Lecture I: Computing and Society: A Gentle Introduction

Reflecting upon technology and society...

Why are we behaving in ways we do and not some other ways? To what degree technology impacts out behavior? powers our preferences? dictates our choices in almost all aspects of our daily activities? What's special about computer and information technologies?

When we reflect upon technology and society, computer and information technologies represent canonical examples of continuous and profound technological impact.

Yet, no singular technological invention or event, no matter how groundbreaking, can account for the creation of the digital electronic computer. Similarly, no digital computer, no matter how powerful or versatile, can singularly explain the rapid transition of our civilization into that of consumers of digital information.

The computer and information technologies are examples of high technologies in constant motion, advancing at a speed that makes projections of their future milestones and impact difficult without a systematic approach grounded in their history and in present technological social and scientific context. Indeed, no invention occurs without such a context created in part by a chain of earlier discoveries, inventions, or contributions, sometimes centuries in the making.

To be is to invent

Inventing and its relationship with our curiosity, needs, desires, and aspirations is what pushes our civilization forward and computing is a canonical example of the continuous interaction between inventing and the forces of cultural, social, economic, technological, and political change.

Inventing is:

- what sets us–humans–apart from other living organisms; inventing is to venture where others have not, stretching beyond conventional frontiers of time, space, and thought;
- what creates new possibilities, sets new standards, brings social and economic progress and enrichment of knowledge;
- an expression of freedom, of power to create but also (and unfortunately) to dominate, and may bring social and economic injustice, destruction, and suffering.

The interplay between our needs and aspirations, on the one hand, and inventing new methods to count, calculate, and compute, as well as to store, transmit, process, and access information, on the other hand, has accompanied human development since the very beginning of human conscious interaction with the environment, when counting was reduced to distinguishing between one, two, and many.

Prehistory of counting: one, two, many...

The development of complex social interactions in areas such as early trade and commerce required numbers for representing quantities, and counting to perform operations on numbers such as addition. These complex interactions also required recording numbers (e.g. sale of goods or paid taxes) and, with the need to deal with operations on larger and larger numbers, the development of some counting aids.

Fig. 1. Inca accountant and tax collector standing next to a counting board; source: Don Felipe Huaman Poma de Ayala, 1583–1613.

Note: the overwhelming majority of languages do contain expressions representing numbers. However, there are primitive languages that lack expressions for naming numbers. The best a native speaker of such languages could do was to distinguish "one" from "many" as in "one child" and "many children".

Mechanical arithmetic: calculators

Numbers, counting and other operations on numbers are also at the point of origin of mathematics. Until the birth of the mechanical calculator industry in the 19th century, the business of advancing calculation methods was being taken care of by mathematically inclined individuals exclusively.

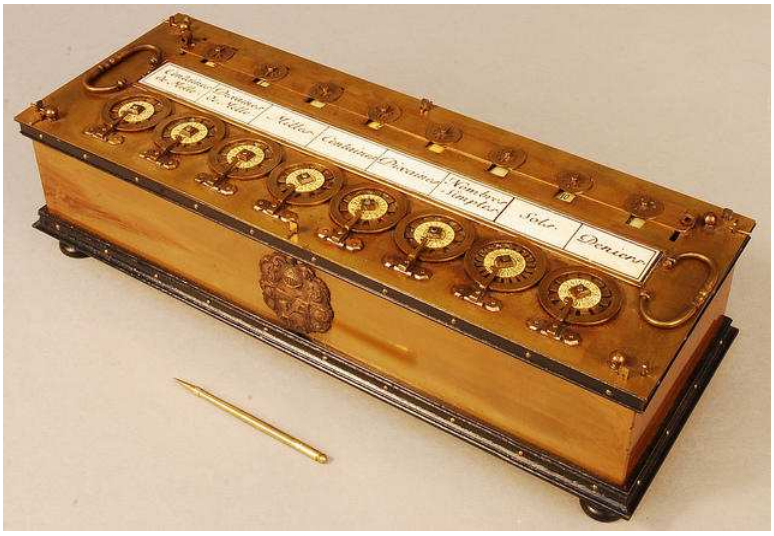

Fig. 2. Pascal calculator replica by Roberto Guatelli (1978); source: Canada Science and Technology Museum.

