Geometrical fundamentals for design and visualization of spatial objects
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Introductory Overview

Every architectural object is a 3-dimensional entity of the human environment, haptically tangible and optically visible.

During the architectural process of planning every object should be designed as a body and should be visualized in pictures. Thus the parts of construction get an order in space and the steps of construction get an order in time. The ideal planning object is a simulated anticipation of the real building object, which is to be performed later on. The possibility to relate the planning object immediately to the building object relies on the fact that they both have the same "geometry". This means: both can be described in the same geometric manner.

Creating and visualizing spatial objects is based on geometrical fundamentals. Theoretical knowledge and practical control of these fundamentals is essential for the faultless construction and the realistic presentation of architectural objects. Therefore they have to be taught and learned thoroughly in the course of an architectural education.

Geometrical design includes the forming of object-models (geometry of body boundaries), the structuring of object-hierarchies (geometry of body combinations) and the colouring of objects.

Geometrical visualization includes controlling the processes of motion, of the bodies (when moving objects) and of the center of observation (when moving subjects) as well as the representation of 3-dimensional objects in 2-dimensional pictures and sequences of pictures.

All these activities of architects are instances of geometrical information processing. They can be performed with the aid of computers.

As for the computer this requires suitable hardware and software, as for the architect it requires suitable knowledge and capabilities to be able to talk about and to recall the perceivable objects and processes of the design with logic abstracts (language of geometry).

In contrast to logical, numerical and textual informations the geometric informations concerning spatial objects are of much higher complexity. Usually these complexes of information are absorbed, processed and transmitted by the architect in a perceptive manner.

The computer support in the field of geometry assumes that the processing of perceptions of the human consciousness can be converted by the computer as a framework of logical relations. Computer aided construction and representation require both suited devices for haptic and optical communication and suitable programs in particular.
Therefore the program package KONDAR is being developed and used at the Technical University Darmstadt in instruction and research. It is being applied for creation, storage, manipulation and distribution of geometrical information about spatial objects.

The individual parts of the system support the following functions:
- Creation and manipulation of 3d-models (generation and correction of shape)
- Synthesis and analysis of object-hierarchies (generation and examination of structure)
- Generation and visualization of pictures and picture sequences (control over the steps and documentation of the results).

The following report gives a general view over the geometrical problems of the design of solid objects and their pictorial representation. A series of examples demonstrates solutions for this problem with Computer Aided Design and Representation.

Shape and Structure of Spatial Objects

All objects of human consciousness can be described as geometrical models in case they have spatial extension. Such models are geometrically structured by
- 0-dimensional points
- 1-dimensional curves
- 2-dimensional surfaces
- 3-dimensional spaces.

As with real objects of the physical world such spaces are filled with matter. They are called bodies. The border between body-interior and -exterior is its surface. The manner of its spatial extension is called the "shape" of the spatial object.

The surface of bodies can be homogenous, a single closed surface without subdivision, as with the sphere. It can also be inhomogenous consisting of various vertex-points, edge-curves, facet-faces. Then the relations between the body elements form a set of relations. This is the "interior structure" of the geometrical model and its model elements.

Combining various spatial objects yields higher ordered objects as complexes of simpler elements (f.i. grouping rooms to a storey and grouping storeys to a building). This complex can again be an element of a complex of the next higher order. An element can as well be considered a complex of elements of the next lower order.

Thus an "object-hierarchy" is constructed in the way of a tree structure (reversed tree) where the main object (level 0) as highest "root"-complex branches out into elements (level 1) of which each "branch"-complex branches out further into its elements (level 2), etc., etc., etc. This is the "exterior structure" of the geometrical object and its objectelements.

A particular property of human consciousness is the following: directing the consciousness onto any spatial object one knows subconsciously that this object consists of lower ordered elements and at the same time one knows "super"consciously that this object is component of a higher ordered complex. This ability of realizing lower ordered parts and the superordered entity enables man intuitiv perception and logical control of complex structural relationships.
Computer Aided Design of Spatial Objects

The design of spatial objects consists of
- shaping: spatial tangible extension of the models
- structuring: spatial logical order of the hierarchies
- coloring: spatial visible appearance of the objects

Generating and processing the shape of 3d-models:
- numerical generation: of coordinate triplets of points
- graphic generation: C of point index pairs of lines
- programmed generation: of line index arrays of facets
- construction processing: through transformations (translation, rotation, dilatation, reflexion)
- through additive and subtractive set operations (connections, sections)

Generating and examining the structure of 3d-hierarchies:
- synthesis: description and composition of objects as complexes of positioned elements
- analysis: structured representation of object hierarchies as tree structures of object elements

Computer Aided Representation of Spatial Objects

Representations of spatial objects are supposed for making possible sensual perception of
- tangible shape of models
- logical order of hierarchies
- visible appearance of the object in color with light and shadow
i.e. to make them visible for the human eye.

Thus the visualization can be directed to - the perception of shape
- the perception of structure
- the perception of color.

The following figures demonstrate applications of the program package KONDAR derived from exercises of architecture students of the Technical University Darmstadt in my branch "Rechnerunterstütztes KONstruieren und DARstellen räumlicher Objekte".
Concept of a stadium

Figure 1  Normal projection: side standard top

Figure 2  Central projection
Design of the "Villa Rotonda"

Figure 3  Building: Explosion projection

Figure 4  Building: Central projection
Figure 5  Portal:  Explosion projection

Figure 6  Portal:  Normal projection (standard view)
Chair S 33

Figure 7 Normal projection: front, side, standard, top

Figure 8 Normal projection (standard view)
Interiors furnishin
Central projections

Figure 9

Figure 10

Figure 11