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Comparative study of planar representations of spatial forms for architecture students

Diana GIUREA[1] Cristian DUMITRESCU[1]

Abstract: The paper treats the topic of planar representations of solid objects using the epure, axonometry and perspective drawings. The purpose of the study is stimulating architecture students' abilities of spatial visualization and contouring a certain graphic language with which, in practice, the architect communicates with his collaborators and clients. The aim of this comparative research consists in the correct understanding of the designed object. The results can improve the architectural design process by increasing the ease of conceiving the architectural object and the quality of graphic representation of a complex form.
Keywords: architecture, epure, axonometry, perspective, drawing.

1. INTRODUCTION

The essence of architect profession lies in the organization and the transformation of the natural and artificial environment by integrating useful spaces and forms to mankind.

This new manmade environment represents a new combination between space, matter and time using a specific design process. The basis for this type of design lies in the permanent dialogue between space and its planar representation made with the aid of projections organized in systems.

These projections are the starting point of the projective geometry which, in the second half of the XIX century, was transformed into a independent discipline.

Fig.. 1. The cylindric system (a,b) and the conical projection (c)

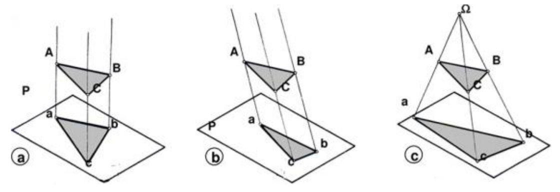
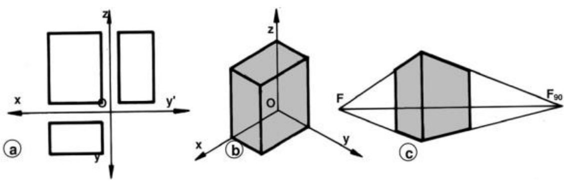


Fig. 2. The epure, axonometric projection, perspective



There are two classic projection systems with which the space can be represented bidimensional:
- parallel system (cylindrical) which uses parallel projecting lines to a given direction. This kind of system can be: straight (Fig. 1.a) when the projecting lines are perpendicular on the projecting plane or beveled when the projecting lines make a random angle with the projecting plane (Fig. 1.b).
- central system (conical) which uses projecting lines that gather in a certain projection point (Fig. 1.c).

In current practice, aside from these bidimensional or planar representations are used three dimensional representations – models.

The architectural bidimensional representations typology corresponds to the projection systems:
- epure: uses the orthogonal cylindrical projection and scale-size rendering the exact forms and sizes (Fig. 2.a);
- axonometric projection: renders spatial forms using a parallel projection when the observer is considered to be placed at an infinite distance from the object (Fig. 2.b);
- perspective: renders space using central projection and the observer, also known as the center of projection, is located at a certain distance from the architectural object (Fig. 2.c).

The manner in which the objects in space are represented through planar views and the capacity of imaging volumes in space by only reading drawings leads to the so called space visualisation skill that is an essencial skill to an architect.

The topic of the present paper resides in the fact that these three planar representations are the basis of the architectural creation in general and at the same time they constitute the architect's language, the way he or she communicates with the collaborators and the clients.

2. EPURE OF DESCRIPTIVE GEOMETRY

The epure is obtained through the orthogonal cylindrical projection of the object on the parallel planes with the coordinate axes given that the projection on a singular plane does not determine the object.

[1] "Politehnica" University, Faculty of Architecture, Traian lalescu, 2/A, 300223, Timisoara, Romania, diana.giurea@yahoo.com, cristian.dumitrescu@arh.upt.ro

The simplest orthogonal representation is the descriptive geometry epure of Mongue which can be obtained using two orthogonal projections followed by the turning down of one plane on the other, keeping unaltered all metric relations, including the surfaces and angles. This type of epure displays the highest degree of abstraction among all bi-dimensional representations.

Although the dimensioning system permits the metric determination of the object from two orthogonal projections, for understanding, it is often necessary to introduce a third projection (Fig. 3, Fig. 4).

