ORIGINS OF CONTEMPORARY INFORMATICS

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Abstract: Throughout many centuries calculation was mainly connected with mathematics. In recent times with an average delay of a decade, inventions in electronics and telecommunications made possible the growth of calculation into computing. Nowadays, informatics implements shortly technological miracles from many scientific disciplines. This paper gives a short review of those discoveries that have significantly influenced contemporary information technology.

Keywords: history of mathematics and informatics, computer industry, software industry

1. Pre-informatics era

According to archaeologists, Neolithic peoples in the 45th century BC have already used quantities, ten centuries earlier than Egypt hieroglyphs and Sumerian script in Mesopotamia were invented. This is the beginning of primitive calculus, with no doubt performed on fingers. The evidence for this fact is that Egyptian in the 35th century BC developed a symbol for 10. Latin name for the first calculation tool is *digitus*.

Although there is no evidence of any mathematical reasoning at that time, it is obvious that ancient Egyptians demonstrated remarkable mathematical sense still visible in their buildings. It is particularly manifested at Keops pyramid that was built in the period between 2.600 BC and 2.480 BC. The ratio of the hypotenuse and the smaller side of its meridial triangle is identical to the golden cut. This is exactly the same value at which the ratio between consecutive elements of Fibonacci series tend. The series, named after its inventor Leonardo di Piza, Filius Bonacii (1170-1230) is also famous for introducing **recurrence**.

It is believed that the well-known **abacus** (Fig. 1) was invented in Babylonia, or in Asia Minor, in the 30th century BC (Meyers, 2000), or maybe in China in the 26th century BC (White, 2000). It is very probable that bead and wire abacus was first invented in Egypt in the 5th century BC. Encyclopædia Britannica traces the

word *abacus* to the Phoenician *abak* (sand). The second explanation is that abacus was named after addition and subtraction tables, the first that use position notation. Nevertheless, this magnificent calculator was used to calculate the census in China in 1982.

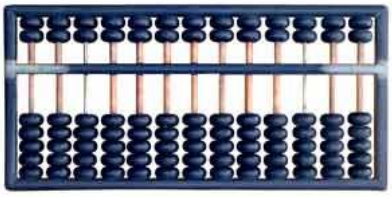

Figure 1: Chinese abacus

Compared with the Chinese abacus, Roman abacus (Fig. 2) was invented most recently, in the 4th century BC. What was the reason for this incredible delay? Probably the fact that although first real mathematicians Thales of Miletus (about 624-547 BC) and Pythagoras of Samos (about 560-480 BC) lived two centuries earlier, the **number 1** was invented by Arhytas from Tarent (430- after 360 BC) exactly in the 4th century BC. Roman abacus consisted of sliding beads arranged on a rack. Calculation was performed by a little stone (in Latin, *calculus*). Calculation process was vague because it was based on different substitutions of groups of objects with a single object. The problem was finally solved when Arabic numbers that were actually invented in India in the second century became wide spread in the 9th century. Exactly at the same time **zero** was included in the set of natural numbers. According to some sources (Guedj, 1998), in Sanskrit (ancient indo-european language) zero was called *sunya*. Its Arabic translation *sifr* is used as a common name for all digits. Italian pronounced sifr as *zephiro*. This is the origin of the word zero in most European languages.

Thank to these inventions Mukhammad ibn Musa Al Khwarizmi (about 790-847), Arabic cleric from Tashkent, was able to set the basis for **written addition and subtraction**. His algorithms covered also multiplication and both division operators. Namely, although ancient Egyptians started using fractions in the 18th century BC, there was no way for their decimal representation. This problem was finally solved in the 16th century when Dutch navigators invented the **decimal point**.

Figure 2: Gravure from the 14th century: Goddess Arithmeticae judges competitions between Boethius (480-524 AD) with Archimedes (287-212 BC) or with Pithagoras (560-480 BC). Boethius uses the abacus and wins

Even without the decimal point, Leonardo da Vinci (1459-1512) has probably managed to design a remarkable calculation device. In two notebooks that were discovered in 1967 in Da Vinci's inheritance, several sketches (Fig. 3) show the construction of a hypothetical mechanical calculator. According to these sketches that were made in 1500, a working model of a mechanical calculator has been constructed recently. It has not been proved that the sketches belonged to Da Vinci, although his genius is more than clear. Famous psychiatrist Sigmund Freud (1856-1939) has stated: "Leonardo da Vinci was like a man who awoke too early in the darkness, while the others were all still asleep".

