

# *Features of Computer Images*

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**Abstract**—An important aspect of human activities is receiving, recording and operating with geometric information possessed by all real objects. It is far from always that a person can receive geometric information directly from the object. In these cases substitutes (geometric models) of these objects, which carry the same geometric information, are used. They are geometric models of three-dimensional objects that people traditionally use in their flat images. The main requirement imposed on geometric models is to save all geometric information of a source object. To meet these requirements, a flat image must be created in accordance with laws discovered early. Unfortunately when creating flat computer images, these laws are not always followed. As a result the received images do not follow the basic requirement distorting the represented depicted three-dimensional world.

**Key words**—flat image, geometric information, geometric model

## I. IMAGES USAGE SIGNIFICANCE

Why do people need images? The answer is known and obvious to everyone: to represent any geometric information. It is known that geometric information is information about dimensions, shape, objects, their relative position in space [3]. Is there any object in the real world that does not possess this information? And can a person exist in this world without the ability to perceive, represent and operate with this information? Of course, he cannot. The significance of geometric information can hardly be ever overestimated and it is difficult to find now and recently the period when people would not represent geometric information one way or another and would not process it.

Images of three-dimensional objects on a plane (perspective, axonometry and Monge's projection) are most widely spread. These images perform the following functions [14]:

- the illustrative and cognitive one being realized in fine arts and in the learning process (visual aids, training simulators). Images performing this function must correspond to the vision of a human eye distorting the reality. In other words, a human eye does not see parallelism;
- the technological one being the basis for design, creation and operation of engineering and civil engineering projects. Images that perform this function must provide geometric information undistorted.

Undoubtedly, both these functions testify to the wide usage of flat images in the most diverse areas of human activities [9, 10].

## II. FEATURES OF IMAGES PERFORMING THE COGNITIVE AND ILLUSTRATIVE FUNCTION

In general the requirements imposed on the images realizing the illustrative and cognitive function are the correspondence to such images that a human eye sees. What is the reality that a person sees? In terms of geometry the following principles depending on the physiology of an eye should be distinguished:

- a human eye does not see parallel elements. As a result, all parallel lines of the same direction intersect at one point, called the vanishing point [15,16,18,19];
- all horizontal lines have vanishing points on the horizon locating on the horizon plane. Each person has his own horizon plane passing through his two pupils and serving as a gravity reference;
- each human eye is restricted in width and height of an observed object. The range of the object vision is called the conventional cone of vision - it is a set of rays reflected from the object and focused in a lens of a human eye (Fig. 1). The maximum value of the angle of this cone is 60°. If an object does not fit this cone to see it, a person must shift his gaze or change his position;
- each conditional cone of vision has the main ray - it is a virtual line that passes through a lens of an eye and an approximate center of an eyeball. The closer the subject area of the object is to the main ray, the sharper the image is. In the conventional cone of vision the main ray occupies the central position and is oriented toward the conditional center of an object (Fig. 1);
- images of objects are displayed on a curve of a surface of a human eye back [1];
- a human eye does not see parallel straight lines, all parallel lines of the same direction intersect at one point (the vanishing point);
- the virtual plane of the horizon passes through two pupils of human eyes, and serves as a gravity reference [15, 16, 17, 18, 19].

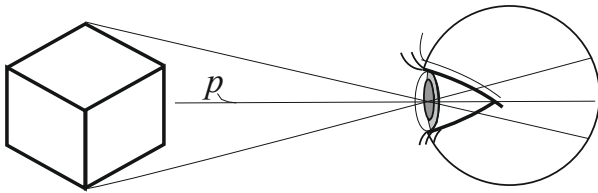


Fig. 1. The conditional cone of vision and the main ray  $p$ .

