The Status of Todays Descriptive Geometry Related Education (CAD/CG/DG) in Europe

Hellmuth Stachel

Technische Universität Wien
Vienna University of Technology

stachel@dmg.tuwien.ac.at — http://www.geometrie.tuwien.ac.at/stachel

40th anniversary of the Japan Society for Graphics Science, May 12–13, 2007, at the University of Tokyo

. . . First of all . . .

Congratulations

to the

Japan Society for
Graphic Science

at the occasion of its

40th anniversary

contacts to Japan around 1967

Prof. Fritz Hohenberg
1907–1987

1966 start of my university career – supervisor: Prof. F. Hohenberg (Graz/Austria).

1968 publication of the Japanese translation (Shozo Masuda) of Hohenberg's textbook

Konstruktive Geometrie in der Technik
[Constructive geometry in technical sciences]

Later Hohenberg published three articles in the Journal of Graphic Science of Japan [**15**, (1974), 1–3, **16** (1975), 17–20, **23** (1977), 27–28] and he felt extremely proud of this.

Finally he became a honorary member of the Japan Society for Graphic Science.

Table of contents

0. Introduction

The aim of my presentation is to explain what Descriptive Geometry is good for — and in which way the Descriptive Geometry education is carried out in European countries.

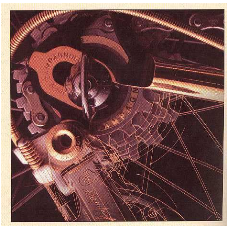
In the *hierarchy of sciences* Descriptive Geometry is placed *within or next* to Mathematics, but also near to Architecture, Mechanical Engineering, and Engineering Graphics.

A few examples shall highlight that Descriptive Geometry *provides a training of the students' intellectual capability of space perception.*

Descriptive Geometry is therefore *of incotestable importance for all engineers, physicians and natural scientists.*

1. What is Descriptive Geometry ?

In American textbooks Descriptive Geometry seems to be restricted to standard constructions like the determination of the true length of a line segment or the intersection of two plane polygons in 3-space.



G. B. BERTOLINE et al.:
Engineering Graphics Communication
Irwin Graphics Series, Chicago 1995, 900 pages

Descriptive geometry is the mathematical foundation of engineering graphics.

Part III provides the basics of descriptive geometry, including the important concepts of true-length lines and true size and shape surfaces, and the relationships between lines and planes.

Part III also expands on the multiview drawing concepts . . . Finally,

Part III introduces the essential concepts of intersections and developments

. . . thus demonstrating the application of engineering graphics fundamentals to real-world requirements.

Descriptive Geometry in Europe

Browsing through German textbooks from the last five decades:

J. Krames (Vienna, 1967):

"Descriptive Geometry" is the high art of spatial reasoning and its graphic representation.

H. Brauner (Vienna, 1986) preferred the name *'Constructional Geometry'* instead of Descriptive Geometry and defined:

"Constructional Geometry" encompasses the analysis of 3D objects by means of graphical or mathematical methods applied to 2D images.

Descriptive Geometry in Europe, cntd.

F. Hohenberg (Graz, 1966) whose textbook focusses on applications of Descriptive Geometry in technology:

"Constructional Geometry" teaches how to grasp, to imagine, to design and to draw geometrical shapes.

W.-D. Klix (Dresden, 2001) gives the following extended explanation:

"Descriptive Geometry" is unique in the way how it promotes spatial reasoning, which is so fundamental for each creative activity of engineers, and how it trains the ability to express spatial ideas graphically so that they become understandable for anybody else.

my definition . . .

Definition:

Descriptive Geometry is a method to study 3D geometry through 2D images.

It provides insight into structure and metrical properties of spatial objects, processes and principles.

Typical for Descriptive Geometry is the interplay

- between the 3D situation and its 2D representation,
- between intuitive grasping and rigorous logical reasoning.

Descriptive Geometry in Europe, cntd.

Beside *projection theory* Descriptive Geometry courses in Europe cover

- *modeling techniques* for curves, surfaces, and solids,
- insight into a broad variety of *geometric shapes*,
- an intuitive approach to basic *differential geometry* of curves and surfaces,
- some *3D analytic geometry.*

An additional aim is to develop and refine the students' *problem-solving skills.*

'Learning by doing' is an important methodological principle.

G. Monge's definition

La Géométrie descriptive a deux objets:

– **le premier**, de donner les méthodes pour représenter sur une feuille de dessin qui n'a que deux dimensions, savoir, longueur et largeur, tous les corps de la nature qui en ont trois, longueur, largeur et profondeur, pourvu néanmoins que ces corps puissent être définis rigoureusement.

– **Le second objet** est de donner la manière de reconnaître, d'aprés une description exacte, les formes des corps, et d'en déduire toutes les vérités qui résultent et de leur forme et de leurs positions respectives.

G. Monge (1746–1818)
Place de Monge, Beaune
Dep. Côte-d'Or, France

two main objectives of Descriptive Geometry

The *two main objectives* of Descriptive Geometry

- imaging 3D objects
- analysing 3D objects

date back to its founder G. MONGE.

The word *'drawing'* does not appear in MONGE's definition.

In Descriptive Geometry 'drawings' are the guide to geometry but not the main aim; we teach geometry instead of construction techniques.