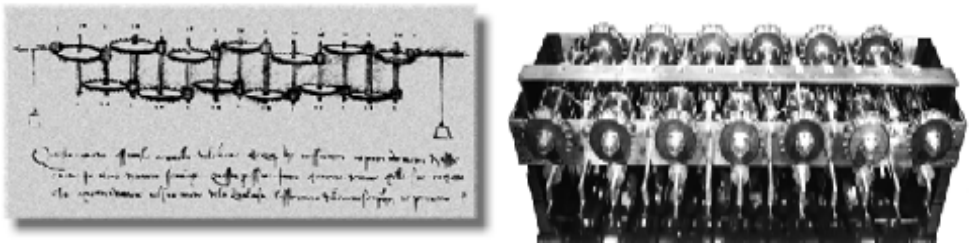

Figure 3: One of Leonardo da Vinci's original sketches and constructed working model

Common usage of the decimal point is due to the genius of Scottish mathematician John Napier (1550-1617). After the invention of logarithms Napier wrote first logarithmic tables (1614: Mirifici Logarithmorum Canonis Desriptio) supplemented with manuals for their usage (1619: Mirifici Logarithmorum Canonis Constructio). In 1612 he invented **Napier bones**, completely based on loga-

rithms. Napier bones were using small marked slabs of ivory to perform calculations. They are the first attempt towards creation of a real calculator.

William Oughtred (1575-1660) improved Napier bones. In 1622 he invented the **slide rule** (Fig. 4), the first and only calculator used by technical engineers until mid-1970s.

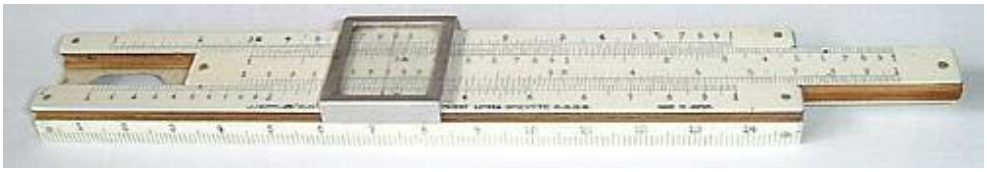

Figure 4: Slide rules have been used as pocket calculators for 150 years

The slide rule enables multiplication and divisions of two numbers, calculation of the second and the third exponent of a number, its reciprocal value, logarithm, antilogarithm and logarithm of the logarithm. The result is correct until the fourth decimal number. But, all operations at the slide rule have to be performed manually. In 1642, famous French philosopher, mathematician and physicist Blaise Pascal (1623-1662) invented the first mechanical calculator based on a mechanism for automatic shift of positions. At that time Pascal was very young so he called his calculator **Pascaline** (Fig. 5). Pascaline had cog- wheels that were rolling at each entry. Negative numbers were represented by their decimal complement. The result was presented at a small window. This concept is still used in mechanical cash boxes.

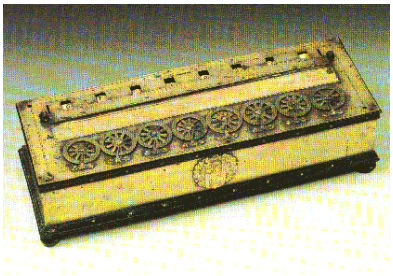

Figure 5: Pascaline

Finally, in 1673, Gottfried Wilhelm Leibniz (1646-1716) invented the first **automatic calculator** with automatic multiplication. Pascal's and Leibniz's machines are the basis of all modern mechanical and electro-mechanical calculators. A century and a half later, in 1829, using stepped cylinder invented by Leibniz, Charles Xavier Thomas de Colmar (1785-1870) produced **Arithmometer**, the first mass-produced calculator. The Arithmometer was a desktop calculator capable of performing all arithmetic operations, including division. His reliability

made it very popular and it was sold almost one century. Finally, in 1875, American inventor Frank Baldwin (1838-1925) restructured Leibniz calculator and called it **Monroe keyboard calculator** (Fig. 6).