Fig. 3. The third projection in axonometric projection

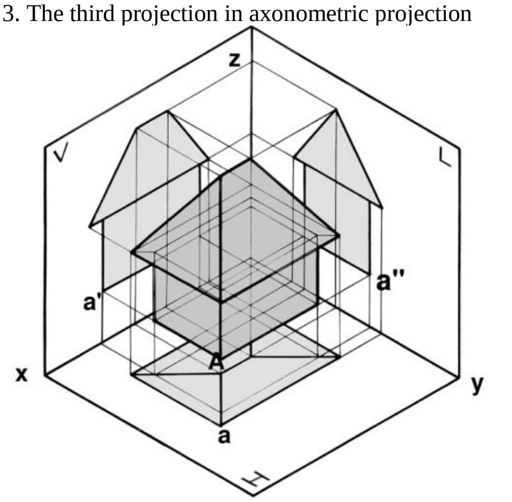


Fig. 4. The third projection in epure

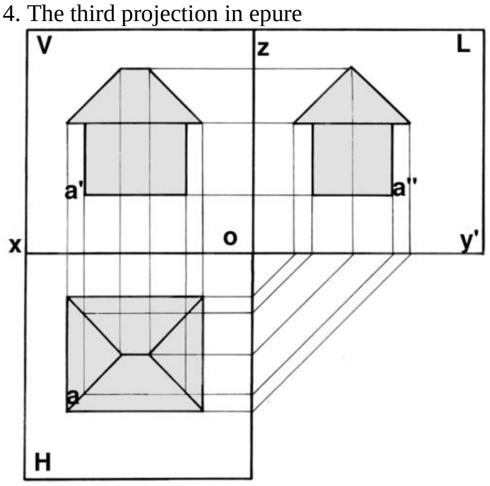
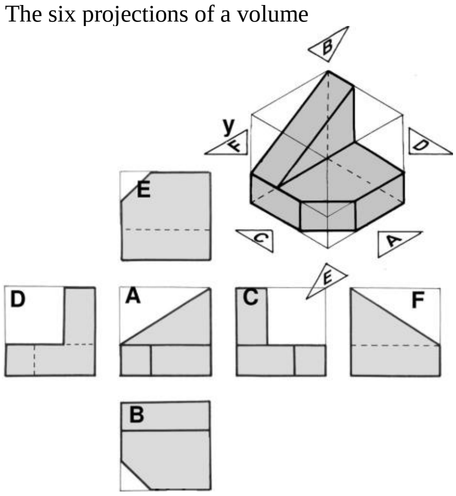


Fig. 5. The six projections of a volume



For a given object one can draw six projections considered to be arranged on the faces of a framework - cube. If these six projections are displayed on a plane then it results the “projections layout” for a certain object (Fig. 5). In practice, a volume can be understood just from three projections, and thus, there are not necessary all six projections.

Usually, a complex architectural design requires multiple representations: floor plans, sections, facades etc. which precisely illustrate details regarding the construction process.

Due to the high level of abstraction, these representations build a specific architectural language and so, the deciphering and understanding of the drawings require specialized training.

In order to highlight the shape and proportions of an object, shadows are often used in the epure. In terms of descriptive geometry, the shadow contour represents the line that separates the enlightened parts of the object from the shaded ones.

In epure, the ray of light is conventionally chosen at a 45^0 angle which represents the internal diagonal of the framework-cube. The faces of the cube overlap with the three main projecting planes. These shadows highlight the shape and the dimension of the designed volumes and render the depth of the different frontal planes.

3. AXONOMETRIC PROJECTION

The axonometric view is obtained with the use of the cylinder projection or the conical one of the shape on an axonometric plane. The axonometric plane is set inclined in relations to the coordinate axes. This representation provides a qualitative image of the object given that it is closer to the visual perception of the object in nature.

Unfortunately, not all real metric relations are retained. For example, the surfaces and angles appear distorted. The reason is the fact that this type of representation is a one-level projection.

The intersection lines between the axonometric plane and the planes of the reference trihedron OXYZ form a ABC triangle named the axonometric triangle (Fig. 6).

It is noted that α, β and γ are the angles made by the image axes with the edges of the reference trihedron. The projections on the image axes of a unit of measure “u” situated on the reference trihedron axes are u_x, u_y, u_z.

The axonometry is divided into three main categories:

3.1. orthogonal projection: the direction of the parallel projecting lines is perpendicular to the axonometric plane. Depending on the dimension of the α, β and γ angles, the orthogonal axonometry can be:

- isometric projection: $\alpha=\beta=\gamma$, the axonometric triangle is an equilateral triangle. The image units are reduced by 0.82 and there are 120^0 angles between the image axes.