Further comments on Descriptive Geometry

Only people with a profound knowledge in Descriptive Geometry are able to extended use of CAD programs.

For similar reasons the importance of mathematics is still increasing though computers take over the computational labour.

Descriptive Geometry is more than 'descriptive' geometry —

as well as *Geometry* is more than its literal sense, i.e., 'measuring the earth'.

Discussing the name 'Descriptive Geometry'

There were several attempts in the past to rename this subject:

- *'Technical Geometry'* or *'Applied Geometry'* stresses its applicability.
- *'Constructive Geometry'* — 'constructive' in its figurative sense — should indicate that manual drawings are combined with mathematical computations.

The original MONGE definition of 'Descriptive Geometry' covers all these aspects.

It might sound too old-fashioned. Hence, for strategic reasons one could replace it by *'Geometric Modeling and Visualization'* or by *'Modeling and Imaging'*.

Discussing the name ‘Descriptive Geometry’

Nevertheless, for a field for research ‘Descriptive Geometry’ is too narrow — from my point of view.

My personal field of research is Geometry.

Using the name ‘Graphic Science’ for a field of research is excellent as it covers three important aspects

theoretical — technical — cognitive

And all three are important for a research-guided education of engineers.

2. What should remain in a student's brain

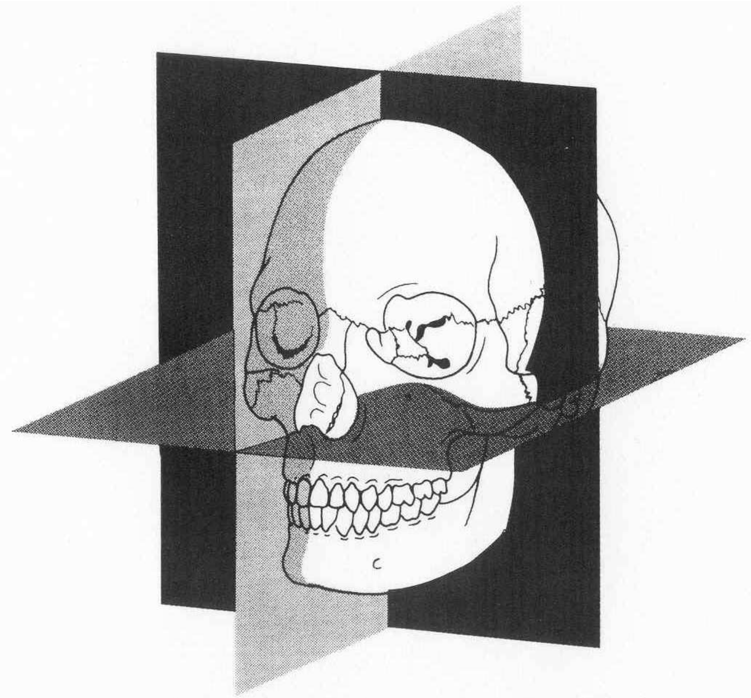
Education in Descriptive Geometry brings about the ability

- to comprehend spatial objects from given principal views (top view, front view, and side view),
- to specify and grasp particular views (auxiliary views),
- to get an idea of geometric idealization (abstraction), of the variety of geometric shapes, and of geometric reasoning.

The first two items look elementary. However, these intellectual abilities are so fundamental that many people forget how hard they were to achieve.

