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New Dimension in Geometrical Education

Methods of Representation Course - New Media, Classical Construction, Geometrical Freehand Drawing

New Dimension in Geometrical Education

ABSTRACT

This paper describes the course "Methods of representation" that has evolved at the Faculty of Architecture in Graz in conjunction with developments in the modern practice of architectural design. We established web sites (http://www.geometrie.tugraz.at/lehre/dm_ue03/ and http://ikg.tugraz.at/dm0/ws04/), which include the introduction in teaching, tutorials and VRLM animations to help students understanding space geometry. The course focuses on classical geometrical representation methods, solid modelling in CAD and geometrical freehand drawing. Each of these parts will be worked out and examples of student exercises will complete the paper.

Key words: descriptive geometry education, CAD, visual communication

MSC 2000: 51N05, 68U07, 97U40

Nova dimenzija u geometrijskom obrazovanju

SAŽETAK

U članku se daje prikaz kolegija "Metode prezentacije", koji se predaje na Arhitektonskom fakultetu u Grazu, a čiji je sadržaj usko povezan sa suvremenim arhitektonskim projektiranjem. Izrađene su web stranice (http://www.geometrie.tugraz.at/lehre/dm_ue03/ i http://ikg.tugraz.at/dm0/ws04/), koje upoznaju studente s predavanjima, vode ih kroz materiju i pružaju VRLM animacije u namjeri da im se pomogne razumjeti geometriju prostora. U kolegiju se stavlja naglasak na klasične geometrijske konstrukcije, 3D modeliranje s CAD podrškom i prostoručno crtanje. Svaki od ovih dijelova se zasebno razrađuje i upotpunjuje s primjerima studentskih programa.

Ključne riječi: izobrazba o deskriptivnoj geometriji, CAD, vizualna komunikacija.

1 Preamble

During the past 15 years new media including new technologies have gradually brought changes in the matter of knowledge absorption on all educational levels. On the one hand new technologies have introduced many facilitating methods and approaches and on the other hand new Medias have made the transfer of information much faster which is at times not in accordance with traditional educational theories. The introduction of CAD technology in technical departments has especially affected the worldwide methods of teaching geometry.

2 The influence of CAD technology on the subject of geometry

Since 1990 CAD technology has been more and more often applied and it is today used at all technical departments. During the period of 1990-2000 different CAD software were mainly implemented at the technical departments in the classes of descriptive geometry. In the new syllabus of the courses in the field of "graphic-visual communication" the content in the field of geometry was reduced - we may even say minimized, while the students were instructed in 2D drawing on PCs. According to Stachel [1] this happened mainly due to a misunderstanding regarding the syllabus of descriptive geometry and its constructive technique by using drawing equipment. Descriptive geometry was neglected although it is the only discipline at the technical departments which teaches future engineers

to communicate with one another by means of drawings and also the only discipline which trains visual spatial intelligence. Just a few years after these changes were introduced Field [2] noticed an anecdotic deterioration of the students' ability of spatial visualization.

Reduced instruction in geometry at the universities has initiated a number of enquiries worldwide ([3], [4], [5], [6], [7]). They proved that there was a direct connection between the study of the subject matter of descriptive geometry and the improvement of visual spatial intelligence([8], [9]) - as one of the most important ability for an engineer. The conclusion after this first euphoric computerization of instruction was that two dimensional CAD software were only understood as electronic ruler, ink and pattern, which clearly defined a very low level as the highest achievement of this type of education.

On the basis of the results of the above mentioned enquiries as well as on the basis of the recommendations by UNESCO on the reform of instruction in the next millennium [10] there appeared a second wave of research ([11], [12], [13], [14], [15]) with the aim to theoretically define the optimum syllabus in the field of visual [16] and graphical communication for students of technical universities. During the last five years new courses in the field of visual communication have appeared at the technical universities worldwide ([17], [18], [19], [20], [21], [22], [23], [24], [25]) which have implemented more geometry into their courses.

The inclusion of the CAD technology as a didactical method in the instruction of geometry is necessary today not by means of 2D software applications but by using different 3D applications, methods of animation and simulation [26]. CAD software is a modern tool to perform descriptive and constructive - space - geometry. In this manner the process of knowledge adoption is facilitated and it offers great opportunities for a further development of spatial intelligence.

