Introduction to Computer Graphics for Designers and Artists

1. Introduction

Over the last years, research and development in computer technology has led to new inventions that have, are, and may change the way we think. We have seen many changes in how we perform tasks, how we communicate, and how we live our lives that are very different from the way they used to be in the past. Computers are being used in almost every task of our everyday lives, from working at the office, to communicating with other people, to getting the news or paying bills. Computers are ubiquitous and seem to be constantly present in any aspect of our lives.

The interesting thing about computers is not only the actual invention, that is, the computer as a device, but also the theoretical framework on which these devices are based upon. It seems that the way human beings are thinking can be codified and simulated. Thinking is not necessarily a process that happens only in the human brain, but can be simulated by other devices. What we refer to as logic is a structure of ideas that is based on some basic operations that when combined with one another lead to what we call thinking. By detecting those operations, computer scientists and electrical engineers were able to create machines that performed those operations through electrical charges. Instead of using neurons they used transistors. These operations when combined together resulted in a "thinking" machine. Of course, human brains perform tasks even more complex than computers can yet it is claimed that the principles are the same.

Although originally, computers were developed to perform computations, it soon became apparent that they could be used to perform other tasks as well. The realization that computers could perform simple thinking led to use them as control devices and as assistants to humans. As control devices they became responsible for controlling other devices, such as engines in cars, robots in manufacturing, heating/cooling systems in buildings, communication equipment in companies, and almost any other device. As

assistants they are used to perform tasks that humans are either too tedious, or too slow in doing, or often impossible. Such tasks are manufacturing , design , or computations.

Design is a task that involves intelligence, imagination, creativity, and other elements of human thinking. It will be shown later that although many claim that design can be performed by computers, to date that has not been practically proven. Nonetheless, computers have been used extensively in the design process as assistants and controllers. In the graphic arts, computers can control other devices that collect information from the environment, assist the artist in arranging visual elements and then control the output devices when printing and plotting. For designers, computers can be useful in performing tasks too tedious, such as drafting, plotting, or visualizing information. Computers can also help designers and artists in the display of visual information.

Visual information used to be very dependent on the means of display. Traditionally, text, images, or animated pictures were displayed on paper, plastic, or film. By using different types of paper, plastic, or film artists could produces more clear, crisp, bright, or colorful information. The tight connection between information and molecules seems to be changing. Visual information can be stored, processed, and displayed on computer screens by altering temporarily light intensities without having to be permanently embedded. The shift has been made from molecules to electrical charges. The ephemeral has replaced the permanent. Yet, the amount of visual information that is produced has skyrocketed. Computer networks have contributed significantly to this shift.

Today computerization has penetrated all design and image making industries. There are many reasons why, in just a few decades, artists, designers, publishing companies, architects, engineers, sculptors, video-graphers, and animators have elected to adopt this new way of working. In almost any case it is that the incorporation of the computer in the making process provides both practical benefits as well as expanded productivity. Computers are not only devices that help us produce faster and more accurate results but

can be also used to expand the knowledge beyond the known and push forward the boundaries of our imagination.

2. History of the Machine

Since the time of Plato it was suggested that logic was a mental entity independent of its agent. Socrates theory of ideas was about entities that existed independent of their thinkers' body or lifetime. By abstracting the real world, one is able to detect the existence of elements and relationships that constitute what we refer to as *thinking*, *remembering*, or *understanding*. The existence of abstract entities seems to be independent of the means in which they reside. By abstracting logical thoughts, Babbage [1] was able to identify a set of basic arithmetic operations and operands that the brain uses to perform computations. He constructed a mechanical machine out of wooden switches that materialized those operations. As switches turned right or left they created patterns that corresponded to the result of the arithmetic computation. Boole [2] later on suggested that arithmetic operations could be extended to perform logical operations using true-false logic. His idea was implemented many years later using electrical charges instead of wooden switches. The first computer was (and still is) a set of on-off switches that materializes arithmetic and logical operations. The difference of electrical over mechanical switches is only in the speed of performance.