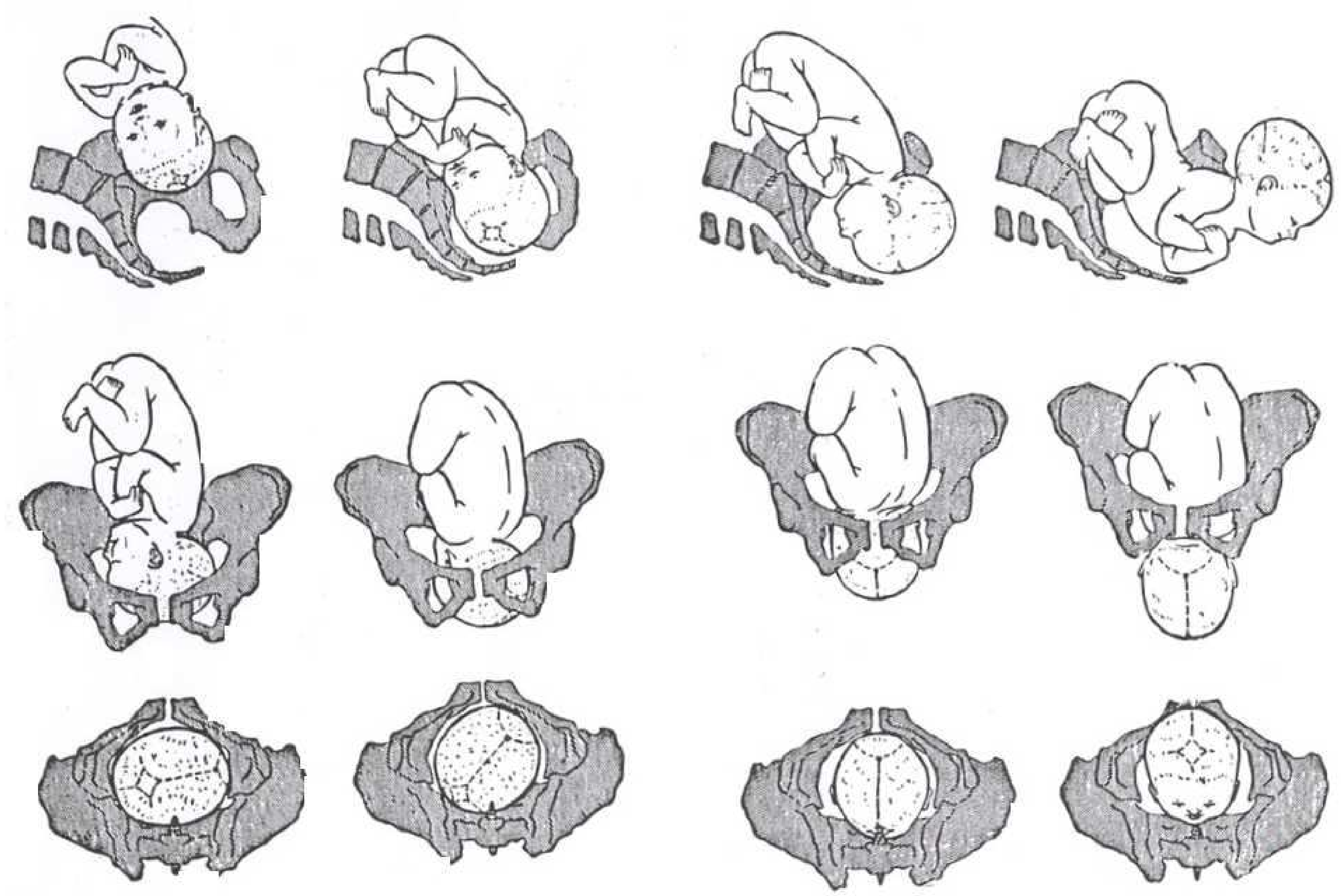
2a) The importance of principal views

- Principal views are *more or less abstract*. But abstraction simplifies.
- Inspecting these plane views is much easier than to concentrate on the true 3D structure or process.
- It needs *training* to become familiar with this kind of representation.
- *Medical doctors* often hold in esteem their Descriptive Geometry education.



Explainig the principal views to dentists

Principal views for gynaecologists



2b) The art of specifying appropriate views

For a detailed 3D analysis particular views (auxiliary views) often reveal the spatial situation.

Views showing planes in edge view or lines in point view can be the key for the solution of a 3D problem.

Appropriate views make the sublime art of Descriptive Geometry.

Only in such courses students are trained to specify and to grasp such views.

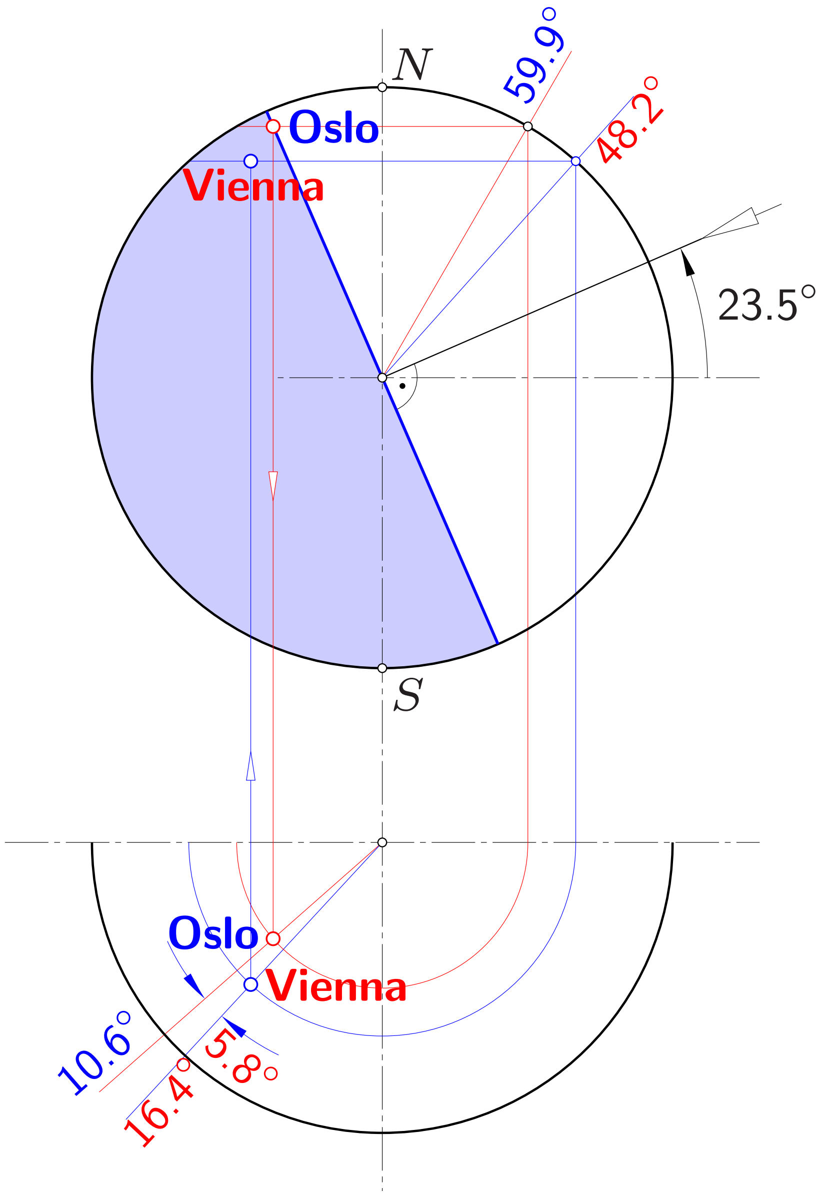
An example

Where does the sun rise earlier on June 21, in Oslo or in Vienna?

