Chapter

# Introductory Chapter: Computer Graphics and Imaging

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## 1. Introduction

Computer graphics is one of the generational changes in computer technology. Its development is so stormy that it has expanded from precious devices designed for military and top industrial applications to schools and households as a common information medium and a medium of education and entertainment. The history of modern computer graphics began to be written after the Second World War. Thenceforth, the area characterized as an area of technical and natural sciences dealing with the graphical information processing using a computer was named computer graphics. The graphical information is much more intelligible and clear for human than, for example, information in numerical form. A computer graphics affects our daily live. Computer graphics helped to mass-expand computers, and it removed the barriers that ordinary people feel when working with them [1] (they are "flooded" with columns of numbers and text and they are drawn into a world where they cannot be orientated oneself).

As can be seen from the previous words, human evolution is tied to the process of collecting, processing, transferring, and recording of information. If we add that most people are gaining the most information by sight, then modern computers are already greatly helping them.

However, the history of computer graphics dates back much earlier. Already Johannes Gutenberg discovered and introduced the basic technology of human information transfer—letterpress, in the years 1444–1448. Genius Leonardo da Vinci examined relationships of science and art around the same period (1452–1515). Joseph Marie Jacquard introduced a loom controlled by punch cards ("a printer predecessor?") in the years 1805–1808. But W. B. Hales created the first analog computer drawings in the years 1944–1945. Ivan Moscovich designed a drawing machine in 1951. A year later, Ben F. Laposky exposed analog computer graphics in Cherokee Sanford Museum in the USA. Then more and more attention was paid to computer graphics, and the result is already well known in present.

Yes, this is the evolution of the computer graphics phenomenon. The phenomena that are increasingly gaining interest in the eyes of the lay public are the following:

- Communication form with computers and user interfaces? Computer graphics
- Design of cars and consumer electronic products? Computer graphics
- Design of buildings and interiors? Computer graphics
- Newspapers, magazines, and catalogs? Computer graphics

- Weather forecast? Computer graphics
- Computer games and entertainment? Computer graphics
- Presentation of an economic, electoral, or statistical results? Computer graphics
- Goods packages in the shops? Computer graphics
- Film, video, and advertisement? Computer graphics
- … and plenty other examples …

Yes, the impact of computer graphics on our lives is really significant. It is already very difficult to find an area in which the use of computer graphics would be no importance in present. It is important not only for processing, for example, images or drawings, but also because for the graphical user interface usage. Here are some trends in computer graphics usage:

- Computer games
- Business and management graphics or advertisement
- Computer-aided drawing and design
- Visual simulation and scientific result visualization
- Image processing and cryptography
- Multimedia, show business, photorealism, user interfaces, or virtual reality and its technologies

These are trends and especially application areas of computer graphics and image processing. Computer graphics is a tool in these cases. Of course, computer graphics is also the subject of research or study.

Approximately 80% of the information is gained by sight. This has been already mentioned above. Therefore, light and colors in the process of visualization (and thus also in computer graphics) play a dominant role [2]. This dominant attribute is also used to process images or to work with graphics. From a physical point of view, light is understood as two things:

- *Particles* (photons)
- *Waves*

In this case, it is electromagnetic waves in the $10^8$ Hz range. From the point of view of color, each color corresponds to a certain frequency. The range of colors ranges from red ($3.8 \times 10^8$ Hz, beyond the visible spectrum continues to infrared) to purple ($7.8 \times 10^8$ Hz, going beyond the visible spectrum to ultraviolet). Within the visible spectrum, a person is able to distinguish more than $4 \times 10^5$ different colors and their shades. According to the frequency transmitted by the light source, the light can be divided into:

- *Achromatic* light—this light is also called white light and contains all colors (a typical source is the sun). The combination of frequencies reflected by the body creates essentially a body color. If the frequency prevails over a certain spectrum, we are talking about the dominant frequency.

- *Monochrome* light—this light is of only one color (e.g., red).

Light is characterized by several of its attributes:

- *Color*—the basic attribute of light depends on the already mentioned frequency (or wavelength).

- *Brightness*—in fact, the intensity of light and the brightness of the light source are in direct proportion to the intensity.

- *Saturation*—saturation of color indicates its purity; the higher the saturation, the narrower the spectrum of frequencies contained in the light.

- *Lightness*—this is actually the size of the achromatic component in the light with a certain dominant frequency.

An important factor is the split of colors. There is a question as to whether there are certain basic colors, by the composition of which all others would be created. There are, however, complementary colors combined with white light. For multiple colors, a standard was created in the form of the chromatic diagram. However, the chromatic diagram does not determine which base colors the others will be composed of or their ratio. Also some chapters in this book contain description of some light and color areas with the impact to/from modern computer graphics.