Although computer technology has improved tremendously compared to the first computer, the main research today focuses on ways to increase the speed of performance and to reduce the size of the machine. Computers tend to become smaller and faster, yet the main principle of operation is the same: a device that "thinks". Of course, the level of thinking that a computer can perform is not the same as human thinking. But it can perform logical computations that are very useful to humans, and quite often impossible for us to do. Think of the Big Blue, notepads, or supercomputers. In that sense, computers can hopefully extend the human brain.

The first computers were developed during the Second World War as a device for facilitating calculation for rocket launches. The architecture of the first electronic computer was based three basic components: the memory, where information was stored, the input-output module where information was entered or exited, and the CPU (Central Processing Unit) where arithmetic and logical operations were performed. This architecture maintains its scheme even today with a few alterations.

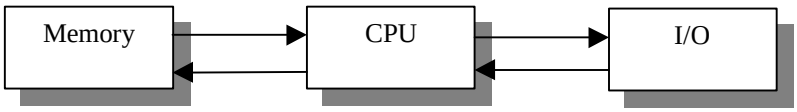

Figure 1.1. The basic architecture of a computer

Since the computer is based upon electrical on-off switches, there has been tremendous progress in the materials and methods of building those switches. Originally, tubes were used, then transistors, then solid state circuits, and finally microprocessors. In each stage/generation, size, speed, cost, and maintenance became the critical factors of acceptance. A transistor is a tiny device made out of copper and silicon that can be turn on or off and won't deteriorate over time. A microprocessor is a collection of millions of microscopic transistors.

Although originally the first computer was developed for military application, soon it became apparent that it could also be used for other applications. Many companies started to invest on computers that could perform accounting, statistics, archiving, and other commercial applications. Great amounts of money were spent on creating better programs, faster and more in-expensive computers. In the 50s and 60s large size computers were created, called *mainframes*, that were very expensive and only large companies, universities, or the army could afford. In the early 70s, the personal computer

was introduced that was fast, personal, friendly, and affordable. That became the beginning of mass-produced computers that targeted at the average citizen. This trend continued in the 80s and 90s.

An interesting twist in the history of computers, is the development of *computer networks.* A network allows computers to share resources. Information no longer needs to be stored on the local memory component but rather be fetched from another computer/server. Even calculations no longer need to be performed on a local CPU component but rather share computation time on a remote supercomputer/server. The architectural scheme that the first computer was based upon tends to become looser since the actual components do not need to be physically adjacent. Instead of regarding a computer as an integrated device that functions on its own, a rather larger picture arises where groups of computers are related to other groups forming client-server relationships. Therefore, a local computer can be reinforced to perform more and faster tasks by simply plugging it in a network. This trend seems to be the dominant in the late 90s.

3. History of Computing

Computers are devices that can process information. Information exists in the world in the form of signals. Those signals can be of any type including visual, audio, taste, sense, and olfactory. The human brain gathers signals from the world, manipulates them somehow into other signals and them externalizes them through movements of the body. This manipulation of signals has long puzzled philosophers as to whether it is a unique function of the human brain or whether it is something external that the human brain just uses. Take a simple example of arithmetic: one apple and another apple results in the notion of two apples. Now apples can be said to be just signals that are converted to be understood as having a specific shape, taste, and color. Nonetheless, the notion that one thing combined with another thing results in two things is a general concepts that applies to all entities, whether they are apples, trees, or planets. The concept that 1+1=2 can be claimed to be a fact independent of whether the senses can witness it or whether it

happens to be for apples. By taking this concept a little bit further we can claim that the same fact applies for logical operations. *If* the apple is cut *then* it will fall to the ground. This is true for all objects on the surface of earth. Therefore, one can claim that the operation if-then can be applied to sets of elements independent of whether they are observed.