The first mechanical calculators started to show up in 17th century (Fig. 2 shows a replica of one of the calculators constructed by B. Pascal (1623-1662)). Some were the work of famous mathematicians such as Pascal and Leibniz and their purpose was to support scientific research and accounting. Their scarcity severely limited their impact on society at large, still served with more primitive forms of calculating aids such as abacus.

Calculators for the rest of us

The industrial revolution that took place in the 18th and 19th centuries brought profound technological changes in manufacturing, agriculture, mining, transportation, navigation; it initiated a remarkable chain of scientific discoveries and technological innovations. The revolution profoundly impacted the socioeconomic and political landscapes and socioeconomic conditions all over the world.

More and more businesses relied on fast processing of large quantities of data (numbers). Employing a large army of "calculators", i.e. of people performing calculation jobs manually was far from being cost-effective and error-free.

In the 18th and 19th century, mechanical calculators and special look-up table publications, called mathematical tables, were used to facilitate calculation, verification, selection, categorization, and extraction of data. They became manufactured in large quantities and varieties.

Mechanical calculators of the 19th century were inexpensive (in comparison with total salaries paid to human calculators), accurate, and could perform all the basic arithmetic operations. The social acceptance of the mechanical calculators was swift (especially on the business side) and soon 'personal' calculators became the first bestselling gadgets.

Fig. 3. A collection of 16th-18th century mathematical tables at the Science Museum Library, London.

The age of computers

The arrival of the first computers in the 20th century was the result of the need to automatically perform operations that were much more complex than those that could be done on calculators.

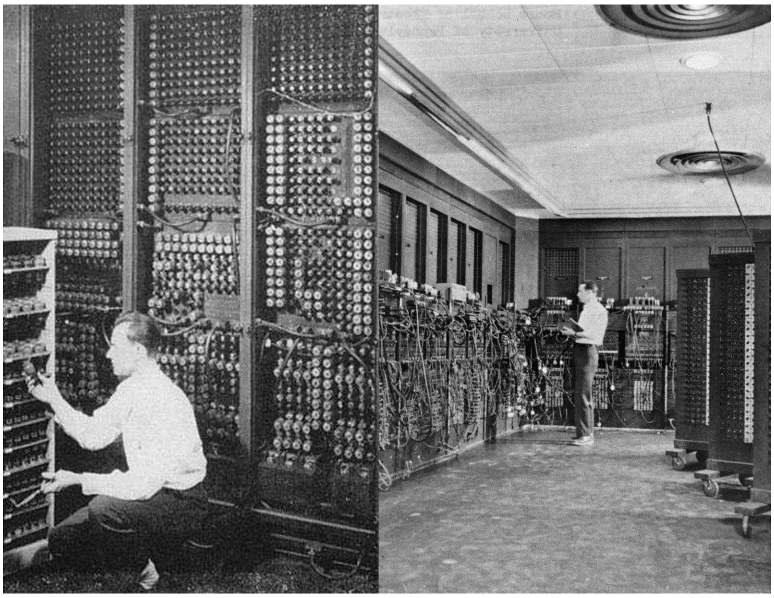

Fig. 4. Eniac "Giant Brain" computer (U.S.A., c. 1946).

The rapid development of computer technologies, from mechanical and electro-mechanical devices to the present-day digital electronic computing and communication devices, rapidly bridged vast land masses, spanned cultural differences, and recreated the world into a digital global village. Computer and information technologies have enriched our intellectual capabilities and allowed for unrestricted and (to some degree) free access to a variety of digital resources.

While the advancements in computing have mostly brought far reaching benefits to humanity, they also sculpted a dark side of the present-day digital reality: computer-related crime continuously threatens the stability of our daily activities so deeply immersed in the computer world, cyber terrorism may cause environmental, economic, and political instability and even cataclysms.

Is the knowledge of the past necessary, helpful?

