

## INTEGRATING CAD AND MANUAL DESIGN METHODS FOR VISUAL SCIENCE

### 1. Introduction

Anyone involved in teaching such disciplines as descriptive geometry, technical drawing, engineering graphics and/or Computer Aided Design courses agrees that these disciplines undergo significant changes. The emergence of computer graphics and modern CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) systems has its impact not only on the change of the designing process itself but also on educational curricula at technical universities. In most cases, especially in the US and in western Europe, it is engineering graphics course with or without descriptive geometry elements that substitutes traditional descriptive geometry course in engineering majors. Not without importance remains the influence of the industry on these courses. During the past years a new design paradigm has been established in the U.S., a paradigm that uses a solid model as the common thread to integrate the design process with engineering analysis and part manufacturing (Barr, et al., 1998). Thus the educators put emphasis on a three dimensional model and its creation, orientation and relationships with the other objects in a three dimensional space. According to Bertoline (1995) a modern course in engineering graphics is designated today to be a medium to communicate information. In Fig. 1 the scheme for a model of concurrent engineering is shown. Concurrent engineering design means a non-linear design process in which all people necessary to design a product work interchangeably together in a team. The three areas of the design process, namely ideation, refinement of a product and its implementation overlap with each other. It is our task to teach engineering students how to seize the idea of a product and transform it to a working model of an object. This activity includes modeling, design analysis and design visualization. Today it becomes a standard that no two-dimensional drawings are used for a design purpose but either a wire-frame model or a solid model of a designed object is used. For the design purpose such powerful systems as IDEAS, CAD-Key, MicroStation or Pro/Engineer are used in the US. Still it has not become a standard at our Polish universities to use CAD/CAM software instead of descriptive geometry courses.

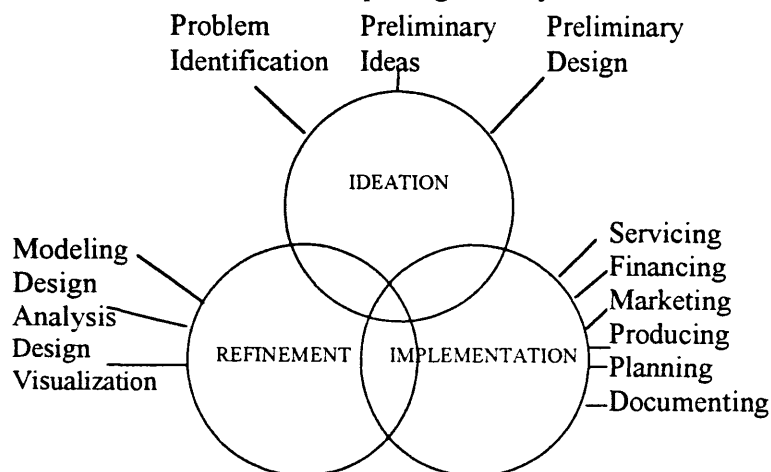


Fig. 1 Concurrent Engineering Design Process

## 2. Visual Science versus traditional engineering graphics courses

During the plenary session of the 8<sup>th</sup> International Conference on Engineering Design Graphics and Descriptive Geometry Prof. Gary Bertoline (1998) came up with a sensational idea of developing a new discipline of Visual Science. This discipline, having its foundations in graphics and philosophy, would bridge engineers and artists sharing common interests in graphics. Bertoline (1998) defines a new discipline of visual science to be the study of the process that produces images in the mind and has three major categories: geometry, spatial cognition, and imaging. Among listed categories and sub-categories we can recognize familiar to us items such as *Spatial Relations, Transformation and Rotation, Visualization or Whole to Part Relationships* to give an example on Spatial Cognition, further *Sketching, Graphic Design, Static and Dynamic* in Imaging category and finally *Plane, Solid and Descriptive Geometry*. One may not quite easily agree to categorization provided by Bertoline (1998) but no one can disagree to importance of the listed factors. The new discipline of Visual Science is supposed to substitute all the „old” disciplines bound to graphics, design and geometry, specifically to descriptive geometry. Further, the advantage of a new discipline recognition is that it would become somehow „interdisciplinary” science between engineering and arts and having advantage of integrating vast area of scientific research.

It is the author’s personal feeling that we all go in the same direction of Visual Science development though the paths to target this aim differ between universities. Besides, when looking at reality of Polish and/or European technical university environment it seems that in the nearest future it will be extremely difficult to formalize the new discipline at technical universities only because of its „psychological” notion, content and background. Are we ready to utilize a new discipline in terms of its „visual” ingredient? How can the word be translated into particular languages? „Visual”, „vision”, „visualization”... the terms related to an eye, perception, imagination. Do we need to make changes in nomenclature? The answer is yes if only we change our attitude towards teaching descriptive geometry and engineering graphics courses. What does the word „visual” mean? According to Hornby (1974) dictionary visual means „concerned with, used in seeing: visual images, *visualize* means to bring (something) before the mind. There is no such a word as „visualization” (or its Polish equivalent) in a Polish language dictionary (Skorupka, 1964).