Such flat image of three-dimensional objects as a spherical perspective largely corresponds to these principles. When a spherical surface is replaced by a cylindrical one, a perspective-panorama appears on it. It has minor distortions that do not affect the perception of the panorama. An eye of a person sees distortions that are noticeable in a perspective created on a plane. But a high caliber performer will easily eliminate them. One creating any perspective should take into account these principles. It is necessary to start creating any perspective in accordance with the following algorithm:

- choose the position of the point of vision;
- determine the value of the angle of vision;
- adjust the position of the point of vision if the angle of vision exceeds  $60^{\circ}$ ;
- determine the position of the main ray as a bisector of the angle of vision;
- determine the position of the plane on which a perspective (pictures) will be created. To avoid distortion, a picture should be selected perpendicular to the main ray;
- determine the position of the main point of a picture as a result of the intersection with the main ray;
- draw an image of the horizon line through the image of the point of vision in the picture;
- add the algorithm for drawing the framework and parts of the represented object [12, 18].

To ignore this algorithm leads to the distortion of a perspective image, and therefore to the distortion of geometric information with all ensuring consequences. Taking into account the images information richness, representatives of all traditional schools of creating perspective images understand all the responsibility they have in case of failure to follow the requirements. If a distorted image realizes the cognitive function, the result is distorted knowledge that a person acquires.

Understanding that not all geometric information is represented in a perspective has led to shaded images. A shadow as an additional image has a great meaning allowing one to find out the shape of the original object on its flat image. The geometric description of the process of creating shadows allowed one to formulate some ideas, principles and clear algorithms forming the Theory of Shadows [13, 20].

A point is taken as a light source in the Theory of Shadows. All the rays from the light source are divided into three groups:

- falling rays- these are the rays lightening the object;

- sliding rays - these are the rays touching the object;
- passing rays - these are all the other rays.

This allowed us to formulate the following concepts clearly:

- the line of its own shadow (LOS) is a set of points touching the sliding rays;
- the line of the falling shadow (LFS) is a set of intersection points of sliding rays with the plane or surface behind a lightened object.

The geometric key point of these concepts allows formulating one of the main principles that determines the relationship of the lines of its own and falling shadows: one and the same sliding ray produces one point of its own shadow and one point of the falling shadow. These are the points  $M$  and  $N$  in Fig. 2.

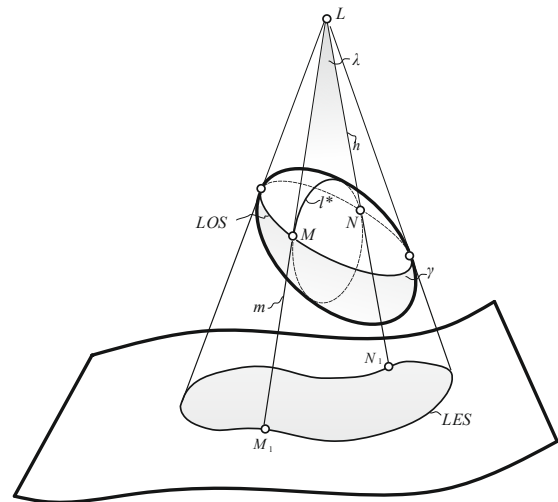


Fig. 2. The creation of the line of its own shadow and the line of the falling shadow via rays' cross-section

The universal algorithm for creating lines of its own shadows and lines of falling shadows is based on this principle. It includes the following equations having the geometric interpretation in Fig. 2:

- 1)  $L \subset \lambda$ ;
- 2)  $\lambda \cap \gamma = l^*$ ;
- 3)  $L \subset m \subset \lambda$ ;
- 4)  $m \supset M \subset l^*$ ;
- 5)  $m \cap \pi = M_1$ ;
- 6)  $L \subset n \subset \lambda$ ;
- 7)  $n \supset N \subset l^*$ ;
- 8)  $n \cap \pi = N_1$ .

where  $L$  is a light source;  $\gamma$  is a free form surface of three-dimensional space;  $\lambda$  is rays' plane;  $l^*$  is the rays' cross-section of the surface;  $n, m$  are sliding rays;  $M$  is the touching point of the sliding ray  $m$  to the rays' cross-section;  $N$  is the touching point of the sliding ray  $n$  to the rays' cross-section;  $M_1$  is the shadow from the point  $M$ ;  $N_1$  is the shadow falling from the

point  $N$ ;  $\cap$  is the intersection of elements;  $\supset, \subset$  is belonging to each other;  $\cup$  is the union of elements.