This calculator was the last in the series of many similar inventions. In 1873, Baldwin applied for a patent of a machine "which at all times has the capacity to add, subtract, multiply and divide with no resetting of the mechanism and with no form of conversion for any of the processes". His company founded in 1912 was a pioneer in electric adding machines. The company still exists.

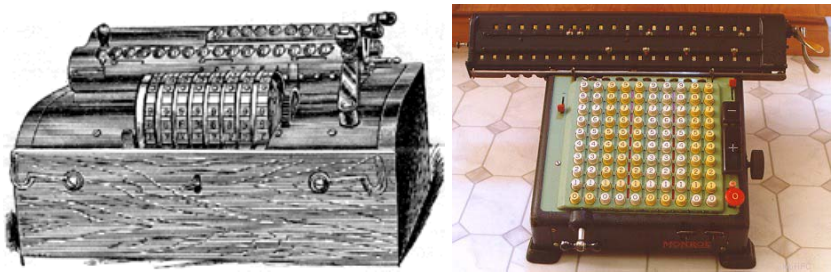

Figure 6: Baldwin's calculator and Monroe keyboard calculator

In the same period, Isaac Newton (1642-1727) started his research that leads to **differential and integrational calculus**. Furthermore, he invented binomial formula and iteration algorithm for approximative calculation of the roots of algebraic equations. His research is the basis for **numerical calculus**. His research and the research of George Boole (1815-1864), who introduced **logical operators** in his famous book "The Mathematical Analysis of Logic" in 1847, are the first theoretical basis for contemporary informatics and computer science. Boole's book "An Investigation of the laws of Thought" from 1854 is considered to be the beginning of Artificial Intelligence.

Probably the greatest invention in the 18th century for contemporary informatics is Benjamin Franklin's discovery from 1780. Franklin (1706 - 1790) discovered electricity. There are many inventions from the 19th century are crucial for the development of real informatics. Here is the list of the most important.

In 1801, Joseph Marie Jacquard (1752-1834) constructed first automatic loom. The control of weaving was based on **punched cards**, first used for this purpose. Charles Babbage (1791-1871), English visionary is known as **father of computing** or **computers**. During his studies at the University of Cambridge he discovered that navigation tables are full of mistakes. In order to reduce ship lose, he decided to construct an operational unit moved by a steam machine. He dedicated all his life to this idea. As a result of the initial research, in 1822 he invented his first applicable model called **difference engine**, based on finite difference calculus. He used two types of cells. In first cells corresponding to today's

registers he stored finite differences, while in the second, corresponding to today's **accumulators**, he was adding interim results. Operations were intended to be performed in parallel. Unfortunately, there were no technical possibilities to construct the unit, so he gave up. He has repeated his research in the period from 1847 until 1849 with no success. Differential engine was finally constructed in 1991 on bicentenary of his birth. It is now exposed in the Scientific Museum in Kensington (Fig. 7).

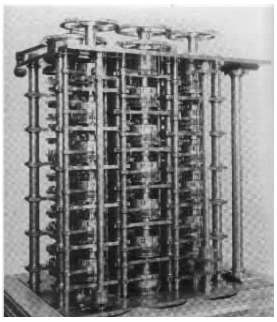

Figure 7: Difference engine

Difference engine is not the only invention Babbage made. In 1833 or 1834, he suggested another interesting machine called **analytical engine**. Babbage himself hasn't left any evidence about it. Fortunately, English mathematician Ada Augusta King, Countess of Lovelace (1815-1852) documented his work. She translated Menabrea records taken during Babbage's stay in Italy and added lots of her comments and instruction routines to be fed into analytical engine. In history of informatics Lady Lovelace is famous for being the **first programmer**.

Analytical engine was imagined as a complex device divided into several functional units. The first was an interface for external communication. It used two **input** sets of just invented punched cards: one for sequence of operation, the second for entry data. The **output** had to be written or punched. All data had to be stored in a **memory** called "*the store*", while operands defining forthcoming operations were supposed to be stored in **processing** unit. The core unit of analytical engine was **arithmetic unit**, called "*the mill*". The mill was intended to do all arithmetic operations and to calculate square root. Although this engine has never been constructed, all modern computers accept Babbage's concept.