- dimetric projection: **α=β≠γ,** the axonometric triangle is isosceles, two image units are equal and the third halves;

- trimetric projection: **α≠β≠γ,** the axonometric triangle is scalene and each axis have different scale.

3.2. oblique projection: the direction of the parallel projecting axes is oblique in relation to the axonometric plane and is divided into the following categories:

- isometric projection which can be frontal, horizontal and random. In this case, the image axes are equal;
- dimetric projection: only two image axes are equal (also known as cavalier projection);
- trimetric projection: the three axes are randomly chosen and the image units are different.

In architecture practice, the orthogonal axonometric projections (Fig. 7.a) and the cavalier projections (Fig. 7.b,c) are most commonly used.

3.3. central projection uses a conical projection and is rarely used in architecture practice.

Fig. 6. The axonometric triangle ABC

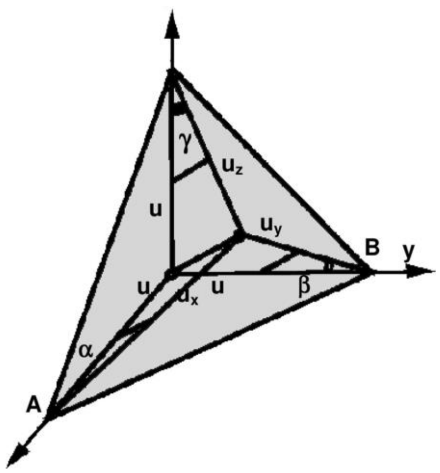
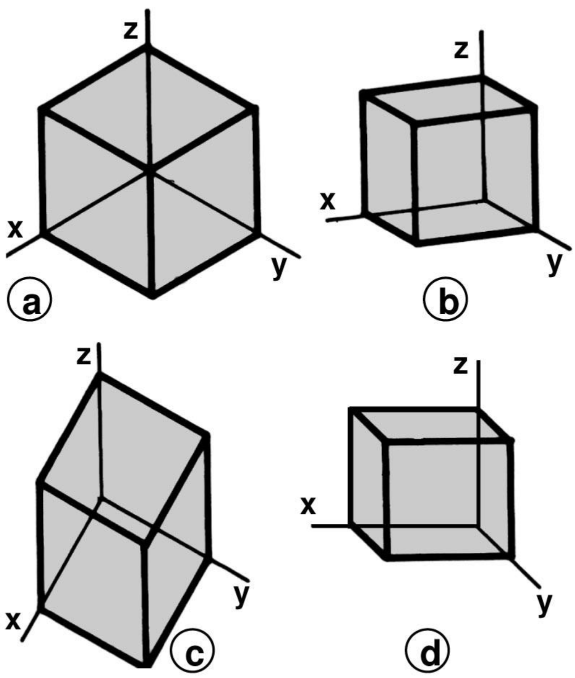


Fig. 7. Types of axonometric projection



As in epure, the shadows are drawn in the axonometric projection considering the light source at an infinite distance and with a certain direction (**Δ,δ**).

4. PERSPECTIVE

The perspective projection is the third modality of bidimensional representation of objects as shown at a limited distance.

It is used both for clients and designers because it manages to convey a closer visualization to reality and can act as a means of correcting the anticipated aesthetic effect.

The perspective drawing can be made at any stage of the design process because it is more economic and has more advantages than a scale model. The perspective can illustrate the relation between the object and its environment.

Theoretical research and design practice have revealed four main categories of perspective drawing methods:

4.1. The dependent method uses the descriptive geometry epure and aims to determine the intersection points of the visual rays with the picture plane. This type of drawing is accurate but difficult and non-intuitive.

4.2. The free (or direct) method permits the construction of the perspective projection without the epure, using the conic projection invariants. It is an intuitive drawing manner because all operations are solved in the picture plane starting from certain geometric elements.

4.3. The axonometric method consists in drawing on a perspective network built on a picture plane which contains the unit of measure on all three directions.

4.4. Observational perspective is the drawing Method based on the observation of the environment. This type of perspective drawing develops a good space visualization skill and can lead to the discovery of the laws of perspective.

In practice, these methods overlap. Thus, the dependent perspective solves the main volumes while the free perspective deals with clear view details.