By changing the position of the rays' plane you can choose a sufficient number of points that determine the nature of lines of its own and falling shadows. This algorithm is the basis for the method of rays' cross-sections [8]. In addition, there are still many special methods that are not the subject matter of this article.

The Theory of Shadows is an obligatory subject to study for those who are engaged in creating flat images of three-dimensional objects. These are, first of all, artists, designers and architects. In addition to the Theory of Shadows they should study the basic laws of creating a perspective. Following the laws allows you to create flat images of three-dimensional objects in which there is no distortion of geometric information. Unfortunately, there are no subjects providing knowledge of theoretical fundamentals for creating a perspective, axonometry and the Theory of Shadows in the programmers' curriculum. As a result, it should be noted that during the long history of flat images of three-dimensional objects performing the illustrative and cognitive function they were imposed high requirements. The key point of these requirements is as follows: to save geometric information of the original object in an undistorted form.

Axonometry is another kind of an image that performs the illustrative and cognitive function [4, 6]. It does not take into account physiological characteristics of a human eye; as a result all parallel lines in axonometry keep their parallelism. In other words, the relative position of parallel elements as it is in the reality is kept in an image. It was an application, though a weak one, to perform the technological function. This feature happened to be in demand in images that were used in civil engineering [8]. Although an axonometric image is not common for a human eye, but original objects on it are recognizable. In this connection, the illustrative and cognitive function was kept in the axonometry in full.

A common feature of perspective and axonometric images is the distortion of geometric information of a real object. Angular and linear dimensions of a represented object are distorted. To determine them, it is necessary to solve rather complex metric problems. This prevents the usage of these images from implementing the technological function.

### III. FEATURES OF IMAGES PERFORMING THE TECHNOLOGICAL FUNCTION

The rapidly developing technological revolution requires realizing the technological function. The main requirement that was imposed on such images is representing of all geometric information of a three-dimensional object without distortion. In other words, real objects should be represented as they are in the reality, and not as they are seen by a human eye. In the 18th century, great French mathematician G. Monge solved this problem. He created images that are known as the Monge's projection. Via these images it was possible to determine shape, dimensions and the relative position of an object in space. But there were some disadvantages: they significantly differed from those that a human eye could see. In order to see the information

represented in them, the appropriate vision training was necessary. As a result such images were widely used in engineering and civil engineering. At present it is not possible to design, create and use either engineering devices or civil engineering objects without G. Monge's images.

To form the readiness to create and use the Monge's projection the author developed the "Descriptive geometry" study course [11]. The process of creating such images with the help of projective multidimensional geometry was explained in it. This course aimed at developing the ability to read geometric information from images that differ from those seen by an eye of a person. This happened to be a methodological mistake that made it significantly difficult to study descriptive geometry. In time, there appeared more problems due to the deterioration of teachers' and students' geometric literacy level in descriptive geometry. As a result the inadequately formulated aim of the study course and poor knowledge of geometry led to the lack of the evidential base in new textbooks. Learning mathematics without the evidential base led the descriptive geometry studies to a dead end. There were two ways out of it:

- to transform descriptive geometry into a logically completed mathematical course with a well-developed evidential base;
- to replace the Monge's projection by 3D images created with computer programs.

A geometric evidential base was made up of a system of knowledge from the multidimensional projective geometry field allowing:

- considering a perspective, axonometry and Monge's projection in general;
- considering images as geometric models;
- formulating an adequate aim of the "Descriptive geometry" study course - to create geometric models.

Unfortunately, this way appeared to be a dead end. The lack of appropriate geometric knowledge, in general, and of the majority of teachers working in the field of geometric and graphic education, in particular, was a basis for that.

### IV. FEATURES OF ENGINEERING-BASED IMAGES

The realization of the technological function of images does not lose its significance at the present day. Therefore, software engineers take in their own hands the process of creating images. At the present day we have holography-and-computer technologies-aided images.