In 1867, Mailing Hansen (1835-1890), a Danish teacher at the Institute of deaf and dumb, invented first **typewriter** with 52 keys called the *writing ball*. This typewriter was sold for the record price of $65.000. It revolutionized not only administration, but also communication. Only two years later, Thomas Alva Edison (1847-1931) built the first **electric typewriter**. Within a few years, nobody

has been writing business letters by hand. Edison is undoubtedly better known for the discovery of the first light that can burn a long time in 1879.

In 1890, US Census Bureau organized a contest to calculate the census. It was estimated that manual processing of data would take about ten years. Herman Hollerith (1860-1929) won the contest. He invented an **electric tabulating system** based on punched cards. With Hollerith's machine (Fig. 8) the census has been calculated within six weeks. In 1924 Hollerith merged his company with two others and formed International Business Machine Corporation, the famous IBM.

Figure 8: Hollerith's machine is the first machine to appear at the front page of a magazine

In 1904, John Ambrose Fleming (1848-1945) derived the first **vacuum tube**. From 1920s until 1950s, vacuum tubes (today called diodes) have been used for all electronic equipment, including radio and TV. Although vacuum tubes were found extraordinary, they needed lots of electricity and burned up easily. In 1926, Julius Edgar Lilienfeld (1881-1963) patented the first semiconductor transistor. His research was almost forgotten until the end of World War II. At the end of 1947, a team of three physicists in Bells labs led by William Bradford Shockley (1910 - 1989) created the first point-contact germanium **transistor** and for this invention received the Nobel Prize in 1956. Meanwhile, in 1928, the first **quartz crystal clock** was built. It is a basis of today's cheap digital watches that use quartz crystal oscillators. There is such a clock on most PC motherboards.

Inventions from the first part of 20th century have significantly accelerated information technology. Namely, achievements in science and technology before 1935 enable the designs and implementation of modern computers. The most important of them are: Eccles-Jordan binary counter, or more commonly **flip-flop electronic switching circuit** in 1919, Vannevar Bush's (1890-1974) creation of the first **analog computer** in 1925 and its improved version called **Dif-**

ferential Analyzer in 1930, Vladimir Zworykin's (1889-1982) invention of **CRT** (Cathode Ray Tube) in 1928, and finally, creation of the first **electronic talking machine**, called the **Voder** (Dudley, Riesz and Watkins) in 1933 and the voice coder **Vocoder** in 1939.

Finally, in 1938 the first computer was constructed. This date is the beginning of the real informatics. Although gigantic its successors had very limited possibilities. But, in less than 45 years, they have become extremely small and very powerful. What are the most important inventions that made information technology inevitable for modern living?

2. Early steps in electronic era

In 1935, German scientist Konrad Zuse (1910-1995) started developing a computing machine called **Z-1**. Z-1 was imagined as a programmable digital computing machine, based on valves. It used binary arithmetics. It was completed in 1938, but it has never been used (Fig. 9). Zuse has continued his research until the beginning of World War II. In this period he invented three improved versions of Z-1, called Z-2, Z-3 and Z-4. In **Z-2** model that was completed in 1940, mechanical logical circuits were replaced with telephone relays. The model **Z-3** from 1941 is famous for being the first **electromechanical digital computer**. Z-3 was controlled by **Plankalkül**, the first **programming language**. It was also created by Zuse in 1944. Unfortunately, neither his computers, nor the language has ever had any influence to modern information technology.

Figure 9: Reconstructed version of Z-1 is now exposed in Deutsches Museum in Munchen

In 1939, John Wincent Atanasoff (1903-1995), known as the **father of electronic computers**, developed the system **ABC** constructed for solving systems of linear equations. ABC is famous for being the first **electrical calculator** with **electronic arithmetic unit**. Two years earlier, inspired by the differential engine, at Harvard University, USA, Howard Eiken (1900-1973) started creating the first and the biggest **large-scale**, **automatic** and **electro-mechanical calculator**,

Harvard Mark I. It has finally been constructed in **IBM** in 1944 and has been officially called **IBM ASCC** (Automatic Sequence Controlled Calculator). This mechanical monster was 16 meters long and 3 meters high. It was constructed of thousands of gears and wheels. Mark I didn't have a memory unit, so all data had to be re-read from a punched paper tape.