city	*Eastern longitude*	*Northern latitude*
Oslo	10.6°	59.9°
Vienna	16.4°	48.2°

We specify a front view with sun rays parallel to the image plane.

We seek Vienna relatively to Oslo.

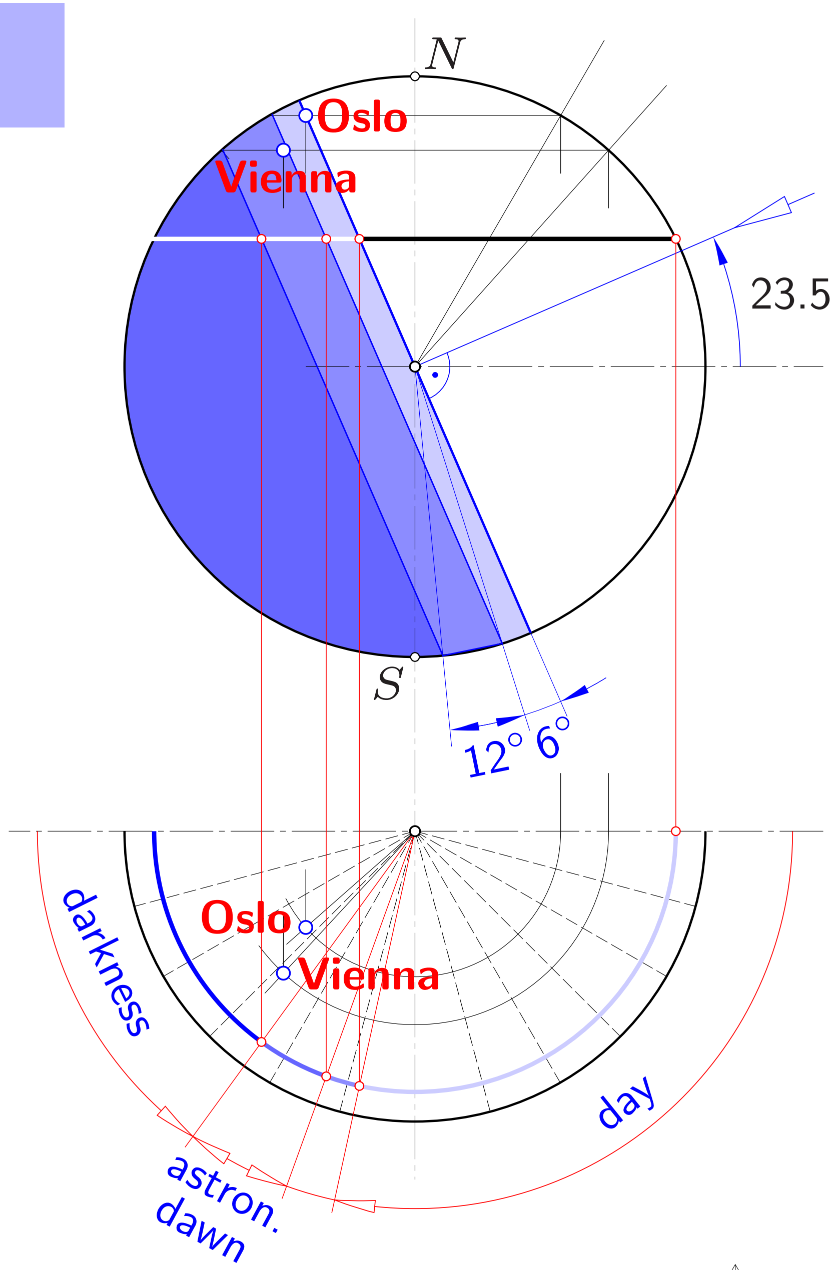


additional problems

a) We can increase the precision by paying attention to the refraction in the atmosphere: For an observer the sun seems to rise while it is still approx. $0,6^\circ$ under the local horizon.

b) In the zone of astronomic dawn the sun is between 6° and 18° under the local horizon.

c) By inspection we observe that the period of dawn is shorter in the neighborhood of the equator.