The concept of independence is quite important. It has led philosophers to abstract arithmetic and logical operations and establish a theoretical structure in which elements and operations can interact. This structure is called *logic*. Boolean logic tries to constraint all logical operations to true-false in order to establish a binary logic. The reason is quite simple. We need to feed the computer, which is constructed of on-off switches with corresponding elements. "On" or "1" means "true" and "off" or "0" means "false". In this manner, complex reasoning can be abstracted to 0s and 1s and be solved through computer operations.

In the same way, elements from the external world can be represented as 0s and 1s and then be processed arithmetically or logically. Let's illustrate these concepts with a simple example: suppose that an apple is represented by the letters a, p, p, l, e and each letter correspond to a numbers in the alphabet starting from a = 1. Then apple is 1, 16, 16, 12, and 5. Now each number can be converted to a binary number by breaking each number is powers of two. 1 is 2 to the 0^{th}, 16 is 2 to the fourth, 12 is 2 to the 3^{rd} + 2 to the 2^{nd} + 2 to the 1^{st} + 2 to the 0 and 5 is 2 to the 2^{nd} + 2 to the 0th. In other words 1, 16, 16, 12, 5 becomes 00000, 10000, 10000, 01111, 00101. We just digitized the word apple.

In the following example we will see how arithmetic operations can be represented through digital logic. Let's take 1+1=2. In binary terms this corresponds to 00001 + 00001 = 00010 (as shown earlier) which is true because 00010 is indeed 2 to the 1^{st} which is 2. In the same way one can take propositions, digitize them, combined them together using binary logic, and convert them back to propositions. It does not matter how many propositions we take or how many logical operations we perform on them.

Everything goes down to the level of "on-off" and if we afford to have millions of switches then we can handle millions of logical operations.

The set of arithmetic and logical operations is called a *language*. A computer language is a set of operations that can handle arithmetic and logical operations on elements. *Data* are elements that the language can handle. A *program* is a set of statements where operations are performed on data. A *compiler* is what digitizes the program in order to run. *Running* a program is to set the switches to on or off and perform the operations.

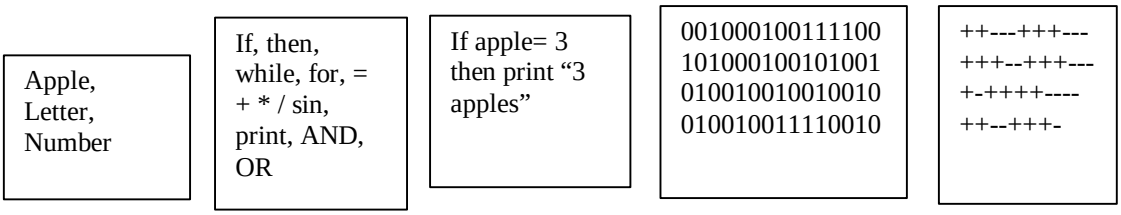

Figure 2 (from left): Data, language, program, binary code, electric charges

Although computer languages are based on universal concepts their compilers are tightly connected to the computer's hardware. The evolution of hardware affected the history of computer languages. In the 1960s line-by-line languages, such as BASIC, were developed. The compiler would interpret every line of the program one at a time. The reason for that was that memory was expensive and programs could not be compiled all at once. Later, when memory became cheap, languages such as FORTRAN and COBOL were developed. When the personal computer was created C became very popular because it could allocate new memory only when it needed it saving memory. When memory and speed became available, new type of languages became developed: object-oriented. In object-oriented languages, such as C++, tasks are performed by independent agents called *objects* and not through procedures. When the Internet became available to

all computers in the world, platform-independent languages were developed such as *Java*. In Java, the compiler creates binary code that is readable by any kind of computer. When parallel-processing computers were created, new languages that could handle tasks in parallel were developed.

An *application* is a computer program that can help somebody do something. This could be something simple such as addition and multiplication, or something complex such as solving differential equations. Companies develop applications that can help one do almost anything from word processing, to music composition, and from designing to networking. An application is a program in the form of binary code that can be run on a computer. *Software* is a term used in contrast to hardware and refers to whatever is involved in programming and compiling.