During 1943, British constructed the machine called **Colossus**. For two years, Colossus has been successfully used to break codes produced by the German encrypting machine Enigma. It is interesting that until 1970, Colossus has been a secret. Encoding algorithm made by mathematical genius Alan Turing (1912-1954) is still unknown.

At the same time, John Mauchly (1907-1980), Persper Eckert (1919-1995) and research team at the University of Pennsylvania, USA, started construction of **ENIAC** (Electrical Numerical Integrator and Calculator) (Fig. 10). ENIAC was finally finished in February 1946. ENIAC is the first **all-electronic computer**, or with nowadays terms, the first **programmable calculator**. ENIAC had an area of $140m^2$, a volume of $90m^3$ and weighted 30t. It consisted of almost 17500 vacuum tubes, 1500 relays, 70000 resistors, 10000 condensators and 6000 switches. ENIAC was based on **decimal arithmetics** and performed 5000 additions or 300 multiplications per second.

Figure 10: For 50 years ENIAC has been well-known as a first computer

In parallel with this construction, at the University of Princeton, USA, in 1945, John Von Neumann (1903-1957) started developing the idea for **EDVAC** (Electronic Discrete Variable Automatic Computer), machine based on **binary arithmetics** and both **stored program** as well as **data**. In 1952, as a result of this project the system IAS (Institute for Advanced Studies) was developed. Nevertheless, the first computer with **stored program** is **EDSAC** (Electronic Delay Stor-

age Automatic Computer), constructed at Mathematical Laboratory of University of Cambridge, Great Britain.

None of these computers had any commercial usage. The first computer used for commercial purposes **UNIVAC** (UNIVersal Automatic Computer) was developed after five years of intensive research. It consisted of 5000 vacuum tubes and many semiconductor diodes. Similarly to Hollerith's tabulating machine, UNIVAC was first used to calculate the census in USA, now in 1951. In 1952, in CBS broadcasting studio after processing 10% of all votes, UNIVAC predicted the winner of 34th presidential elections. The name UNIVAC has been used as a synonym for computer. Programming part for UNIVAC-1 was conducted by Grace Murray Hopper (1906-1992). In 1952, using her experience from Mark I, she invented the first **compiler** called **A-0**. This is the beginning of **automatic programming**. Hopper is also famous for discovering and naming first **computer bug** (Fig. 11). Natural extension of compilers are programming languages**.** The glory of being the first **programming language** goes to **FORTRAN** (FORmula TRANslation). It was created in 1957 by John Backus (1924).

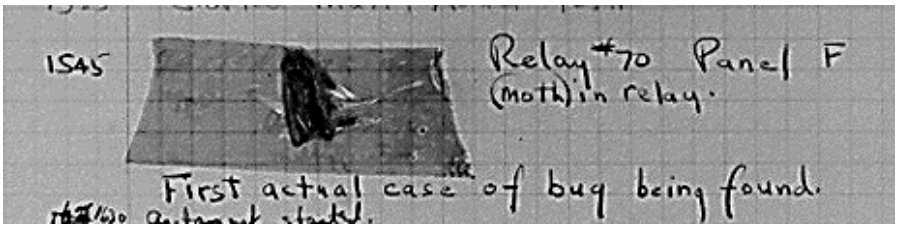

Figure 11: First computer bug was found in one relay of Mark II

First computers used acoustic memory that stores data like sound waves in a mercury steam. This memory had limited capacity of several thousands bits, very high production price and low reliability. Any of these features was a good reason to invent new technique. Soon after, **magnetic-core memory** was invented. As a result of this technological development, **IBM 650** was made in 1954. It had magnetic-core internal memory and **magnetic drum** with capacity of 2KB as peripherial memory. About 1000 IBM 650s were installed all over the world. Its extension was the model **IBM 704** from 1955. It was the first commercial computer based on **floating-point hardware**. IBM 704 is the first computer that used FORTRAN. Finally, with IBM 305 RAMAC that was constructed in 1957 the era of **disk memory** started.

