Combining Different Kinds of Perspective Images in Architectural Practice.

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Abstract
This paper is about combining photo-, video-, endoscope captured images with handmade or computer generated ones. Practically all optical systems are known to produce more or less curved perspective (spherical or cylindrical) which depends of angle-of-view, and a computer as a rule (as handmade) constructs linear perspective images. To combine them on any media correctly, an operator has to be professional painter or designer, because there is no mathematically determined way to combine them.
The author's-made demo-computer program is able to generate spherical perspective of simple spatial constructions. It allows to illustrate mathematically and visually the principles of optical curved perspective, laws of their combination with linear ones and helps to feel how to achieve the accordance with natural visual architectural images.

The targets
One of the main tasks of endoscopy is documental truthfulness of visualization of architectural objects in real architectural environment. The best way is probably to combine "natural captured images" with anyway generated images of designed object(s). "Natural images" mean photo and video captured images of an architectural site. "Generated images" mean endoscopy of scaled models or computerscopy of mathematical models of designed objects. Some problems arise during combining these different images. Even if all the parameters (point-of-view, target point, zoom, *etc.*) of both pictures are the same, the result of combining is often unsatisfactory. Such misleadings as a rule are determined by different ways of creating of natural and generated perspective images.

Linear perspective
The are two base methods of converting three-dimensional information into flat images. The first is usual linear perspective. It was "rediscovered" in the epoch of Renaissance and was widely used by great artists and architects. During the centuries it was thought as the only method that allowed to present real 3D space on picture surface. But some authors paid attention to inaccuracies of this kind of projection. The first one is the considerable distortion of spatial object proportions which is lethal to an architectural presentation. For example, if the vector-of-view is along a long street, the linear perspective image seems about 1.5 times longer than the real human feeling of the same real street. The second is the unnatural morphing of 3D curved lines and surfaces. For example, if a perspective image has a linear array of circles (such as tops or bases of colonnade) then the axises of the ellipses are abnormally rotated from horizontal line in the corners of a picture. The third is the deformation of angle between 3D vertical lines and line of horizon that are different from 90^0 when vector-of-view is not absolutely horizontal. Other numerous linear perspective distortions are the consequences of the three above mentioned.
On the other side famous artist M. C. Escher (born 1896) presented series of pictures that visually proved the nonlinearity of human perception.

Figure 1. M. C. Echer. Nonlinearity of perception. [see 20p01.tif]

Figure 1 illustrates the impossibility of linear perspective method of representation spatial lines and constructions. A person lying under two wires can see two vertexes under his legs and above his head and a distance between them in front of him. So in this projection these wires cannot be represented as a straight line!
More dramatic situation is shown on the right side of the picture. If we see the line of horizon behind a tall building and the vector-of-view is not horizontal one then result of linear perspective projection is abnormal. It is evident, the vertical lines of the building are not perpendicular to the line of horizon. It is impossible to make them vertical and leave the linear perspective decreasing of the building's top. If we will use multiple projection surfaces, the parts cannot be constructable in one. Of course, this extreme statement is correct for the biggest angle-of-view-pictures, but normal 30^0 used for linear ones is not enough to present architectural space. The only way to overcome this contradiction is using nonlinear perspective principle.

Nonlinear perspective
The idea of the nonlinear perspective in architecture is not younger than the idea of the linear one. Nonlinear perspective images are more natural for the human perception. Straight lines are the human invention -- they do

not exist in nature. Geometrical analysis of some famous paintings (landscapes, for example) shows that most natural effects are achieved by using the spherical projection.
The only defect of nonlinear projections is the deformation of straight lines due to different angles of view. For normal perspective images the angle-of-view should not exceed 40^o. Usually viewers see such pictures with the angle-of-view not more than 15^o. There are two ways to correct this mistakes. The first is to enlarge the output format, and the second is to decrease the distance between an observer and a picture.
The other image deformations become visible if the vector-of-view used in calculations is different from viewer's. Vector-of-view is one of leading factors of any perspective; changing vector-of-view results to considerable morphing of final image. Simple advice: do not look on corners of the picture. There are many ways to solve these problems. Some of them were discovered centuries ago. For example, corners fading on paintings of Rembrandt van Rijn, blurring corners or placing a number of small details near the "target point", etc.
The visual curveness of 3D-straight lines is the factor subconsciously used by observer to gather spatial information. The genius intuitive feeling of natural transformations of straight lines in the mind of preceptor allowed ancient architects to create special visual effects. Well-known enthasis of classical columns (Figure 2) or horizontal curvatures of Parthenon (Figure 3) and vertical ones in Russian Pokrova church (XII c.) (Figure 4) are the examples.

Figure 2. Enthasis columns [links see 20p02.tif]
Figure 3. Curvatures of Parthenon [midden see 20p03.tif]
Figure 4.Russian Pokrova of church [rechts see 20p04.tif]

The accurate usage of such effects gives the possibility for an architect to rule the scale, proportions of a building, etc. The design using linear perspective laws exclude such phenomena.

Demo-program.
The special computer program (DCAD) was developed for studying some visual effects of nonlinear perspective projection. The main interest was in formula of translating three-dimensional coordinates of points into flat perspective image. It performs the simplest kind of spherical projection. The base 3D element imported from text file (*.dcd) can be freely moved or rotated in space. Vertexes calculated using nonlinear perspective formula were approximately connected by straight lines and only array of them can represent a sinusoidal line.

The authors are thankful to professor Yu.N.Orsa for useful discussions.

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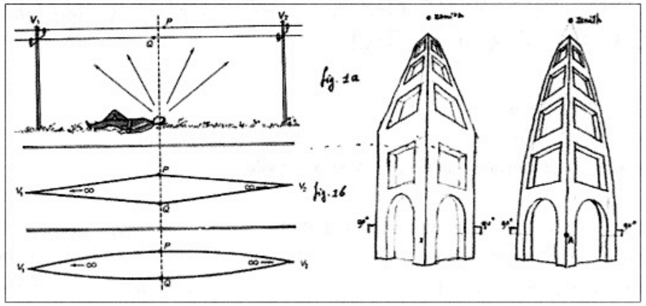

Figure 1 M. C. Echer Nonlinearity of perception

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The only defect of nonlinear projections is the deformation of straight lines due to different angles of view. For normal perspective images the angle-of-view should not exceed 400. Usually viewers see such pictures with the angle-of-view not more than 150. There are two ways to correct this mistakes. The first is to enlarge the output format, and the second is to decrease the distance between an observer and a picture.

The other image deformations become visible if the vector-of-view used in calculations is different from viewer's. Vector-of-view is one of leading factors of any perspective; changing vector-of-view results to considerable morphing of final image. Simple advice: do not look on corners of the picture. There are many ways to solve these problems. Some of them were discovered centuries ago. For example, corners fading on paintings of Rembrandt van Rijn, blurring corners or placing a number of small details near the "target point", etc.

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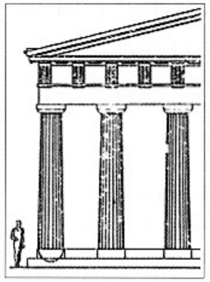

Figure 2

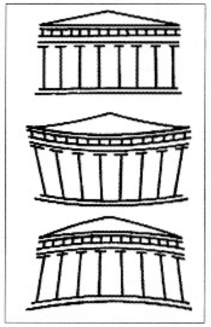

Figure 3

Figure 4

Figure 2 Enthasis columns
Figure 3 Curvatures of Parthe-non
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