As mentioned earlier, computing is not confined to arithmetic computations but can be extended to include logical operations. Originally, computations were performed to solve mathematical problems or to verify equations. Soon enough it was understood that computations could also be used to understand and predict complex phenomena either in the physical world or in the world of imagination. Weather behaviors, molecule structures, astronomical phenomena, and other such patterns can be computed by manipulating data, rules, and parameters. Information about a physical phenomenon is entered and the machine computes a result by manipulating parameters and rules.

The area of research that studies the codification of tasks that can make a computer do what humans do is called *Artificial Intelligence* (AI). Problem solving, pattern recognition, design are areas of AI. From the development of the first computer, philosophers thought that they could make a computer that could replace the human brain. Some even went further to suggest that computers could replace and extend the human brain. Their claim was based on solid evidence: since the computer could theoretically perform extremely large numbers of logical operations in speeds far faster than humans, it seemed logical that one day a super-human computer would be developed. To date this has not happened. Instead what happened is that computers

helped humans do things they cannot do with their brains. They have extended the human brain but not replaced it.

4. History of Design and Computing

Design is the task of creating forms and, at the same time, meeting certain criteria. Designing involves stages in which tasks are performed. Some designers are often not aware of what they do during the design stages. Nonetheless, they do perform their tasks and they do eventually produce designs. So, as theorists argue [3], design is a mental process that involves certain logic. If design operations can be identified in such a way that they can be rationalized in steps, then a computer can be used instead. Over the last forty years, it has been a struggle to prove that this is true, that is, that computers can design.

As mentioned earlier, computers can interact with humans in many different ways. They can complement, compete, extend, or replace one another. Since design does involve to a certain extend logic, a computer can be utilized and therefore all of the above scenarios are possible. Different people have come to claim different scenarios ranging from programmers to science fiction writers.

The development of the first capable computer systems in the 1960s created an enthusiasm among scientists that computers could do almost anything. This was based on theoretical evidence but poor computer performance at that time. Many books and papers were written on how to make intelligent designer-computers. However, only a few applications were developed that were rather unsuccessful because the hardware of that time was not powerful enough to implement the theories. At least, this is what they claimed.

In the 1970s the attitude changed towards the scenario of complementing the designer. With the introduction of new display means, such as color screens and plotters, computer-aided design (CAD) systems were developed. These systems were able to

perform simple yet powerful tasks such as three-dimensional viewing, calculating, erasing, or transforming. The scientists from the 60s ended up compromising many of their expectations and developing design systems that could respond to design questions or learn simple tasks.

In the 1980s CAD systems were evolved to handle almost any kind of shape and perform complex form-making operations. Theorists focused on stylistic issues and tried to develop rule-based operations that could explain, replicate, or alter the phenomenon of style in design.

In the 1990s two new concepts were introduced, that of networking and virtual reality. CAD systems started to address the issue of hyper-links and collaborative design and many CAD systems were transformed into navigators. A navigator is a system that allows one to move in three-dimensions in a realistic environment called *virtual reality*. Although virtual reality does not address design issues, it is a useful tool for visualizing design proposals.

It is evident that design and computing are both affected by hardware evolution. Theoretically computers can perform design, the problem though is that real design is very complex. With the capabilities of today's computers, computer-generated designs look very simplistic and are therefore criticized by many as being too naïve.

Summary

- Computers are being used in almost every task of our everyday lives
- Thinking is not necessarily a process that happens only in the human brain, but can be simulated by other devices.
- Although originally, computers were developed to perform computations, it soon became apparent that they could be used to perform other tasks as well.
- By abstracting the real world, one is able to detect the existence of elements and relationships that constitute what we refer to as thinking, remembering, or

understanding. The existence of abstract entities seems to be independent of the means in which they reside.