Of course, holograms are the most convenient way for perception reproducing an exact three-dimensional copy of the original object that keeps all its geometric information. It should be noted that it is a great problem to build an engineering or civil engineering object using a holographic image. The problem with representing and obtaining dimensional characteristics of the object remained unsolved. As a result, the holograms basically perform the illustrative function. They are used for producing prints of sculptures, jewelry, etc. Problems with dimensional characteristics of an object in holograms thwart the application of other areas of human activities. There

is one more reason. It includes the structures bulking that create holograms, a large number of computer resources and specific requirements when working with light. The plane still remains the most popular carrier for images.

The rapid development of computer technologies has led to the replacement of a flat sheet of paper for a flat monitor screen. A large number of computer programs create various images on it. The developers of these programs went their own way. They ignored the geometrical basis and methods that had been developed for more than a century. This was seen even in the names. A perspective and axonometry began to be called both 3D-images and three-dimensional images, and Monge's projection was called both 2D images and flat ones. Unfortunately, it is already a tradition not to see obvious things: a two-dimensional plane (it cannot be the other) contains only a flat image that can or cannot keep geometric information about the original three-dimensional object.

One of the reasons for this is the concept of "dimension" which has not widely been used yet [2, 4, 5]. But it has quite clearly been defined in multidimensional projective geometry. But, unfortunately, a small closed group of people masters this area of knowledge. The majority of people using the term "dimension" denote a wide range of concepts. As a result, it is difficult to achieve mutual understanding.

The idea of using computer three-dimension images was easily picked up by many teachers of geometric and graphic subjects. This way seems to be easier. One need not torture a teacher and his students with descriptive geometry. It is enough to master one of many computer programs. But will these images widely be used in the design, civil engineering and operation of engineering and civil engineering projects? Are they adequately adapted to these processes? That is the question now. Today 3D images perform basically the illustrative function. But the quality of such images can be questionable.

Let us examine two examples for proving it:

- The image of a summerhouse created by AUTOCad 2015 (Fig.3). It is presented as a result of the video course "AUTOCad 2015 3D drawing, modeling and visualization" training published by Dmitry Lapin and Pavel Luk'yanchenko.
- The image of a gasoline filling station taken from the most popular life simulator of a professional driver of large goods vehicles "C-1 Long Distance Truckers" (Fig. 4).

Let us try to determine which images they are: axonometric or perspective. At first sight, both images do not keep parallelism. Therefore, we can assume that this is a perspective. Consequently, parallel lines of the same direction must intersect at one vanishing point. But if we prolong the images of parallel straight lines of the same direction their common points have a wide dispersion. In other words, there are no vanishing points. The question is whether this is a perspective or axonometry?



Fig. 3. The image of the object in AUTOCad 2015



Fig. 4. The fragment of "C-1 Long Distance Truckers"

Both images tend to be adequate to those seen by a human eye, i.e. perspective.

Let us suppose that there are distortions when printing that are still perspectives. Let us try to determine what these perspectives are. Judging by the location of pillars of the summerhouse (Fig. 3), they intersect at the top, at the vanishing point while prolonging. We can assume that this is a perspective in an inclined picture with the low horizon. The vertical lines are supposed to intersect downwards in the gasoline filling station image (Fig. 4). It is likely to be a perspective in an inclined picture with the high horizon. Searching for the horizon line in both cases is a problem. Horizontal straight lines of the same direction do not have one common point. One can only assume the position of the horizon line.

In the images (Fig. 3, 4) both structures are considered to be shaky. This happened because the main ray did not turn out to be the bisector of the angles of vision. The violation of this requirement leads to the reality distortion. As a result, the main vertical line in both images changes its position from the middle of the image of the object to the right. In case with the summerhouse the main vertical line passes the stairs area and in case with the gasoline filling station it is focused on the driver. This leads to the fact that vertical elements on the left are seen as inclined. In addition, ignoring the position of the main ray as a bisector of the angle of vision results in an actual increase of the conventional cone of vision and its inefficient usage. As a result, the summerhouse swings in the image and the gasoline



filling station collapse. For such images a draftsman would certainly get a bad mark [13].

Shadows imaging is known to aim at supplementing geometric information which allows us to show the shape of an object more fully. The shadows presented in these images are against this aim and cause more questions.

The first question touches upon not shapes of depicted objects, but our solar system. How many suns shine simultaneously?