Historically, computer graphics devoted much to transformations. Yes, a geometric transformation, an imaging and morphing of models or objects, is one of the most common tasks of computer graphics systems [3]. In order to manipulate with graphical objects in computer graphics, it is necessary first to define the manipulation space. Its basic property is its dimension. This dimension can be numeric or non-numeric. There are several numerical dimensions in terms of their character: topological dimension, Hausdorff (fractal) dimension, self-similarity dimension, capacity dimension, and also non-numerical dimensions, for example, information dimension, etc. All definitions of these dimensions are relative. The most used dimension is the topological dimension expressed in integer terms. The topological dimension is the range of objects commonly used in the math. Thus, the topological dimension can be also understood intuitively. With regard to the topological dimension, the most commonly used objects are:

- Zero-dimensional object (a point)

- One-dimensional object (a line, a curve)

- Two-dimensional object (an area, a surface)

- Three-dimensional object (a solid, a body)

All geometric objects convertible by continuous transformation to the above objects have the same topological dimension (e.g., a curve is assigned to a line, a plane is assigned to a surface, etc.). Typically processed objects are divided into vector and raster [1]. However, in order for the transformations to be made, it is necessary to define certain coordinate systems in respect of which the transformations are carried out. The transformations used in computer graphics are used for geometrical transformations. In the case of projections, the perspective projection is the most common. Other approaches are the axonometric projection and combinations of different projections and views. A more recent method is a 3D object morphing transformation in terms of control elements of modeling means. In terms of simulation, it is either morphing an object in a time continuum (e.g., an aging, a disintegration, etc.) or morphing an object after an interaction (a collision). In general, both defining and modeling, as well as subsequent transformations or object projections, are among the basic processes applied in computer graphics. In these cases, the curves and surfaces are often used also for graphical object definition or modeling. But the curves and surfaces are used in the computer graphics area, in particular, for two reasons. The first one, mentioned above, is their usage in the area of graphical object modeling. The second reason, nowadays, with a rising trend, is to use them "in the background" as the control attributes of various activities used in the computer graphics.

Each curve or surface must have its mathematical description for a possibility to perform various transformations with a curve/surface, such as shifts, rotations, or scale changes [3]. They are also used for 3D scanning post-processing. Here you can use these curves/surfaces designed in different shapes but with one big plus. This represents the knowledge of the mathematical notation (equations) of a curve or surface. Thus, it is possible, for example, to easily calculate the length of curve and surface area or simply shape it. Overall, it is not necessary to work with all curve/surface points but only with some curve/surface control points. The nonuniform rational B-spline (NURBS) curves/surfaces are the most flexible and also most applicable. Some curves and surfaces are usable also in some cases of special type of displaying.

It is also possible to use 3D displays instead of 2D ones (the examples of 3D displays are volumetric and holographic displays). Then a visualization and visibility solution are no longer needed. These types of displays are still relatively low-robust and low-performance devices at a very high cost. However, this does not mean that their usage is irrelevant in the future.

The performance of current computing systems allows the real-time displaying of spatial objects [4]. The results from this area are already widely used in architecture, engineering, and film (movie) industry. Displaying spatial objects began to develop with the development of the first graphical display units. Initially, it was the display of simple wire-frame models. Next, the surface of the body itself was displayed, but it was only a matter of filling the object surface with one color or simple shading. In addition, the algorithms have been developed to allow photorealistic imaging of spatial objects, allowing the display of shadows and reflections on object surfaces. But even so, it was only a piece of information about a three-dimensional space that did not allow or in part to gain spatial information from a given output. The solution, though it seems to be only partial, is to explore and exploit the very way in which human receives visual information and thus an examination and an exploitation of spatial vision.

Stereoscopic imaging is between 2D and 3D displaying but bringing to a viewer a sense of depth or space [5]. Stereoscopic vision is one of the basic characteristics and abilities of people, as well as many other forms of life on Earth. The stereoscopic projection is based on the principle of displaying different images into each eye through a special device such as glasses with different colored glasses (anaglyph), switchable glasses, polarizing glasses, stereoscopes, or helmets/glasses for virtual reality (also with mobile devices usage). For example, a color space image can be seen by an observer through switchable glasses. On the displaying device, the image for the left and the right eye is alternately displayed, and the right and the left eye are obscured in sync for the observer. The color space image can be seen also by the observer through the polarizing glasses. Both the left and right eye images are simultaneously displayed on the displaying device, but they are polarized in perpendicular planes. Overall, the perceived depth of the image is an important part of modern type displaying, for example, in virtual reality systems.