This course

- is a historical voyage through the centuries of human involvement with calculating and computing;
- begins with the prehistory of computing, when the understanding of numbers and performing basic arithmetic operations on them was the domain of just a few;
- explores our present-day computing reality, trying to decipher its meaning, to arrange what we know and understand in a coherent body of knowledge that can be used to confidently discuss problems faced by our society (such as social obligations and individual rights and freedoms in the digital age), to understand where we are and were we are going, or to predict what else is there to invent.

Is the knowledge of the past necessary, or even helpful, to understand the present or to predict possible trajectories of social an technological advancements in the future?

A few observations and examples instead of the direct answer

- *Scientifically justified facts do not have an expiry date only because they have been established in the past.*
  They will stay valid as long as the foundations used to justify them remain accepted as true.

  For instance, 1 plus 1 remains 2 in "standard" arithmetic (yes, there are non-standard systems of arithmetic) in spite of the fact that our understanding of addition of numbers has begun to shape thousands of years ago.

  Similarly, the fact that a single molecule of water is composed of two parts hydrogen and one part oxygen (hence H_2O), established in 1805 by Joseph Louis Gay-Lussac and Alexander von Humboldt, remains valid although our understanding of the concept of "parts" or atoms has evolved substantially.

- *Past experiences, or history, shape our behavior and preferences, hence our future.*

  We use special purpose software and hardware to protect our computers from malicious attacks not only because such attacks may happen but because they did happen and are happening as we speak.

- *An invention is just the final step in a complex chain of preceding discoveries and inventions.* Such a chain may span centuries.

  The microprocessor–the heart of every modern computer–was "invented", or rather offered commercially for the first time in 1971. Informally speaking, the microprocessor is a 'chip' (or an integrated circuit) that contains the circuitry of the entire so-called central processing unit (or CPU) of a modern computer.

  The invention of the microprocessor was based on the invention of the *integrated circuit* (1958) which, in turn, was base on the invention of the transistor (1947), and so on.

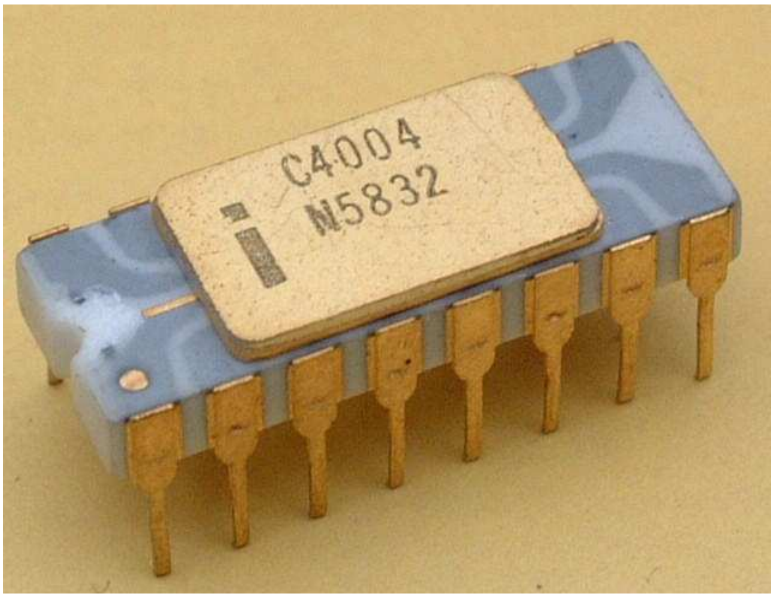

Fig. 5. The first commercial microprocessor – Intel 4004 (1971).

  Already during the early years in the development of the integrated circuit technology (early to mid 1960s), the speed with which these integrated circuits were becoming more and more complex and sophisticated in their abilities allowed some electronics engineers to conclude that the development of such a CPU computer chip was possible.

Unfortunately, at that time there was no technology that would allow to fabricate such devices cost effectively. The world of electronics had to wait until 1971 for such a technology and the first microprocessor.

The microprocessor's "invention" was not the case of a radically new idea occurring to someone just at the right time. The invention was powered by business objectives to manufacture new electronic devices.