3 The importance of visual communication for students of architecture

A creative person is one who can process in new ways the information directly at hand - ordinarily sensory data available to all of us. A writer needs words, a musician needs notes, an architect needs visual perception, and all need some knowledge of the techniques of their crafts. Also a creative individual intuitively sees possibilities for transforming ordinary data into a new creation, transcendent over the mere raw materials [27]. Precisely one part of the educational process is to make up the development of creativity of students by helping to develop different skills. We can say that for future architects probably the most important skills are a good ability of perception, visual orientation and the ability to clearly transfer their (three dimensional) imaginations in a two dimensional medium. Another important skill is the ability to read two dimensional drawings fast and in a correct way as well as the possibility to realize interdependencies and connections between numerous two dimensional drawings. The skill of visual communication is developed by studying geometry and we can certainly say that by developing this skill creativity of students will also be developed.

4 Geometry courses at the faculties of architecture

The instruction in the field of geometry at the faculties of architecture is based in teaching students to define architectural three dimensional forms and their representation in a two dimensional medium. At the beginning of the studies it is necessary for students to develop visual skills and to adopt geometrical knowledge from the field of representation of three dimensional objects in a two dimensional medium. After a few semesters and with more knowledge in the field of construction and structure design of architectural forms the students need to study complex forms and their geometrical characteristics.

The use of CAD technology in the process of architectural design has facilitated the generation of geometrical forms and helped to improve the representation of architectural achievements. Generating architectural forms with the help of different 3D CAD software has introduced a new quality to the design process. This quality refers primarily to the possibility of a more creative expression of the designer in the process of generating standard forms as well as allowing him/her enormous freedom in generating new forms. Computer aided architectural design of these complex geometrical forms often leads the designer in an unexpected direction, therefore it leads to a new dimension of creativity through interaction between the architect and the computer. It is safe to say that today with the computer aided design the creativity of the designer is no longer conditioned by the technique of the project representation (as it was the case in the classical design process). Today there are nearly no limits to this interactive creative process as well as the results of this interaction solely depend on the theoretical knowledge of geometrical forms and their characteristics, adequate choice and use of 3D software application. At this place we would like to remind and to point

out that this CAD process takes place only in a virtual environment. Today the Rapid Prototyping Technology offers the possibility to manufacture physical objects of complex geometrical forms directly from CAD data sources and to check the extensive virtual design.

On the basis of the aforementioned it is quite clear that the students today could only be prepared for adequate applications of future software and for further developments of the CAD technology by a thorough education in the field of geometry.

5 The syllabus of the course ”Methods of representation”

Starting with the academic year 2002/2003 a new curriculum was introduced for the studies of architecture at the University of Technology in Graz. Besides many revisions which affected most courses also the course ”Geometry” was modified and renamed into ”Methods of representation”. The instruction of the former course ”Geometry” included 3 lectures and 2 exercise classes (per week) in the first semester and 2 exercise classes in the second one. The number of classes in the new course was reduced to 2 lectures while the exercise classes in the first and second semester remained.

The course ”Methods of representation” can only be attended with basic knowledge in geometry. Students learn this ”basic geometry” either in a 2 years course at high school or in an obligatory supplementary ”basic course” at university called ”Ergänzungskurs aus Darstellender Geometrie” which includes 30 lecture and 30 exercise lessons. This course is organised by the Institute of Geometry (http://www.geometrie.tugraz.at/lehre.html), lasts 2 months at the beginning of the first semester and covers almost the whole learning matter of Austrian high schools. Students learn the basic principles of orthogonal projections, with main views and auxiliary views, with basic construction dealing with points, lines and planes in space as well as an elementary constructions in ground and frontal projection of conic sections, spheres, cylinders and cones of rotation and their planar sections. Using the above mentioned knowledge in the field of geometry the students are completely prepared to adopt the contents of the course in ”Methods of representation”.

One innovation of the course ”Methods of representation” concerns the cooperation between the Institute of Geometry from the Faculty of Mathematical and Physical Sciences and the Institute of Architecture and Media, a newly founded institute at the Faculty of Architecture. Another innovation affected the syllabus of the course in the first semester: classical geometric constructions and freehand drawing were combined with the potentials of new media [1].

The syllabus covers the problem of the representation of architecture by means of classical constructional methods and with the help of CAD technology. In the lectures students receive basic theoretical instructions in the field of geometry and CAD technology. In the exercise classes these instructions are applied and practiced by editing and solving ”real” architectural examples and problems.