We can answer this question by looking at Fig.3. If you look at the shadow falling on the floor from the lower grille of the right facade, then we have the high sun (sun № 1). If you look at the shadow falling on the lower roof from the right raised element of the upper roof, then the sun is tilted approximately at the angle of 45° and is located on the right side (sun № 2). This matches the shadow falling from the steps on the ground. The lower roof is likely to be shone by sun № 3, which is located close to the horizon. Otherwise, the shadow from the lower roof would fall on the foreground and background. So we have three suns to astronomers' surprise.

Further discussions raise the following questions:

- The vertical plane of the right facade, the plane of the risers and the right sides of the pillars, judging by their shadows, are also intensively shone, as well as the horizontal planes. But they have a much darker tint than the shone planes. Why?
- What makes the shadow fall on the second tread? If it is from the right overhang of the lower roof, then why does such long overhang provide such short shadow at 45° rays' inclination? Judging by its size, the shadow must also fall on the ground. But for some reason there is no such shadow.
- Why does not the shadow of the steps fall on the wall which is also shone?
- The top roof, which is a pyramid, at the given rays' inclination must be completely shone by any of the suns № 1 and № 2. But in this image it has its own shadow. Why? It might be shone by sun № 3.

Looking at Fig. 4 we have more questions. The first question is again about the number of suns in our solar system. Let us assume that the driver is shone by sun № 1. The shadow falling from him testifies that this sun is located high enough on the left side behind him. The bumper of the car is already shone by high sun № 2. Two different suns shine the dispenser and its stand. But definitely this is not sun № 1. Then both vertical sides would be shone. Here, we have only the left and upper sides shone. It means that the sun shines from the left and upper. And this is already sun № 3. The stand under the dispenser is likely to be shone by sun № 2. It is hard to say what shines the position lamps of the driver's cab. Judging by light flecks, this light falls from the front of the top. This is sun № 4. Which of the mentioned suns shines the background trees? Judging by the shone tree crowns, it shines from the right and side (sun № 5). But then why does their shadow fall as if they were shone from the left? It is a real case of the tail wagging the dog.

The principle concerning the sliding rays is completely violated. They do not want to cross the planes and surfaces that are behind the shone objects. Why? These are the sliding rays touching the near corner of the left side of the building of the gasoline filling station, the dispenser side facing the driver and the upper front edge of the roof.

If the sliding rays do not touch an object, this object is in shadow and cannot produce a falling shadow. But the trees stems somehow managed to produce the falling shadows, although they themselves are in the shadows! Apparently the sliding rays - easily turned - touched the tree stems. The shadow falling from the driver also easily turned from the wheel, which should produce a part of the falling shadow. There are also other questions:

- It is not clear what is on the roof of the driver's cab near the position lamps: a shadow, or a dirty spot, or a dent?
- Is the driver dressed in such a light-absorbing suit that there are no either spots shone or his own shadow on it?
- What material is the bumper of the car made of? Has it absorbed all the rays falling on it?
- The car body, judging by the location, is under the roof of the gasoline filling station. What, then, could make it so bright? Or is there a hole in the roof of the gasoline filling station through which it is shone?
- Why does not the open door of the cab produce the falling shadow?

The article cannot cover all drawbacks making the discussed images look fantastic.

## V. CONCLUSION

In the conclusion we can say that geometric information of real objects and their images is significantly different. It would seem that such low quality of images is not so important if they perform the illustrative function. Though, we can face some problems here. For example, an architect, a designer will find it difficult to sell their project, in which there are many distortions in illustrations. The customer will intuitively feel that something is wrong here. Lie always causes doubts and antagonism.

But apart from that, programmers with such "knowledge" of perspective fundamentals and the Theory of Shadows create various simulators. What are benefits of simulators in which the reality is so distorted? If we take Internet forums, they do not demonstrate any gratitude towards the developers of such programs. There are more low-key or negative responses. People still need images that would not distort the reality, but keep all geometric information of original objects in the way that they are seen by a human eye. Therefore, the developers of computer programs that create images need to use acquired experience in the field of the Image Theory.

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