The invention was achieved by combining new chip design and manufacturing technologies with existing computer architecture solutions and industry objectives (such as "computer on a single chip is possible").

- *History offers insights into the shaping of human behavior and that may guide forecasting of future technological tendencies and advancements.*

  One thing that we have learned from the historical studies is that our own biological evolution is progressing at a much slower rate than our ability to learn and invent. For instance, our present biological ability to exactly remember facts (e.g. number values) and to mentally manipulate them is at the same level as it was two thousand years ago or even earlier.

  However, during these 2000 years we have developed successive generations of technologies that profoundly enhanced our otherwise mediocre abilities to mentally (and accurately) manipulate abstract concepts.

  Such facts suggest that we will always need devices, such as computers, to enhance our intellectual abilities, to learn more and faster.

- But there is more, the success of *personal* calculators, the popularity of *personal* electronic gadgets such as Sony Walkman or Nintendo Game Boy, the rapid social acceptance of home and *personal* computers in the past, and, currently, of smart phones and tablets indicates that we have always enjoyed "*personal*" gadgets (those that enhance our intellectual and communication abilities, and those used just for entertainment), that they will remain successful and will continue to power future technological advancements in consumer electronics.

Fig. 6. Nintendo Game Boy (1989).

Basic vocabulary

Before we begin our journey through the centuries of computing we need to introduce, or agree upon, some basic terminology related to computing and society such as: society, operation, computation, calculator, and computer.

Society

A society is an organized group of people located in a certain geographical region or virtual space, and considered in a certain historical period. Such a group is characterized by its organizational structure (e.g. dominance hierarchy) as well as the roles, obligations, responsibilities and rights of individual members and subgroups. Society is also characterized by its values, beliefs, as well as technological and economic advancement.

Human societies are characterized by patterns of relationships (social relations) between individuals who share a distinctive culture and institutions; a given society may be described as the sum total of such relationships among its constituent members. In social sciences, a society invariably entails social stratification and/or dominance hierarchy.

A society can be formed by a small group of individuals, as in the Royal Canadian Yacht Club (Toronto, Ontario), or Canadian Society for Civil Engineering, or as large as the Canadian society made of all the citizens and landed immigrants of Canada, say, in the first decade of the 21st century. A society could be a virtual association of people participating in activities provided by the new electronic technologies (e.g. social networks, new media, cybercafes, student study networks, Second Life-type virtual realities, etc.).

Fig. 7. Second Life screen-shot.

Operation

In mathematics, an operation is a function with some arguments (or input values) which, when applied to its arguments, returns a value (or an output). Here is an example.

EXAMPLE 1: The Operation of Addition.
Addition accepts two input values n and m and returns the sum $n + m$. So, given $n = 2$ and $m = 3$, this operation returns 5.

The use of the term *operation* in computing is similar as it captures the process of deriving output values from inputs.

EXAMPLE 2: Search in a text.
Given a text, such as

This is one of the examples of a search for a keyword example.

and a keyword, such as *example*, this operation returns all the words in the text that contain this keyword. So, in our case, the search operation returns two words: 'examples' and 'example' as shown below

This is one of the <u>examples</u> of a search for a keyword <u>example</u>.

Note that the search operation has two inputs: a text and a keyword.

Some operations always return a value (as in the case of addition). Other operations may return values only for some but not for all input values. For instance, the search for the keyword 'computer' in the text of Example 2 produces no output.

Algorithm
Given a list of operations (let us call them basic operations), an *algorithm* describes a "complex operation" which is defined in terms of these basic operations. Such a definition is always written in terms of a finite number of basic operations. An algorithm describes the way the output values are to be constructed (or computed) from inputs.

EXAMPLE 3. Suppose that we want to develop an algorithm for house cleaning having the following basic operations in our disposal:

- $ThereAreDirtyWindows(house)$
  returns TRUE if there are some dirty windows in the *house*, and FALSE otherwise;

- $ThereAreDirtyFloors(house)$
  returns TRUE is there are some dirty floors in the *house*, and FALSE otherwise;

- $SelectDirtyWindow(house)$
  selects a dirty window at random;

- $SelectDirtyFloor(house)$
  selects a dirty floor at random;

- $Clean(object)$
  cleans $object$ with water and detergent;

- $Vacuum(object)$
  vacuums $object$.

