and engineering until the development of low cost electronic calculators in the 1970s and are still used for some purposes today.

In 1642 Blaise Pascal devised a mechanical calculating machine to help his father, who was a tax collector, in his work. Pascal's calculator was a gear driven adding machine capable of performing additions and subtractions with considerable accuracy.

The principle of Pascal's 'adding wheel' is still in use today in the mechanical odometer (mileage counter) of many older cars. (The Pascal programming language that we will discuss later was named in honor of Blaise Pascal.)

About 1674 Gottfried von Leibnitz improved on Pascal's adding machine to produce a calculator capable of multiplication and division. It was also able to calculate numerical roots and is regarded as the forerunner of the mechanical calculating machines that were common before the advent of electronic calculators.

Although impressive, these early calculators "*were more in the nature of ornate curiosities*" [4 :70] and from this time onward, the need for accurate calculations began to increase greatly.

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Biographical Sketch

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He has undergraduate degrees in science, education and computer science. In his research MA he investigated the history of the origin of the discipline of Information Systems (IS) in Australia, and how universities devised IS curricula. His PhD involved a study in technological innovation in a university in Melbourne. His main research interest is technological innovation where he investigates why one technology is taken up in a given form by one organization, and not taken up at all or taken up in a different way by another organization. Such studies are often framed by actor-network theory (ANT). This links well with his interest in the history of computing and information technologies where he uses past events to clarify current processes, with both people and technology playing important roles. His other research interests include: history of computing in education, information systems curriculum, information technology in educational management, project management and electronic business.

He has written a number of books relating to information systems education, project management and e-business and has published numerous book chapters, journal articles and conference papers. He is also Editor-in-Chief of the journal of *Education and Information Technologies* and the *International Journal of Actor-Network Theory and Technological Innovation*.