- Computers tend to become smaller and faster, yet the main principle of operation is the same: a device that "thinks".
- Great amounts of money were spent on creating better programs, faster and more in-expensive computers
- A network allows computers to share resources.
- Computers are devices that can process information.
- Complex reasoning can be abstracted to 0s and 1s and be solved through computer operations.
- Companies develop applications that can help one do almost anything from word processing, to music composition, and from designing to networking.
- Computations could also be used to understand and predict complex phenomena either in the physical world or in the world of imagination.
- The area of research that studies the codification of tasks that can make a computer do what humans do is called *Artificial Intelligence* (AI).
- Problem solving, pattern recognition, design are areas of AI.
- Design is the task of creating forms and, at the same time, meeting certain criteria.
- For designers, computers can be useful in performing tasks too tedious, such as drafting, plotting, or visualizing information. Computers can also help designers and artists in the display of visual information.
- Over the last forty years, it has been a struggle to prove that this is true, that is, that computers can design.
- Theoretically computers can perform design, the problem though is that real design is very complex.

References

[1] Johnson, C., “Robots”, Penguin, 1994, pp. 22-32.

[2] Stewart Ian, Concepts of Modern Mathematics, New York: Dover Publications, 1995, pp.255-268.

[3] Terzidis K., “The role of computers in the design process”, Design Decision Support System Conference Proceedings, Eindhoven, 1992, pp.15-23.

Further Readings

- Dictionary of computing. New York: Oxford University Press ; Oxford, c1983.
- Encyclopedia of computer science / Anthony Ralston, editor, Chester L. Meek, assistant editor. New York: Petrocelli/Charter, 1976.
- McGraw-Hill dictionary of computers / Sybil P. Parker, editor in chief. New York : McGraw-Hill, c1984.
- Farace, Joe. The digital imaging dictionary / Joe Farace. New York: Allworth Press, c1996.
- Latham, Roy. The dictionary of computer graphics and virtual reality / Roy Latham. New York : Springer-Verlag, 1995.
- Vince, John. Dictionary of computer graphics / John Vince. White Plains, N.Y. : Knowledge Industry Publications, c1984

Key Terms

application, 5
Artificial Intelligence, 6, 8
Babbage, 2
Boole, 2
compiler, 5
computer-aided design, 7
CPU, 3
Data, 5
Design, 1, 6, 8
digitized, 4
language, 5
logic, 4
networks, 3
objects, 5

program, 5
Software, 5
virtual reality, 7

Review Questions

1. Is geometry a human invention or a human discovery?

(Hint: There is no correct answer. The answer should be build on supporting arguments and consistency of argumentation)

2. Can computers improve design (not drafting)? Why or why not? How?

3. If computers could design on their own, what would be the implications for design-oriented professions?

Quiz

1. Digitize the word "acadia" (a=1):

a) 00001, 00011, 00001, 00100, 01001, 00001

b) 00000, 00010, 00000, 00011, 01000, 00000

c) 00001, 00010, 00001, 00100, 01001, 00001

d) 00001, 00011, 00001, 00100, 01000, 00001

Answer (as many apply): a b c d

4. Computers can design on their own

a) true

b) false

Answer (circle one): a b

5. AI stands for

a) Art Information

b) Artificial Intelligence

c) Access Input

Answer (as many apply): a b c

6. Why is virtual reality useful in design?

Answer: _____

7. What is the trend for CAD systems in the 90's?

Answer: _____

8. What does CAD stand for?

a) Computer-aided Drafting

b) Computer-aided Design
c) Computer-assisted Design
d) Computer-assisted Drafting

Quiz Answers:

1. A 00001 = 1 or a, 00011 = 3 or c, 00001 = 1 or a, 00100 = 4 or d, 01001 = 9 or i, and 00001 = 1 or a
2. b (false) Design is a task that involves intelligence, imagination, creativity, and other elements of human thinking. It will be shown later that although many claim that design can be performed by computers, to date that has not been practically proven.
3. B AI = Artificial Intelligence
4. Although virtual reality does not address design issues, it is a useful tool for visualizing design proposals
5. In the 1990s two new concepts were introduced, that of networking and virtual reality.
6. CAD = Computer-aided Design