- WHILE *Condition* DO *Operation*
  this operation continuously performs *Operation* while {*Condition*} is TRUE
  (e.g. WHILE *have money* DO {*buy a donat and rest*}).

What we want is an algorithm for cleaning a house which consists of cleaning all dirty windows and vacuuming all dirty floors. Here is the algorithm called $ClaeanHouse(house)$ that could be used by a robot to clean houses.

```
CleanHouse(house)

  WHILE TherAreDirtyWindows(house) DO
    {
     window = SelectDirtyWindow(house);
     clean(window);
    }

  WHILE ThereAreDirtyFloors(house) DO
    {
     floor = SelectDirtyFloor(house);
     vacuum(floor);
    }
```

Calculator

A calculator is a device (mechanical, electro-mechanical, electronic) designed to perform a fixed number (typically small) of operations (typically arithmetic).

Fig. 8. Rapidman 802 calculator (Rapid Data, Toronto, 1972).

Computer

A computer is a device designed to perform (theoretically) an unrestricted number of operations on numbers and other abstract data objects. Modern stored-program digital computers perform complex operations by following algorithms defining these operations. The algorithms are written as the so-called computer programs. Before the operation described by a program can be executed in a computer, such a program must be translated into computer-dependent instructions that a given computer is programmed to recognize and execute.

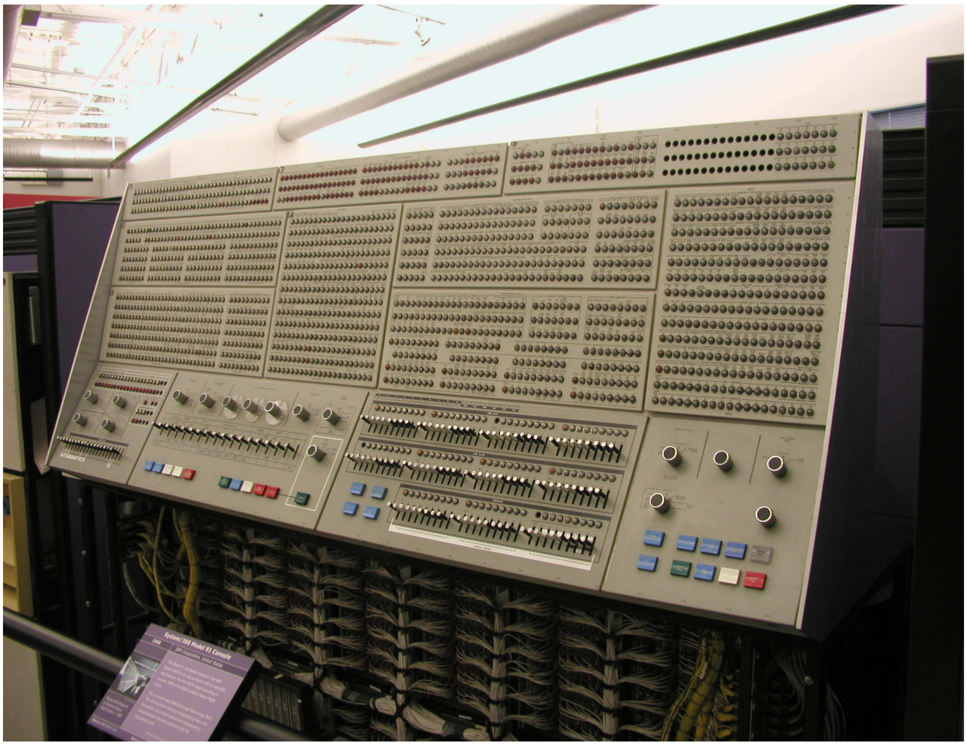

Fig. 9. The IBM System 360 (IBM, 1960s), operator's console at Computer History Museum.