During a very short period, computers have become more efficient. During their early stages from 1945 until 1956, they haven't become significantly smaller, but despite their increadible dimensions, they started getting out from research labs

and entering enterprises. The initial step was made. Computer technology was ready to face up to technological innovations.

3. Naissance of computer and software industry

The greatest problem with early computers were electronic tubes. They were the main reason for computer massiveness, enormous heating and consumption of electricity, but in addition they didn't allow any acceleration of arithmetic and logical operations. Meanwhile, transistors replaced vacuum tubes in radio and TV sets. In 1956, they were in use in computers too. The first computer based on **transistors** was **NCR 304**. It was designed in NCR (National Cash Register) and made by General Electric in 1959. Its CPU consisted of 4000 transistors and 8000 diodes. Its magnetic-core memory had a capacity of 48000 characters. NCR 304 is the first of many computers of second technological generation.

New computers also needed something to replace long and difficult binary codes of machine language. The first attempt was assembly language, but although programming code became more obvious, it was again very difficult. The only high-level programming language available at that time was FORTRAN. The first standardized programming language for commercial purposes **COBOL** (COmmon Business Oriented Language) was invented in 1960. The team was lead by Grace Hopper. By 1980, COBOL was the mostly programming language in the world. At the same time, the second mathematically oriented language **ALGOL 60** was promoted. ALGOL is the basis for many modern programming languages.

In this period, transistor technology enabled birth of **early supercomputers**, **Stretch** by IBM and **LARC** by Sperry-Rand. These computers were developed for atomic-energy laboratories. They could handle an enormous amount of data, but they were too expensive for business sector's computing needs.

IBM could offer much cheaper computers. In 1964, IBM delivered the first booking system to American Airlines. Within several years, all greater world airlines made the same. At the same time, they created **System/360**. This model is the first from series of compatible computers. From that time, IBM is a world standard for computer industry.

Computers have finally entered different areas of everyday life. They also created many new professions like programmer, analyst and computer systems expert. During only seven years, entire software industry began. Still, computers were too big, too slow and too expensive.

4. Further development

Main tendency of all computer manufacturers at that time was to develop bigger and more powerful computers. The only exception was Digital Equipment Corporation. In 1965 they produced first **minicomputer PDP-8**. This computer had limited instructional and extraordinary communication capabilities. PDP-8 was used for system control, including telephony. In parallel with computer (r)evolution, electronics was advancing very fast.

At the beginning of 1961, Jack Kilbi (1924) and Robert Noyce (1927-1990), engineers from Texas Instruments created the first integrated circuit. Kilbi suggested printing the circuit on germanium plate, while Noyce proposed silicon made from quartz. In 1968 Kilbi, whose idea was generally accepted, co-founded **Intel**. Replacement of transistors with integrated circuits is the begging of third technological generation. Finally, computers became very small and didn't generate heat, which was previously damaging sensitive internal parts.

Third generation computers were incomparably more powerful than all their predecessors. In order to simultaneously perform several tasks and even run several programs they needed a central program that could monitor and co-ordinate memory. Such program was invented and called **operating system**. It is very interesting that the most powerful operating system **UNIX** was introduced exactly in this period. UNIX was invented by Dennis Ritchie (1941) and Kenneth Thompson (1943) from **Bells labs** in 1969.

At the same time, distribution of messages became more and more inevitable. By the end of 1969, the first distributed network called **ARPAnet** linked 4 university nodes in the USA. The first node was set at UCLA, a month later at SRI, then at UC at Santa Barbara and finally, the University of Utah. The first connection was made from UCLA to the SRI. The project initially started in 1962 at ARPA (Advanced Research Projects Agency) within DoD (Department of Defense). ARPA was created by President Dwight D. Eisenhower (1890-1969), UNIVAC's predicted winner of presidential elections.

At the end of 1960s, all necessary conditions for computer revolution have already been fulfilled. But, computers were still very expensive, too complex and unfriendly. They were still *tools of a technological elite* (White, 1999).