While defining the syllabus of this course many questions emerged which gave a direction to the further development. Some of these questions can be expressed as follows:

- Which are the needs of an architect to represent his/her ideas?
- Which are the needs of the students in their first year of studies for the representation of their first concepts?
- Which form and art of representation should the students be taught today, taking the fact into account that the current CAD software (AutoCAD, Abisplan 3D, Archi-Cad, Nemetschek,...) support to 99% the process of handling and representing architectural projects in practise?
- What is the difference between a draughtsman and a creative project planner if they both use the same tool for their graphical expressions?
- What can make our course thrilling and interesting for students and how can we motivate them to increase their knowledge?
- How much geometry do we need in our syllabus?
- How do we find a good balance between classical construction design and the handling by means of CAD?
- What makes our course different from all the other courses in this field?

[1] In the second semester the students learn about the field of computer graphics. Students get an introduction in the field of free form surfaces including theory and practical exercises. The intended purpose of the rest of the syllabus is to enable the students to represent future projects.

Of course we cannot present the discussion on the aforementioned topics (including pros and cons) in this work but some specific answers to the questions were offered in the first part of this paper and some will be presented in the following part.

The subject matter of our course consists of three parts

- classical constructions,
- CAD constructions and
- freehand drawing

and is divided into 10 thematic units.

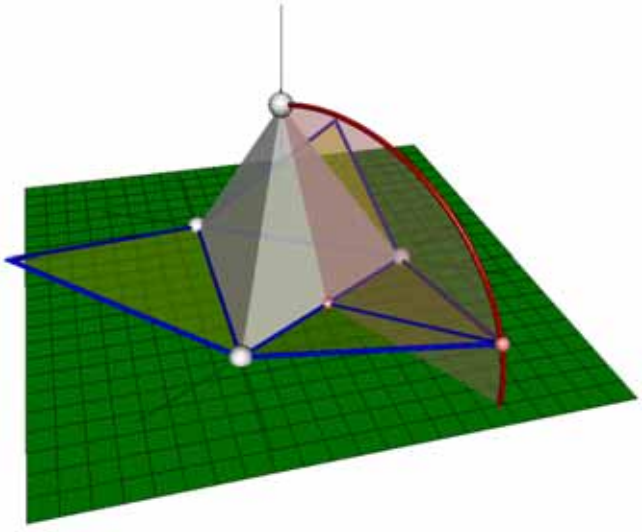

Figure 1 *3D animation*

Classical and CAD exercises units interchange during the semester and in each unit one exercise of freehand drawing is carried out. With this approach the students should be enabled to realize the problem of representation in three different ways. Each exercise course has a tutorial paper and if necessary a 3D animation which facilitates the understanding of the corresponding spatial problems (for example the generation of a tetrahedron by rotating equilateral triangles, see Fig. 1).

During the semester students have to complete five assignments and the examination is divided into two parts. One part of the examination includes the check of knowledge in the field of classical construction design (Fig. 2) and the second part concerns construction designing in CAD (Fig. 3). In the examination examples architecturally effected objects by famous architects are used but only adapted and simplified in order to represent the essential principles (Fig. 4).