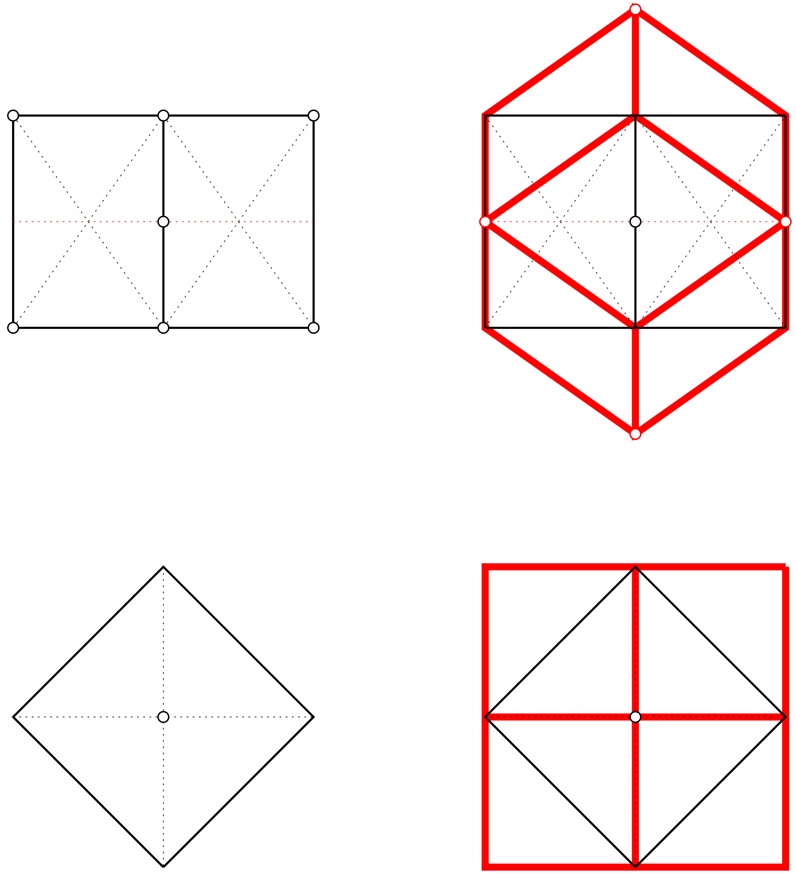


Mentally manipulating 3D objects?

The *rhombic dodecahedron* can be built by erecting quadratic pyramides with $45°$ inclined planes over each face of a cube.

Any two coplanar triangles can be glued together forming a rhomb.

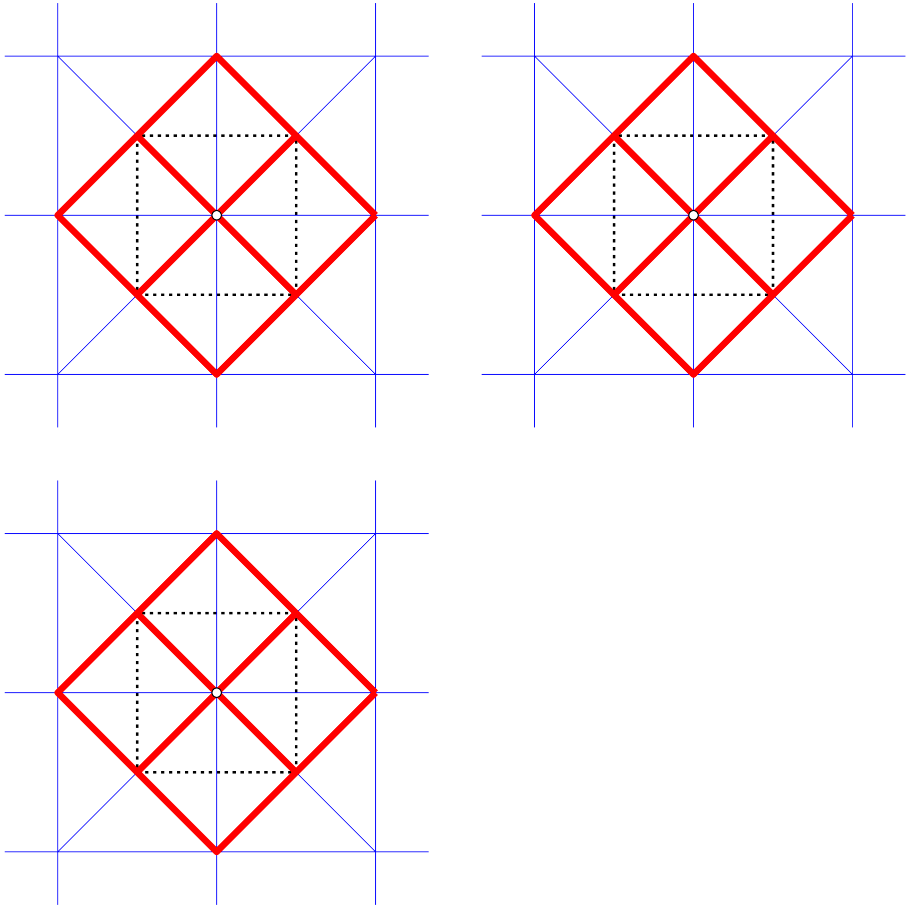
Question:
How does this polyhedron look like from above when it is resting with one face on a table?



Cube and rhombic dodecahedron

Special views reveal 3D properties

The rhombic dodecahedron is the *intersection of three quadratic prisms* with pairwise orthogonal axes.