If we think of the new discipline what problems would we suggest to include in the course of visual science? Should some elements of theory of perception, imagining and visualization be included in the course? What methods and means are working the best to enhance spatial abilities of the future engineers?

During the last academic year the author of this paper worked at the Michigan Technological University teaching courses in engineering graphics and 3-D visualization. It is obvious that students still lack visualization abilities, abilities so much substantial for their future engineering profession. In the US for example, a basic engineering graphics course includes the following: projection theory and projection methods classification, basic constructions in orthogonal projection (Mongean projection), auxiliary views, isometric sketching, solid intersections with planes, metric and English units systems, dimensioning, tolerancing, basics of solid modeling with the use of one of the CAM packages. Special course which aims at spatial abilities enhancement are proposed to these students who prove to be so called „low visualizers” (Sorby, 1998). In 3-D Visualization for Engineering Graphics course a lot of work with hand-made isometric sketching based on a coded plan is done (Fig.2). No Computer Aided Design is proposed in this special course. Students complete many tasks only with a paper, hand, pencil and mind. Research conducted on the spatial abilities (Sorby, Gorska, 1998) proved that this specific course has significant impact on improvement of spatial abilities for students who have problems to „see” and „think” in three dimensions.

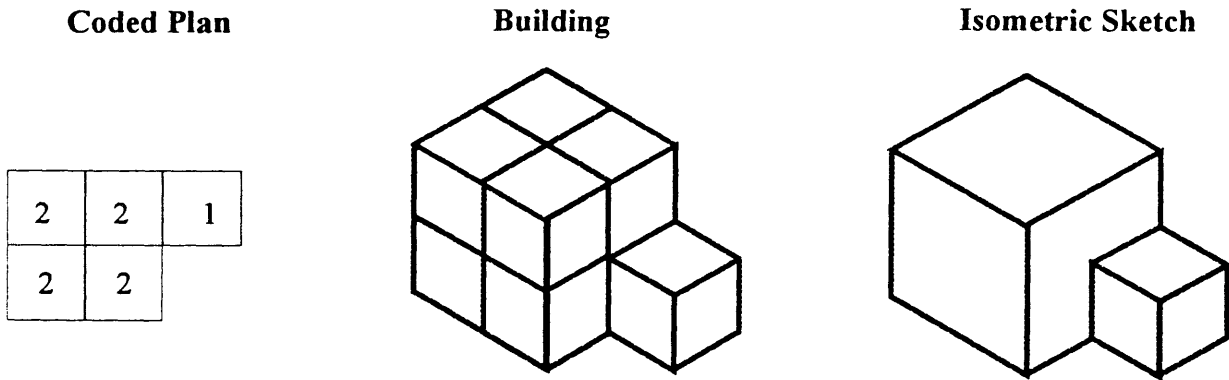


Fig.2 Example of an isometric view sketching based on a coded plan

### 3. Problem solving methodology

#### 3.1 Descriptive Geometry Tools

Some problems may be extremely well developed and solved with the use of simple methods of descriptive geometry, some not. To provide an illustration the author has taken an example from a student class (Fig.3). The task is to construct a set of four mutually tangent spheres so that each of the following spheres must be tangent to the previous one but must not lie in any specific position in relation to the assembled system or to the reference planes system. The solution for the problem is easy if we construct spheres one by one using Mongean projection. Manual solution appears to be quick and easy. Let's have the first sphere with a certain radius. Let us cut off a portion of this sphere with a plane  $\alpha=Ol$ , where  $l$  is a horizontal line. The first sphere with a given radius is assumed to be tangent to the horizontal projection plane. The line of intersection between the given sphere and the plane  $\alpha=Ol$  has not been drawn in the picture to avoid blurring of the drawing. Let us now construct an auxiliary view plane  $\pi_3$  such that it is perpendicular to line  $l$ . In this auxiliary view we are able to draw the second required sphere with the center  $O_2$  and tangent to the sphere with center  $O$ . Then we construct tangency points between the two spheres. Center  $O_1$  of the additional sphere shown in view on  $\pi_3$  is only taken to determine big circle on which lie all the centers of the spheres tangent to the two previously determined spheres. Then we construct spheres with centers  $O_3^1$  and  $O_3^2$  in the auxiliary view on  $\pi_4$ . The two new spheres will be positioned so that they do not lie in a specific position in reference to the basic planes. Finally we „come back” to the „third”, „first” and „second” views respectively on projection planes  $\pi_3$ ,  $\pi_1$ , and  $\pi_2$ .