The most commonly used perspective drawings are:

- Two points perspective with the measure points (Fig. 8);
- One point perspective is typically used for roads, railway tracks, hallways, or buildings viewed so that the front is directly facing the viewer [1] (Fig. 9)
- Three-point perspective exists when the perspective is a view of a Cartesian scene where the picture plane is not parallel to any of the scene's three axes (Fig. 10)

For a complete perspective drawing, one should include shadows, reflections, depth and entourage in order to obtain a real-life image.

Fig. 8. Two points perspective

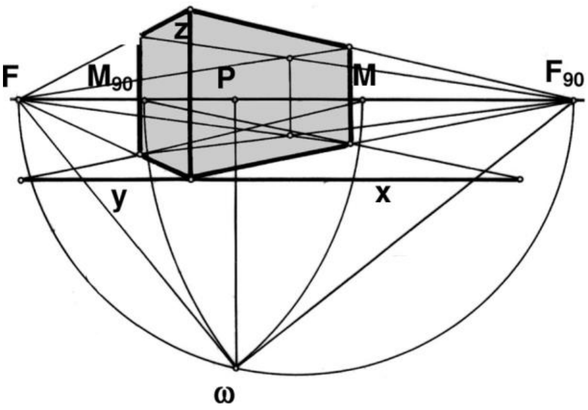


Fig..9 One point perspective

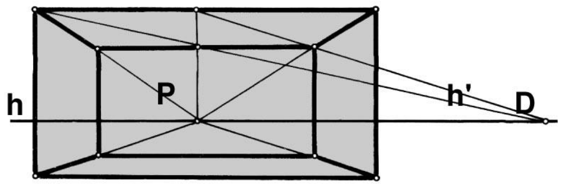
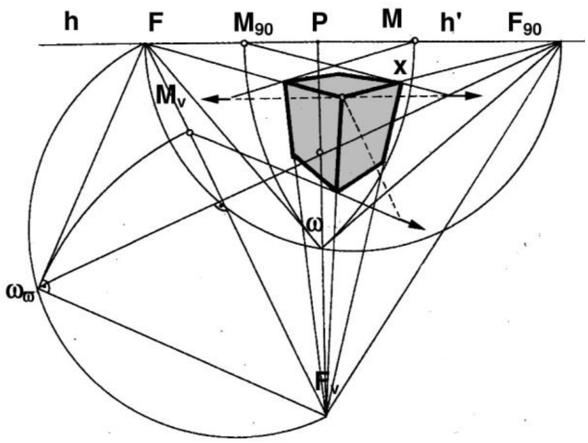


Fig. 10. Three point perspective



5. COMPARATIVE STUDY OF SPATIAL REPRESENTATIONS

After briefly presenting some theoretical data on the three possible representations of architectural objects, we believe that a discussion is necessary on the best methods of representation for several categories of shapes, illustrated in Fig. 11.

It seems appropriate to divide the study into the following stages:

5.1. The necessity of the study

• helps the design by finding and highlighting the best shape that corresponds to a given function;

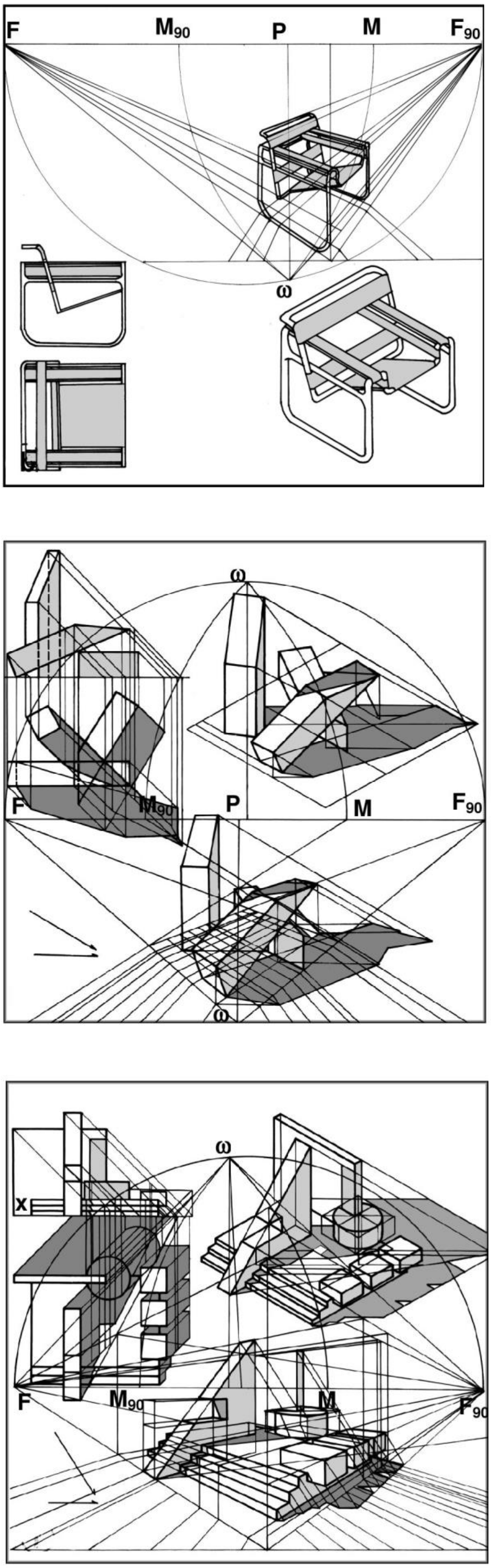
• aims at understanding the designed object;