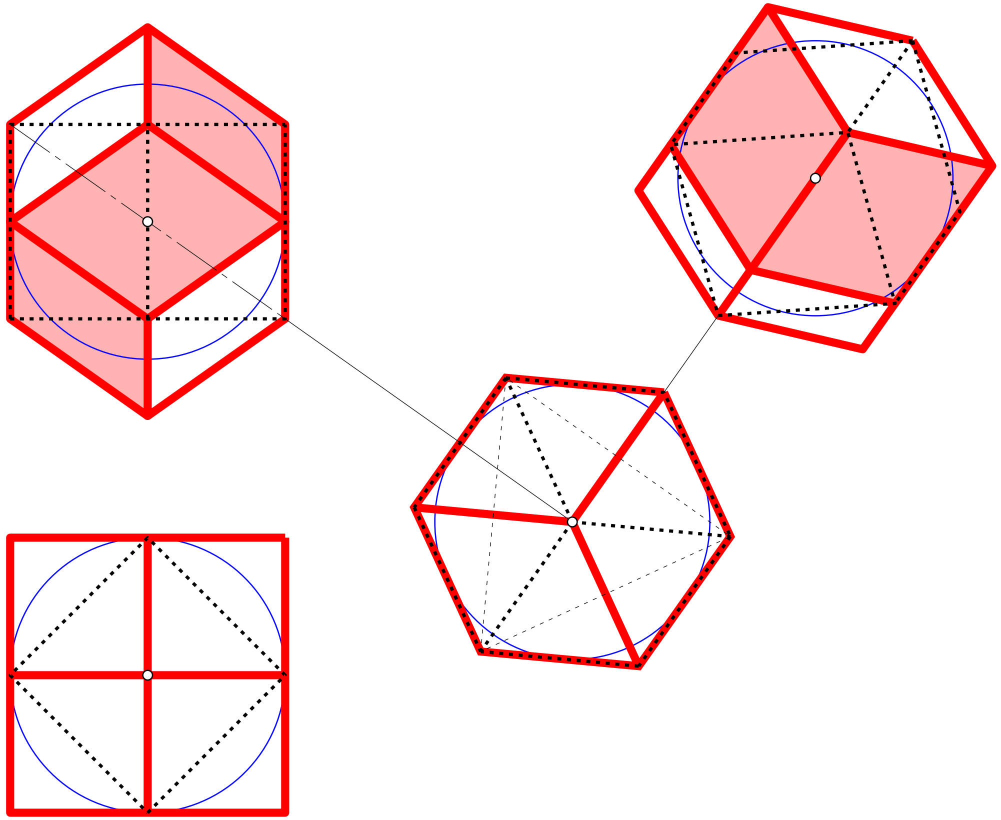


Special views reveal 3D properties

The rhombic dodecahedron is the *intersection of three hexagonal prisms* with axes in direction of the cube-diagonals.

The side and back walls of a *honey comb* belong to a rhombic dodecahedron.

Each *dihedral angle* makes $120°$, and there is an in-sphere (contacting all faces of the initial cube).



A simple 3D operation carried out mentally

The rhombic dodecahedron is a space-filling polyhedron.

Proof:

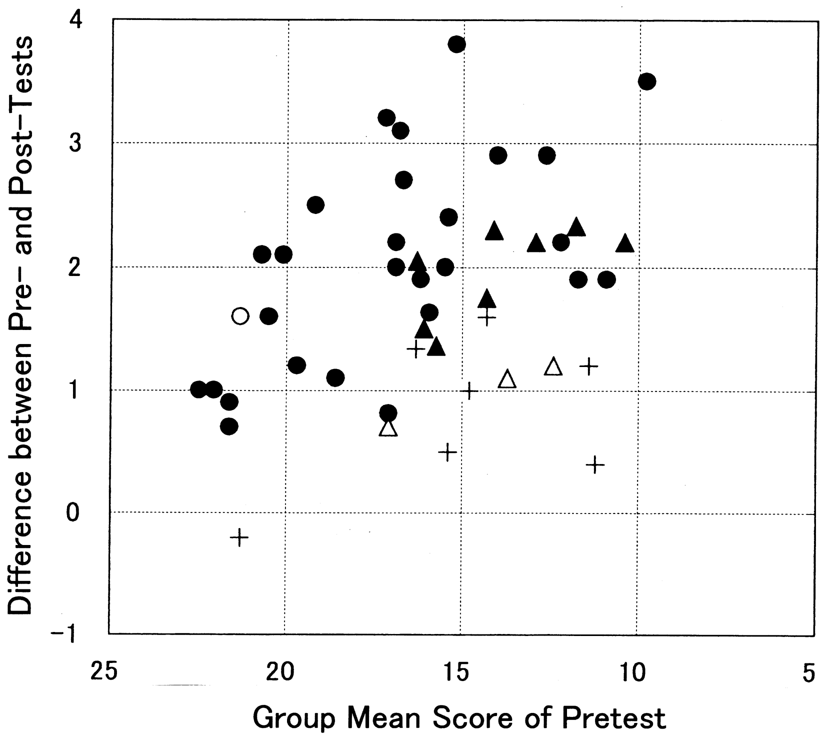
- Start with a *'3D-chessboard'* built from black and white cubes.
- Then the 'white' cubes can be *partitioned* into 6 quadratic pyramides with the vertex at the cube's center.
- Glue each pyramide to the *adjacent* 'black' cube thus enlarging it to a rhombic dodecahedron. □

3. Descriptive Geometry in presence of computers

K. Suzuki:
J. Geometry Graphics **6**, 221–229 (2002)

MCT-Test: Differences between pre- and post-test at Japanese students before and after the geometry education:

- ● Descriptive Geometry
- ○ Computergraphics,
- ▲ Engineering Graphics,
- △ 3D-CAD,
- + control persons



What is obsolete:

- complicated manual constructions,
- hard theoretical proofs
- the theory of how to obtain images of particular 3D objects

What is still necessary:

- **3D-competence**, i.e.,
- capability to comprehend 3D objects and situations from given images,
- mental orientation in 3-space
- basic knowledge of 3D geometry and its applications.
- Promoting creativity and problem-solving skills,
- producing attractive illustrations.