The pure geometric problem formulated above induces three-dimensional thinking. When one would want to solve the same problem with any graphic software he/she would immediately notice that constructing mutually tangent spheres becomes a task not or almost not solvable in many CAD packages. We need to assume specific constraints which will force the constructed objects (spheres) to be tangent. The task will take plenty of time to find the correct solution using CAD/CAM systems, while half an hour is sufficient to solve the same problem with pure descriptive geometry methods..

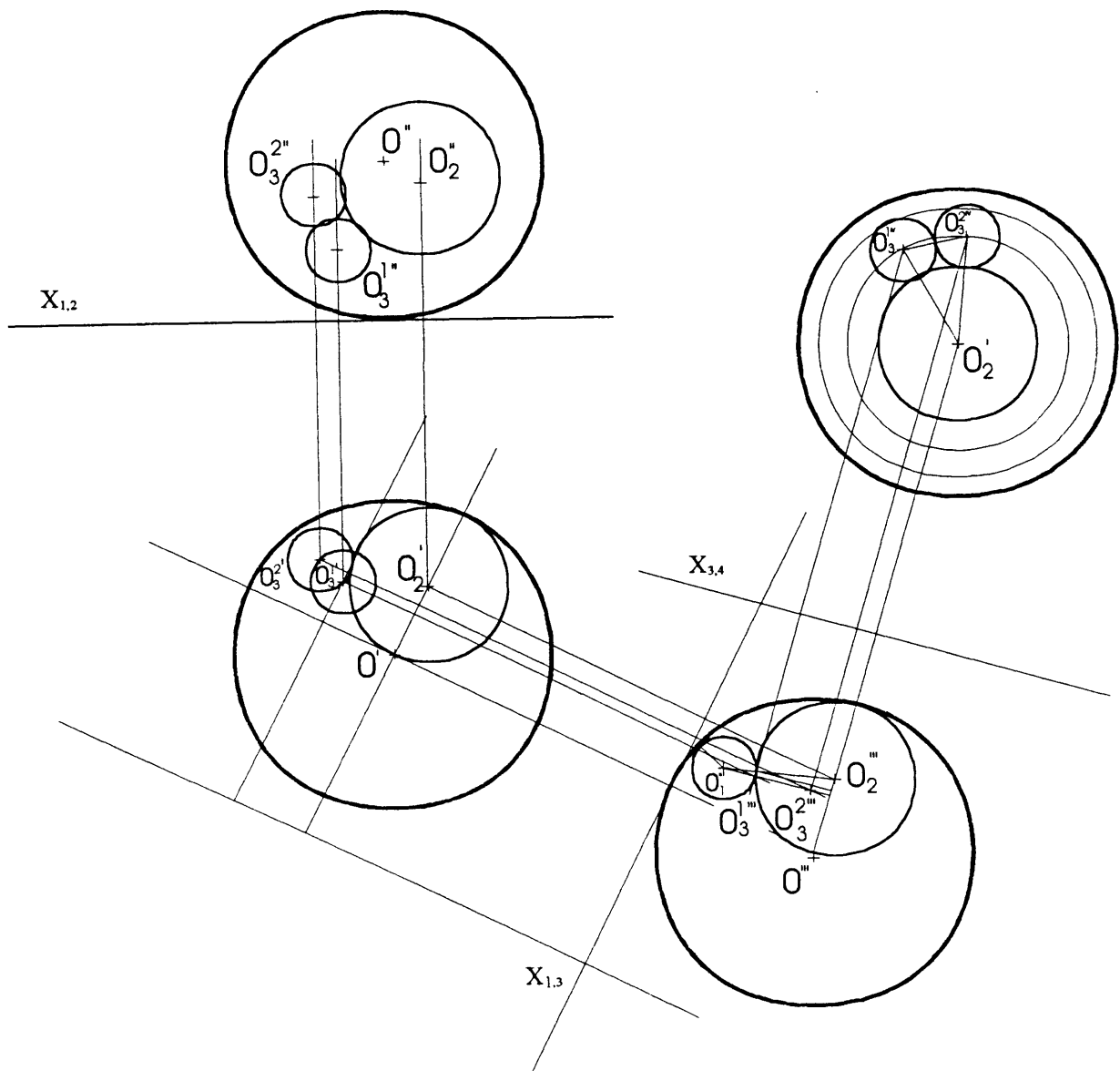


Fig.3 Four mutually tangent spheres problem solved with help of descriptive geometry methods