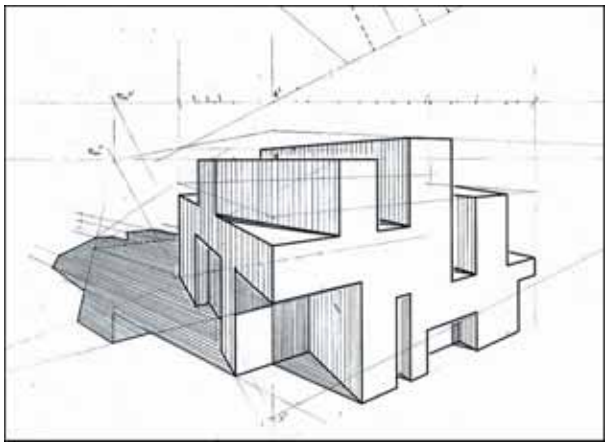

Figure 2 *Examination example - classical construction design*

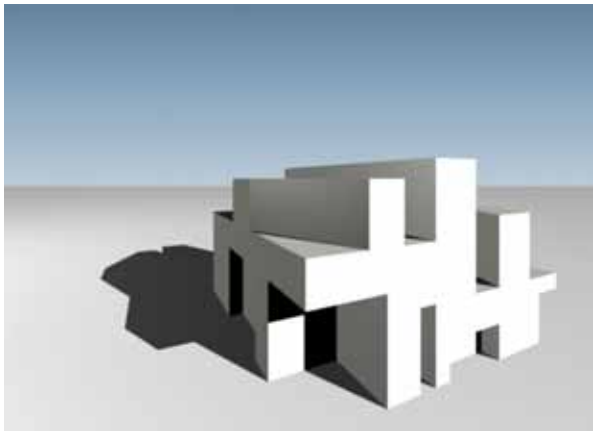

Figure 3 *Examination example - modelling in CAD*

Figure 4 *Original to the figures 2 and 3, Bellevue Art-Museum in Seattle, Architect Steven Holl*

5.1 Classical construction design

The aim of this part of the course is to enable students to represent their objects on a two dimensional medium, i.e. paper with pencil, ruler and compasses - primarily by studying axonometric (Fig. 5) and perspective projection of objects (Fig. 6).

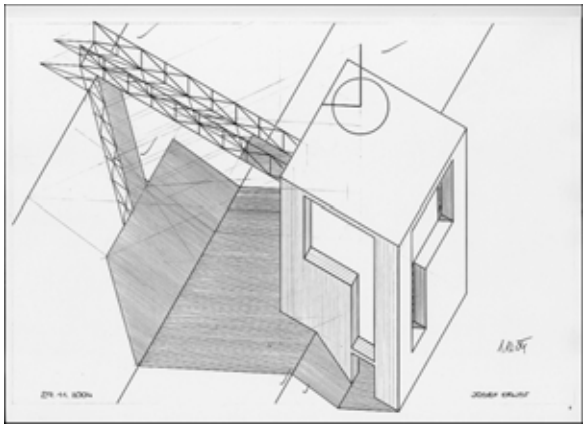

Figure 5 *Axonometric projection*

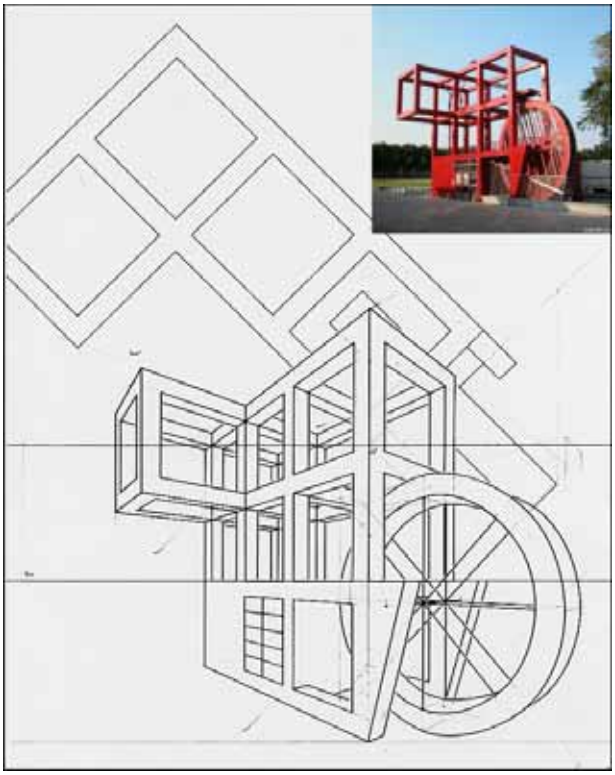

Figure 6 *Perspective projection*

With the classical construction design the rules of construction are taught, strategic thinking is encouraged, a gradual understanding of geometry and also basic components of perceptive skills are developed [28]. In this manner the adopted fundamental knowledge may be applied during freehand drawing or while using software packages. The content consists of horizontal axonometry, perspective, shadow construction by means of parallel source of light in both axonometric (Fig. 5) and perspective projection (Fig. 7) as well as the reconstruction of perspective images (Fig. 8).