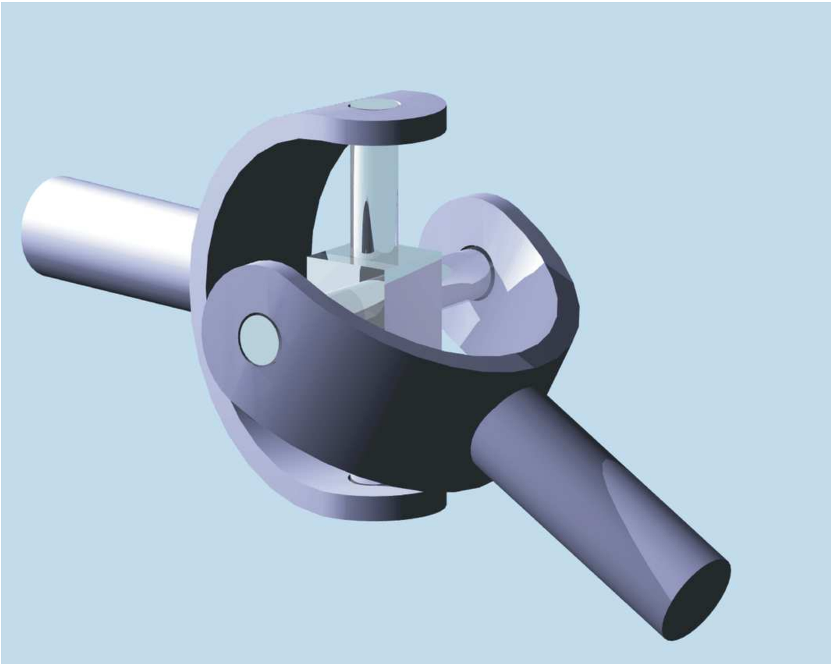
Additional demands:

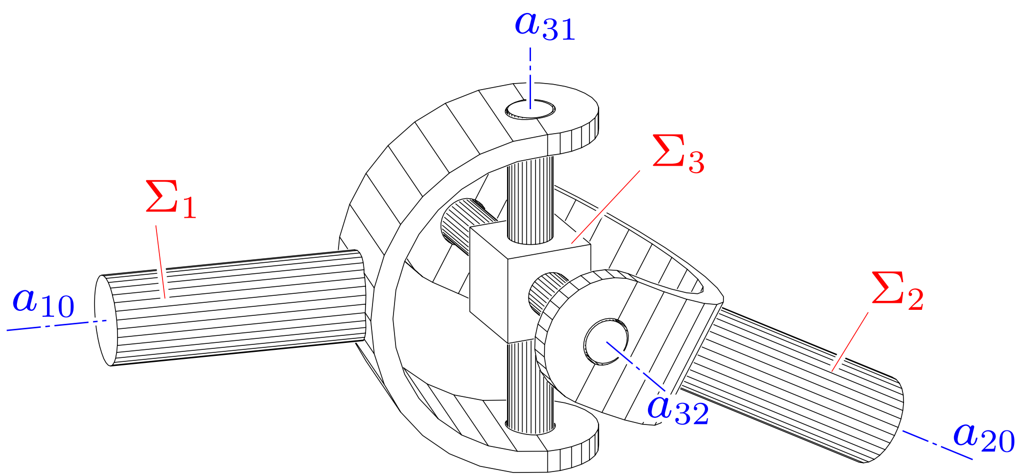
- Handling software for geometric modeling and visualization
- treating new geometric shapes (e.g., B-spline surfaces)
- competence in handling graphics files in different format
- design of animations.

Needs for the future:

- mental orientation in 3-space (e.g., user coordinate system),
- reducing the flood of graphic information to the essential.

shaded or line graphics





Kardan joint

'Data compression' by line graphics ?