The development of new technologies within computer systems and within modern computer graphics too is taking on a dizzying pace. One of the areas where progress is most noticeable on a daily basis is undeniably virtual reality (next VR) and its related technologies [6]. VR uses computer graphics in a wide range. A virtual reality system is an interactive computer system that is capable of creating an illusion of physical presence in an imaginary or near-real world, synthesized by the VR system. A VR system provides a perfect simulation in a tightly-bound human-computer interaction environment. Thanks to the technological advances and decreasing prices, various VR devices are becoming more common in research, industry and entertainment. These are, in terms of mass interest, resulting of financial returns, a long-term "draft horse" of technological advances in associated technologies including computer graphics. Despite the indisputable advantages that the modern solutions of the VR provide, it is not a common practice to use them within a professional environment. Primary, systems based on classic user inputs and outputs such as a keyboard, a mouse, and a conventional 2D monitor continue to dominate. Although interfaces are an important feature of VR systems, they are not only the one and at all not main. The ability to create an illusion of physical presence in synthesized space, or to influence the real space with synthetic elements, can be considered dominant. The first imagination of the perfect VR was presented in the cult movie "The Matrix" and its continuations. What is real and what is virtual? VR systems provide a better experience, and they are more interactive, but the complexity of their implementation is very high. VR subsystems are divided according to senses that affect visualization subsystem, acoustic subsystem, kinetic and statokinetic subsystem, touch and contact subsystem, and other senses (e.g., smell, taste, pheromone sensitivity, etc.). Some senses commonly perceived in the real world do not have much importance to implement in the virtual world at present. However,

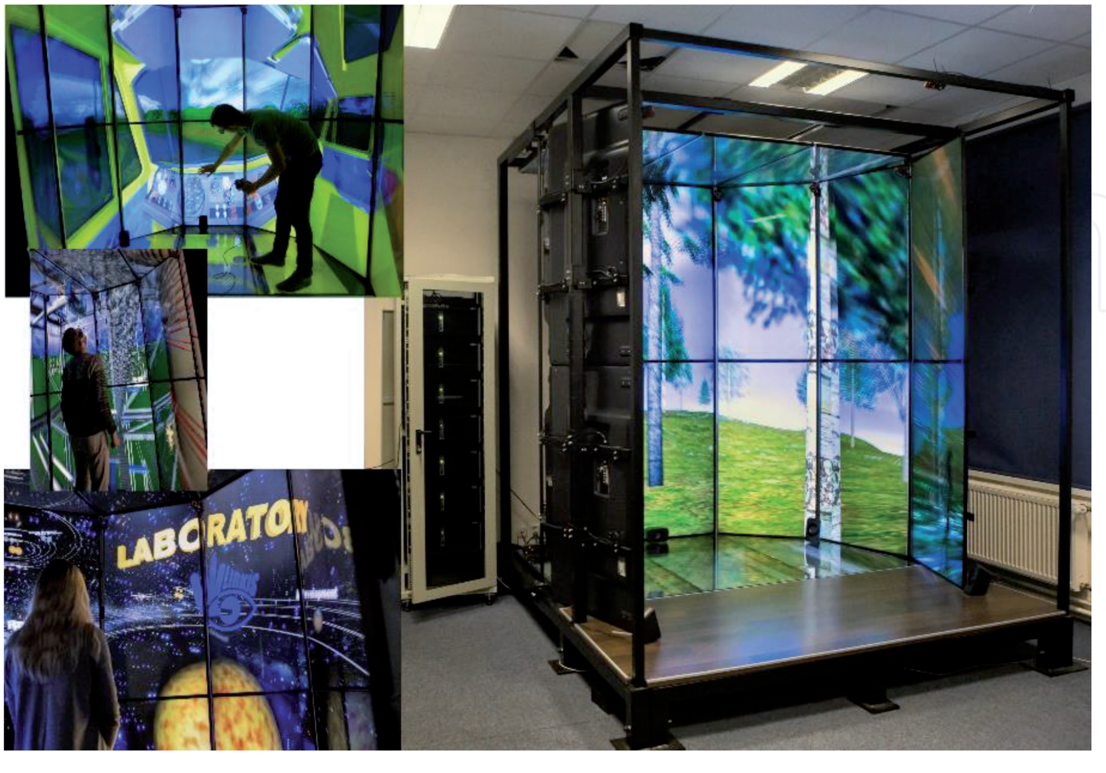


**Figure 1.**
*Virtual cave in laboratory LIRKIS at technical University of Košice and the examples of immersive visualization in this environment.*

the visualization subsystem is the most important, and so computer graphics is at the first place in this case. Visual immersion is very important. The virtual cave [7] in the LIRKIS laboratory at the Technical University in Košice and the examples of immersive visualizations within this cave are shown in **Figure 1**.

The abovementioned areas of computer graphics are just some of the wide range of current computer graphics. The overview of modern approaches, procedures, algorithms, as well as devices in the area of definition of graphical scenes and objects, light and colors, graphical transformations and graphical libraries and systems, projections, curves and surfaces used in computer graphics, visibility solving, filling and texturing, shading and lighting, realistic and photorealistic imaging, stereoscopy and spatial imaging, image filtering or user interfaces, and virtual reality should be the content of this book.

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