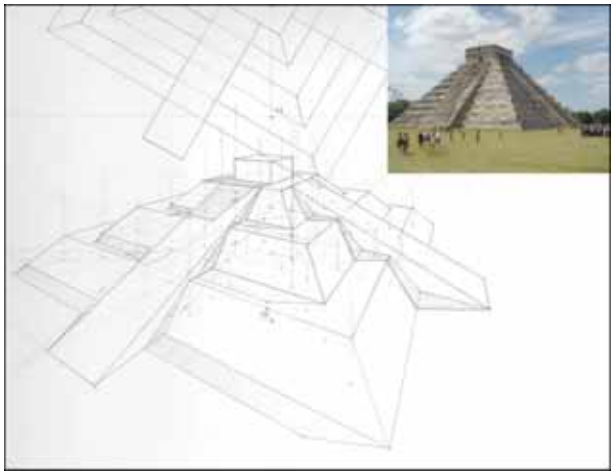

Figure 7 *Shadow construction*

In the lectures students receive general information on different axonometric representations while in exercise classes only horizontal axonometry is practiced - for architects the easiest and the fastest way to represent three dimensional forms by hand.

The basics of perspective representation were introduced into the syllabus for some reasons. The first one is connected to the understanding of parallelism in perspective images (points at infinity, neutral points, etc.) and the application of these rules in freehand drawing. Another reason is directly connected to CAD software and the appropriate use of perspective parameters in CAD software in order to receive desired perspective images and not images by chance. Conversely the knowledge of perspective is essential for the reconstruction of perspective images and for the photomontage of new projects into existing architectural context (Fig. 8 and 17).

One more reason of studying perspective is that perspective drawings (of architecture) by hand exude an own personal touch because of the particular drawing style of the acting person. This is an important matter in architecture in contrast to the often sterilely produced computer presentations.

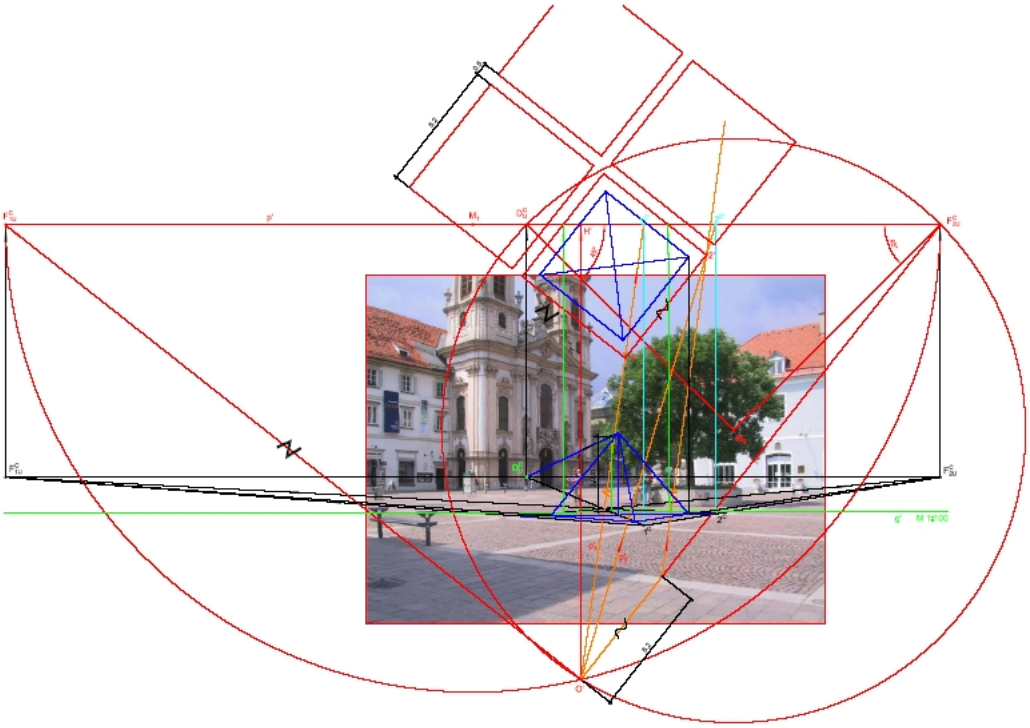

Figure 8 *Reconstruction - Mariahilferplatz, Graz.*

5.2 Freehand drawing

The aim of this part of the course is to enable students to accomplish geometrical freehand drawing ([29], [30], [31]). The content is connected to the syllabus of classical construction design and the design by means of CAD. Mastering this skill starts with the drawing of lines and two dimensional geometrical patterns (Fig. 9) whereby precise drawing is trained as well as fine drawing by hand.