5. Age of microcomputers

1970s started with two inventions. Ted Hoff (1937) from Intel Corporation introduced the first **microprocessor** Intel 4004 on 108 KHz and capability to perform 60000 instructions per second. Soon after, first **EPROM** was connected to it. In 1972, first **personal microcomputer** MITS (Micro Instrumentation and Telemetry Systems) 816 was born. Alan Shugart (1930) from IBM produced the **floppy**

disk and designed first **Winchester** hard disk. Donald Ervin Knuth (1938), generally recognized as Father of Computer Science, published first volume of his famous edition "Art of Programming". Bob Metcalfe (1946) invented standard method of transmitting data between computers connected in a local area network, called **Ethernet**.

In 1975, three young boys led by William Henry Gates (1955) produced a personal computer without a keyboard, screen and periferial memory called **MITS Altair 8800**. Its price was only $367. It made Altair 8800 cheap enough to be available for ordinary people. Bill Gates together with Paul Allen (1953) wrote first **BASIC** compiler for Altair 8800. Soon after Steve Jobs (1955) and Steve Wozniak (1950) created **Apple II** with I/O parts that Altair 8800 was missing.

In 1976, IBM released first **laser printer** IBM 3800 with relative speed of 215 pages per minute. As an answer, Texas Instruments released **thermal printer** TI 99/4. Sony Electronics released 3½ inch double density floppy disk. Together with Philips, they enabled **CD audio technology** to hold digital data. This technology was first used in 1985. Finally, in 1981, IBM made marketing decision and started producing personal computers. Their first PC was based on three years old Intel 8086. First IBM PC introduced **CGA** (Color Graphics Adaptor) **graphic cards**. Operating system was made by Microsoft. The results of cooperation between these three companies are well known. Next year, Epson America produced first **notebook** with built-in printer and **LCD** (Liquid Crystal Display) screen. Famous IBM PC XT was sold in 1983 for incredible amount of $5000.

Probably the most important event in history of personal computers is birth of **Macintosh** (Fig. 12) in January 1984. Famous Mac based on 32 bit Motorola 68000 processor was the first PC to use **mouse** and **graphical operating system**. Its concurrent IBM PC AT introduced EGA (Enhanced Graphics Adaptor) released half year later was a toy compared with Mac, particularly because it was still using old fashioned MS DOS. By today, Mac is famous to be the last, but not the least crucial invention in contemporary informatics, although even its successor **Macintosh Plus** from 1986 introduced revolutionary inventions. The most important was SCSI (Small Computer System Interface) disk support for communication with variety of peripherials.

Figure 12: First Mac at the Institute of Informatics and Power Mac G4 with I Mac in the background

In parallel with incredible development of computer industry, software industry started becoming more and more important. In 1978, Visicalc introduced first **spreadsheet program**. First **text processor** WordStar was introduced next year by Micropro International. In 1983, Mitch Capor (1950) produced new spreadsheet program **Lotus 1-2-3** with a concept that is used by now. In 1985, IBM introduced **Token-Ring** concept. Two years later Microsoft finally launched first Windows 1.0. First Windows operating system similar to Mac's was released in 1995. The last result that is the basis of modern software production is **HyperCard** from 1987. This hypermedia system was created by Apple Computers.

6. Odyssey 2001

In 1950, Turing wrote: "I believe that in about fifty years' time it will be possible, to program computers, with a storage capacity of about 10^9 (N.A. bits, or 120MB) to make them play the imitation game so well that an average interrogator will not have more than 70 per cent chance of making the right identification after five minutes of questioning." By now, HALL 9000 seems to be the only computer that could pass Turing test. At the end of 2001 the question is: "What can overcome 1984?" or "What will enable the creation of fifth-generation computers?".

There are many interesting ideas about the future of contemporary informatics. Fabian (2000) mentions some of them: "optical computers performing at the speed of light, Atomic/Molecular level, multi-dimensional, "infinite storage", Nano-computers, Total-Virtual-Reality Networks, Cyber servants, Personalized-Guardian/Tracking Systems, Global-911, Deep-Knowledge Artificial Intelligent software, . . . ".

But, which technical innovation will enable at least one of them? 2001 is not over yet.

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