### 3.2 Pro/Engineer Tool Application

The same example has been taken into account to make presentation of a powerful design tool, namely Pro/Engineer. Pro/Engineer is a premier, feature-based, parametric modeling package from the Parametric Technology Corporation. The software tool is designed to automate the mechanical development of a product from a conceptual design through production. The package includes the following modules: PT/Modeler (design development software), PT/Render (rendering capabilities under Windows NT system), PT/Library (parts, nuts, screws, bolts, brackets) and PT/Computer Based Training (HTML). Highly sophisticated and a powerful tool for a designing process is very demanding from an engineer. It requires plenty of hours to seize general idea how to facilitate the program itself. For the presentation purpose the author tried to solve above given problem. First problem occurs when one wants to create a shelled sphere. Pro/Engineer has a very specific modeling system diametrically different from that the other Computer Aided Modeling/Manufacturing systems have. First you design a part which consists of features, then you make an assemble

of several parts, later you are able to do the billing of materials, to do rendering and finally perform manufacturing if there is a Windows NT system installed on your computer. The former users of such design packages as AutoCAD notice to their surprise that Pro/Engineer system has entirely different system of a solid model creation. There are no explicitly available Boolean operations of addition, subtraction or interference. The user needs to get used to a new philosophy of a software. This philosophy is described in the following.

A part is described by a sequence of features. These features may be: an extruded protrusion, a chamfer feature that bevels the edge, a hole, a cut and many others. Features are ordered in a construction list. Parts are built one feature at a time, starting with the base feature. All other features are *based* on this base feature. In other words the base feature is parent to all other features. Move the base feature, and all other features move with it. As a result, selection of the base feature is an important step in a model building process. The first feature should be a set of datum planes as it provides an absolute reference for the rest of the part. Second, the base feature should probably be the largest feature of the part or assembly. In Fig.4 we have an example of a shelled sphere with assigned datum reference planes shown. This is only the first step to create the base feature. Then we will need to make an assembly of this sphere with smaller spheres. The way of sphere's creation is also diametrically different from the methodology used in other CAD packages. First we create a closed section of a revolved surface, then we regenerate a section, next we perform revolution and finally we apply the shell operation. Once we have the task completed we need to proceed to assembly creation.

An assembly is a collection of parts, built one part (component) at a time. As you bring a component into an assembly, it is necessary to orient the new component with respect to the assembly. There are six degrees of freedom that fully constrain a tree-dimensional object in a three-dimensional space. The first three degrees of freedom describe the translation in the assembly coordinate system. The later three are the angular components, commonly called pitch, roll and yaw, indicating rotation about the assembly axes.

A parametric design means that we provide locating and sizing dimensions to all features in the part. These dimensions are parameters that control the feature. The features are parameter-driven. Parameters can be either assigned fixed values or they can be calculated from another parameters. There are two basic types of features: some involve geometry and others only references. An example for reference feature is a datum plane that is used to reference a connecting element to a base element.

Pro/Engineer provides also tools to view a model in three-dimensional space, to do shading, to perform typical for CAD packages activities such as: zoom, color and material assignment, layers creation. Drawing files (\*.drw) can be produced based on the three-dimensional model Drawings provide a set of views including projection, sectioned and detailed views.

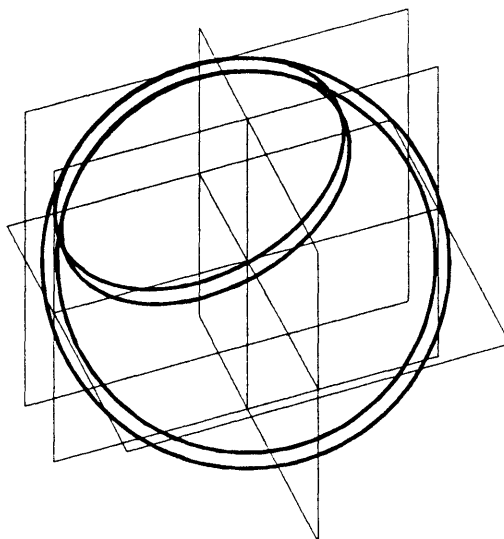


Fig.4. An example of a shelled sphere creation in Pro/Engineer

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#### A b s t r a c t

The author provides an overview of different methods applied by engineers to solve certain design problems. Manual and CAM methods have been introduced based on a problem of mutually tangent spheres. Pro/Engineering tool and its features have been described in the paper. Visual science theory introduced by G. Bertoline [2] has been investigated in context of both linguistics problems of the term translation into Polish language and in context of descriptive geometry and engineering graphics different courses contents. The advantage of a new discipline of visual science recognition, an "interdisciplinary" science between engineering and arts is that it has an advantage of integrating vast area of scientific research in different areas.

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