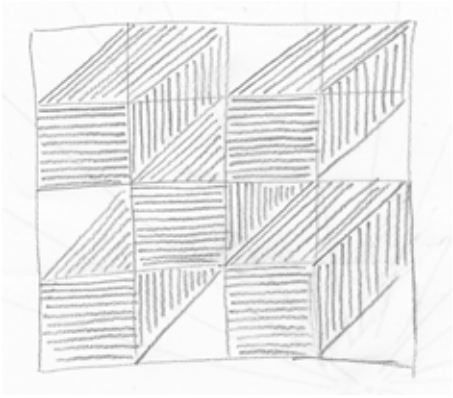

Figure 9 *A two dimensional pattern*

After practising the basic geometrical principles and rules of axonometric projection in classical construction design the students are introduced to axonometric sketching of simple and complex forms (Fig. 10).

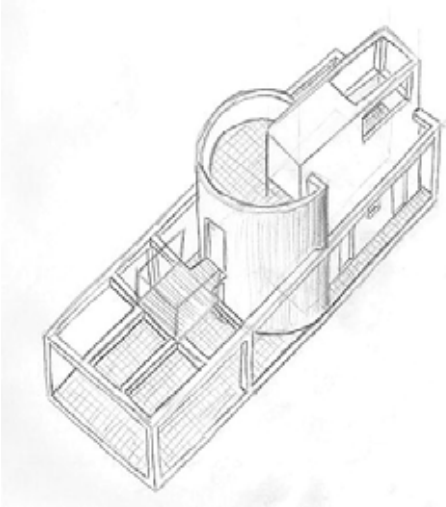

Figure 10 *A complex three dimensional form in axonometric projection*

The first part of perspective sketching is performed by copying perspective images of architectural objects (Fig. 11). The aim of this part of sketching is to recognize basic geometric elements and rules in a perspective image and to imitate the style of the original as well as possible.

Figure 11 *A given 2D perspective image (left) and a student's drawing (right)*

The second part concerns the drawing of a given three-dimensional object (Fig. 12). The task for the students is to recognize basic geometrical bodies in a complex geometrical form and to apply the rules of perspective during sketching. Thus the students practice their perception skills and the skill of precise transformation of the elements of a three dimensional object to a two dimensional medium. This last mentioned skill is directly connected to the modelling process in CAD systems. It trains the process of strategic thinking and of finding solutions for complex problems.

Figure 12 *Drawing of a given 3D object*

In this manner students experience two different ways of perception and its transfer to a two dimensional drawing - copying a 2D image and sketching a 3D object - which they will need in the process of further successful project designing.

5.3 Solid modelling in CAD

The aim of this part of the course is to train students in solid modelling and modification of three dimensional forms ([32], [33], [34]). Students have the possibility to use Auto-CAD but at the same time the concept of the syllabus is made in such a manner that the thematic units may be covered in any 3D CAD software of students' choice. The emphasis is placed on acquiring knowledge of basic geometrical principles in the generation of 3D forms as well as learning a strategic way of thinking while solving geometrical problems in complex architectural forms. The thematic units begin with the drawing of two dimensional geometrical forms. Further on, these forms are used to generate spatial models (Fig. 13) by extrusion.

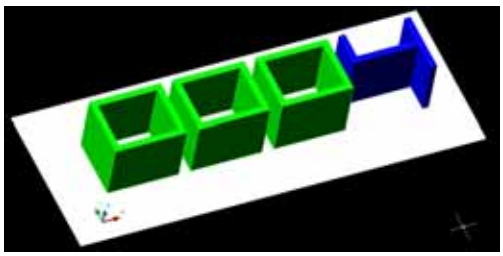

Figure 13 *Extrusion of planar geometrical forms*

Moreover basic geometrical solid models are modified and changed into complex geometrical forms (Fig. 14). They are used to build up hierarchical relations between the participated objects (Fig. 15).