• facilitates finding a method and style in the design activity;

• high efficiency of design, managerial benefits, etc.;

• is a necessary preliminary stage for rendering and modelling objects in space through different computer programs;

Fig. 11(a,b,c,). Three representation methods of the same object



5.2. Conditions for optimizing this study

• precise and clear design to facilitate understanding of the shape represented;

• representation of the imagined form as accurately as possible, using shadows, reflections, entourage elements, etc.

• using the same scale of magnitude. One shall take into account the correlation between epure, axonometric representations and especially perspective representation that usually appears smaller than the other ones, as the sizes decrease in depth. To compensate for this effect, one can increase the perspective directly on the picture plane either by using a different skyline (fig.12.a) or keeping an existing one fig.12.b).

5.3. Development of the study

It consists of drawing each shape in the three methods of bidimensional representation and pointing out the observations for each category, following the best ways of highlighting. Thus:

• *Epure* will follow the reduction of the number of projections and section to the required minimum, for understanding the formal peculiarities of the presented object. Taking into account that any object is executed according to images in the epure drawn to a certain scale and rated accordingly, one shall also monitor if the presented position allows a formal and dimensional clarity of the object.

• *Axonometry* with reductions to scale according to the typology, depends on the place and direction from which the object is seen, in order for it to be interesting and the shadows to be seen. Because from axonometry several sides of the objects are presented, one shall look to present those formal peculiarities that could not be rendered in the epure.

• *Perspective,* as we have seen, depends on the type of the perspective image, on the position of the observer, of the sun and of the entourage elements in order to put the representation in advantage. One shall take into account that with this type of representation the skyline which is found at the height of the observer determines a relatedness of the elements in height and various possibilities of representing horizontal surfaces.

All these representations are presented during the seminar hours to the professor coordinating the study, verbally presenting the arguments for choosing each representation solution. Although each representation has its own peculiarities, ultimately in their ensemble they determine a better knowledge of the presented object, and in the end they form the space view.

5.4. The evaluation

The evaluation of the results of this study stands out from the didactic point of view by the easiness and correctness of these plane representations, by the acquisition of graphic coordinates by which one can quickly switch from one representation to another, by the argumentation brought to choosing one of these versions.

Then, in years to come, the adequateness of this exercise and of the conducted study leads in professional practice to the easiness of conceiving and representing spatial forms in various computer programs, in the global development of the entire design activity, in the management of the architecture office and, ultimately, in the objects and architectural ensembles made, as a materialization of the permanent dialogue between the three bidimensional representations.

Thus, the presented exercise is only a preliminary stage of plane representation of volumes, then continued in various informatics programs.

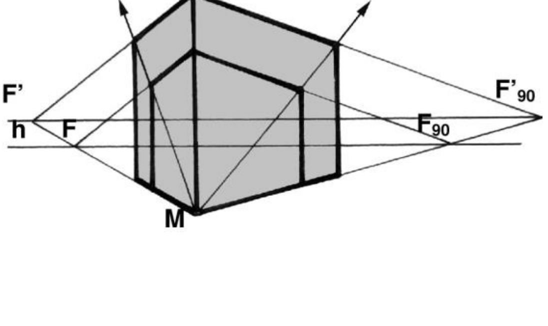
In generating formal elements, as essence and result of the design process, the CAD („Computer Aided Design") systems provide the designers with special possibilities by using the ***interactive geometrical modelling,*** in which the designer inputs data in the computer and receives the answer immediately or within a short time, the form being created and processed directly in "space".