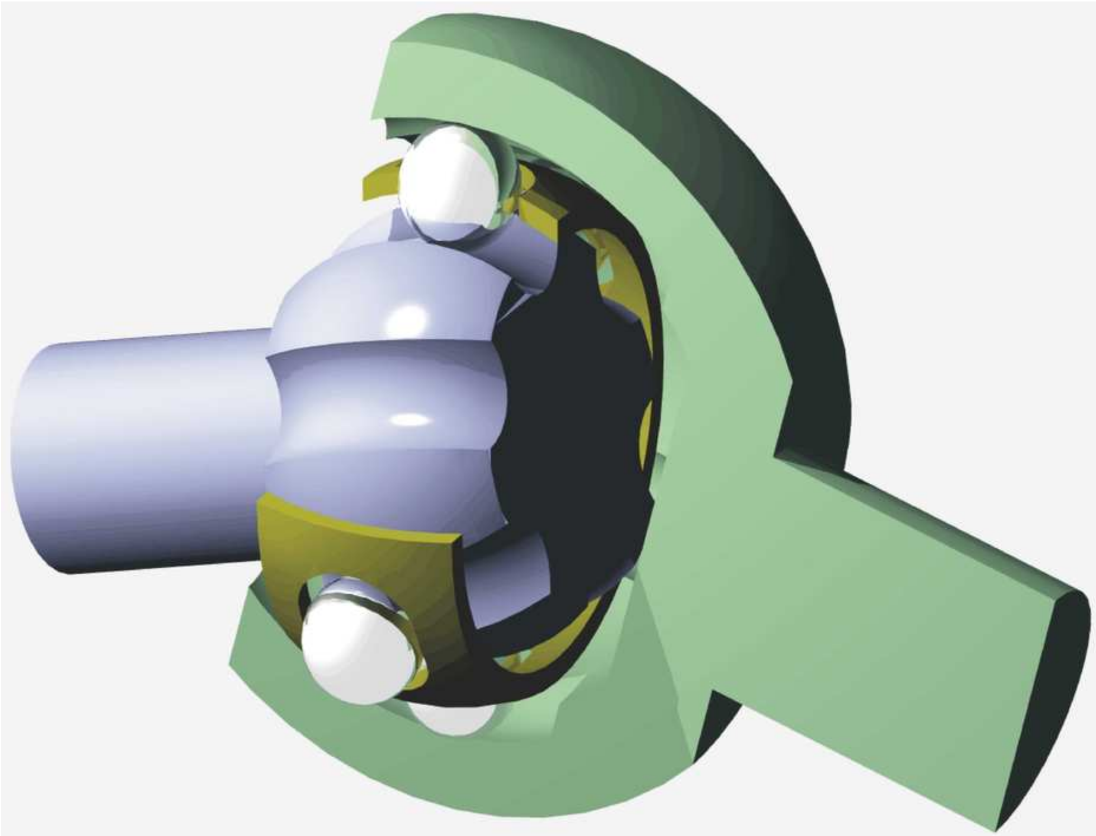
How to meet these demans ?

New tools must have an impact on education.

Students can solve more and more complex problems using computer software as a ‘black box’ while there is still a lack of basic understanding.

This is a problem of methodology, of the right balance between imparting knowledge on the one hand and the intelligent use of powerful computer programs on the other.

How to meet these demans ?



constant velocity ball joint

There will be a way in the near future to combine the benefits of educational CAD programs with the training of spatial reasoning in an optimized way.

Descriptive Geometry education is changing

Descriptive Geometry education has changed in central and East European universities.

It has been reduced – in particular in Mechanical Engineering, while in Civil Engineering and Architecture this subject is still in a strong position.

CAD packages combined with free-hand sketches are more and more replacing manual constructions.

Often the introduction into the usage of a CAD program is included — at the cost of a training of spatial reasoning.

DG education in secondary schools

In Austria there is still an optional subject /DG in secondary schools.

An Austrian pupil won last year the Bentley Award for modeling with MicroStation.

Bentley website: *"The BE Awards of Excellence salute the great work of Bentley users around the world . . .*

Nominations are judged by an independent panel of jurors comprised of peers, industry experts and educators, and winners will be announced on Monday, April 30, 2007 at the BE Awards of Excellence ceremony in Los Angeles, California."

Awarded Austrian pupil's work

References

[1] R. Bereis: *Darstellende Geometrie I*. Akademie-Verlag, Berlin 1964.

[2] G.R. Bertoline, E.W. Wiebe, C.L. Miller, L.O. Nasman: *Engineering Graphics Communication*. R.D. Irwin Inc., Chicago 1995, Chapter 11, pp. 597–695.

[3] H. Brauner: *Lehrbuch der konstruktiven Geometrie*. Springer-Verlag, Wien 1986.

[4] F. Hohenberg: *Konstruktive Geometrie in der Technik*. 3. Aufl., Springer-Verlag, Wien 1966.

[5] W.-D. Klix: *Konstruktive Geometrie, darstellend und analytisch*. Fachbuchverlag, Leipzig 2001.

[6] J.L. Krames: *Darstellende und kinematische Geometrie für Maschinenbauer*. 2. Aufl., Franz Deuticke, Wien 1967.

[7] G. Monge: *Géométrie descriptive*. Nouvelle édition, J. Klostermann fils, Paris 1811.

[8] H. Stachel: *Descriptive Geometry, the Art of Grasping Spatial Relations*. Proceedings 6th ICECGDG, Tokyo 1994: vol. 2, 533–535.

[9] H. Stachel: *A Way to Geometry Through Descriptive Geometry*. Прикладна геометрія та інженерна графіка (Applied Geometry and Engineering Graphics, Kyiv) **70**, 14–19 (2002).

[10] H. Stachel: *Descriptive Geometry in today's engineering curriculum*. Transactions of FAMENA **29**/2 (2005), 35–44.

[11] K. Suzuki: *Activities of the Japan Society for Graphic Science — Research and Education*. J. Geometry Graphics **6**, no. 2, 221–229.