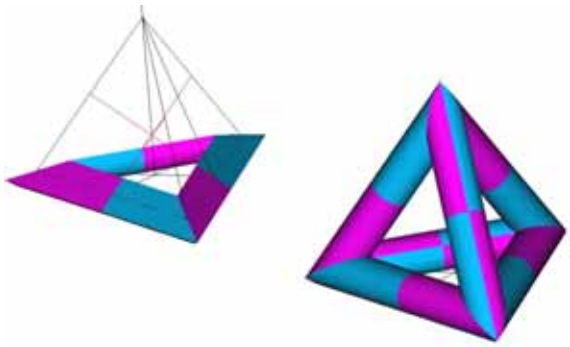

Figure 14 *Complex geometrical forms*

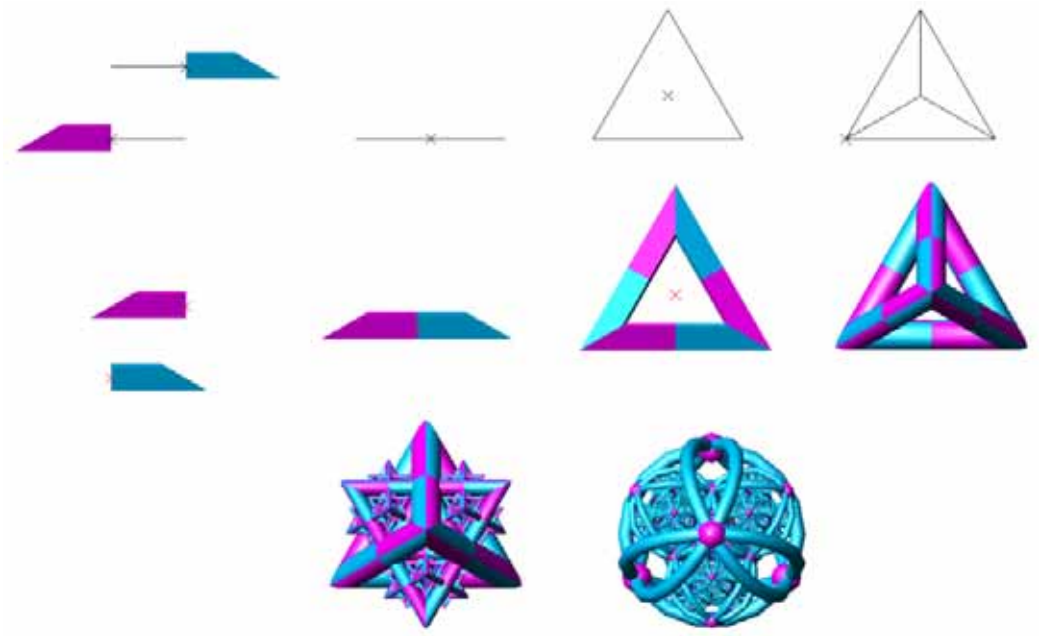

Figure 15 *Hierarchical organized forms*

For this purpose Plato's bodies are constructed and used after analyzing their geometry and rules of their generation.

The course finishes with the modelling of complex forms from architectural practice (Fig. 16).

Figure 16 *Complex architectural forms*

During the course new relative user coordinate systems (UCS) are defined and the work is automated by using blocks. The theoretical knowledge from the field of shadow construction and perspective which was taught in classical construction design is furthermore implemented and practised by the definition of light sources and perspective views from predefined camera and target points in order to apply photo-mounting (Fig. 17).

The chosen thematic units and problems which are handled by means of CAD technology should students enable to clearly see the advantages and restrictions of CAD.

Figure 17 *A modelled fountain inserted in a photo - Mariahilferplatz, Graz.*

6 Evaluation

The course ”Methods of representation” is evaluated every year by ”TUGonline” - a information management system at the University of Technology in Graz. This system supports the communication between the students and the University. Besides the evaluation it includes timetables, the registration of courses, examinations, etc. The students are automatically contacted by the system at the end of the semester and they are asked for a feedback. The outcome of the last years shows that students are very satisfied with the course especially with the diversified content, various interesting examples, the tutorials, the organization of the course and the regular updated web site.

7 Conclusion

In this paper we tried to show how teaching descriptive geometry has changed at the technical departments in the last 15 years by using of new media especially CAD. In our opinion the most important part in handling with CAD packages is a well-founded education in the principles of geometry. The students could only be prepared on the new technology if the traditional geometric education is combined with new media because geometry is the basic science which stays further on and CAD is just an exchangeable tool which will be further developed depending on the state of the art.

In the course ”Methods of representation” at the faculty of architecture we tried to integrate the above mentioned - i.e a combination of classical construction design, computer aided design and geometrical freehand drawing as a link in between. Therefor we used many various examples from different architectural fields but also theoretically geometrical examples. The handling with geometrical motivated examples is the basis for further development of students' creativity. We tried to establish a simple and clear way from the basics to complex geometry with the aim to facilitate the students to manipulate their geometrical knowledge for further work.

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