The computer is used in the creation phase, as a helping instrument, in making the idea sketches (in the near future with an increased contribution), for visual verifications (today), but never as a system which applies a predefined algorithm. This stage of design (creation/conception) belongs to the creator (architect or designer), and the computer is found among the instruments used together with the manual sketch, scale model and photography, all based on perspective images.

One must specify, however, that a complete approach of the design of the form (and also of an architecture design in general) must not be made exclusively with the aid of the computer. The two work methods complete each other. The drawing doubled by a good space view helps the designer to spatially intuit the form. With the drawing one visualizes the intuited form, which is characterized by a preliminary form, from which the computer study starts.

In computer programs, three-dimensional visualizations are of three types:

Fig. 12a. The increased perspective using a different skyline



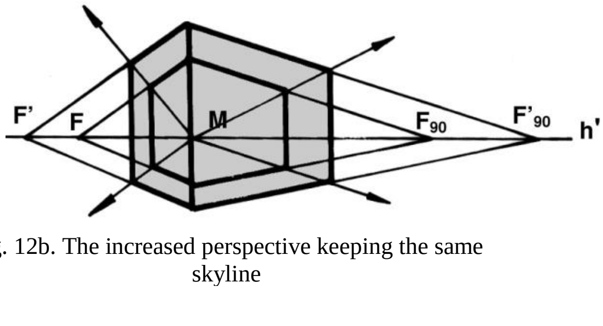


Fig. 12b. The increased perspective keeping the same skyline

- *static*, under the form of rendered images;
- *dynamic*, under the form of cursive animation;
- *virtual*, which allow interactions in operating them by means of different graphic methods.

The freedom provided by the new modelling and rendering technologies allows architects to carry out, besides an accurate representation of the volumes, light studies in which one can observe the method of artificial sunning, shadowing and lighting of the volumes, materiality and color studies (Fig.13).

During the last years one can notice the tendency of separation between the modelling process and the rendering process, because of the complexity of the programs used and the hyperspecialization of the users. This tendency led to the specialization of a number of architects and designers in the field of visualizations, who very often are used in related fields, such as cinematography, scenography or publicity.

6. CONCLUSIONS

This didactic exercise by which the student presents a spatial form in all the bidimensional representations shows a series of formative advantages, among which we would like to mention the following:

• acquiring space vision and facilitating reading and understanding other drawings which show plane representations of objects in space;

• optimization of the spatial characteristics of the forms resulting from a creation act;

• finding the best methods of formal presentation of the designed object, using entourage elements, shadows, mirroring etc.;

• knowing and perfecting the basic rules of plane representations of space;

• developing a communication language (at school with the teachers and subsequently with various collaborators) by discussing the formal reference points resulting from comparing these images;

• acquiring experience in plane representation of spatial elements, which can be further beneficial in using various programs for computer aided graphics.

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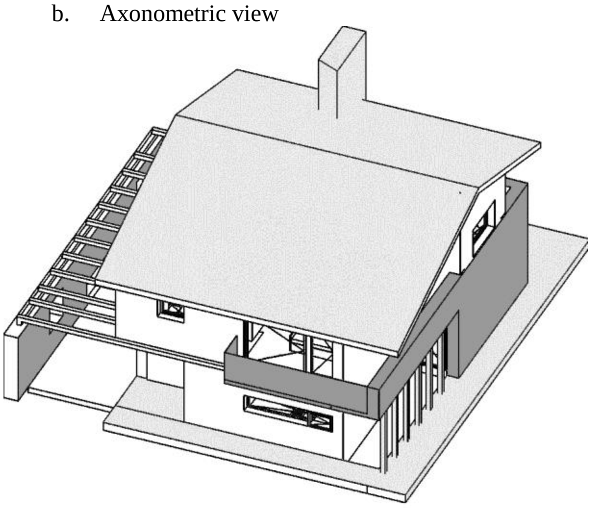
Fig. 13. Computer aided design process.

a. Floor plan

b. Axonometric view



c. Perspective rendering