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BETWEEN DESCRIPTIVE GEOMETRY AND CAD 3D

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Abstract. Descriptive geometry (DG) provides methods to analyse three-dimensional space through two-dimensional drawings and prepares to create technical documentation. Geometric form of an engineering project is presented by the means of projection methods based on a 3D model, which is present in designer's imagination. The forthcoming era of Building Information Modelling (BIM) brings changes in the way the engineer works, as the vision is translated directly from the designer's mind into a digital model. The main tasks concern creation of the model and the two-dimensional documentation is obtained automatically. Currently during the first semester of study, every engineering student participates in a descriptive geometry module, adjusted to the specific requirements of the given course. 3D modelling programs are introduced throughout the course of study. In both cases the academic aim is to develop competency in effective operation in space. Therefore, it is worth investigating which skills acquired through the descriptive geometry education can be applied in the initial stage of 3D modelling. The paper attempts to develop an introduction to 3D modelling which takes into consideration skills acquired from the previous experience in descriptive geometry with a reference to the issues of modelling. The aim is not to present topics from descriptive geometry in the digital environment but to apply its knowledge in modelling and creating of 2D documentation in practice. When constructing the content of such an introduction, it is necessary to select previously learned constructions and algorithms, but also do not limit the creative approach. At the same time it is difficult to ignore the fact that many of the key issues for descriptive geometry in a digital environment can be achieved with one click. The formulation of the problem should therefore include options for available solutions in selected software. The paper presents some tasks for building solids, creating tangent surface, setting defined views and many more.

Keywords: descriptive geometry, 3D modelling, graphics education, BIM

1 Impact of BIM on engineering education

BIM is a very broad term that describes the process of creating and managing digital information about buildings in their lifecycle. This comprehensive approach is expressed in a definition formulated by buildingSMART alliance which sequentially refers to all aspects of design, construction and operation of the building ([2, 3, 5]) (Table 1).

Table 1: BIM definition. 3D Model is a medium for collecting and transferring data [3]

Components	Progressive BIM definition	The role of a 3D model - examples
Information about the model	Record of a digital 3D model	Record of geometric form, visual assessment of a project at early stage, database, detection of collisions, visualisation at different stages, mean of collaboration within the project team, mean of information exchange
Information about modelling	The creative process of modeling from design to function, detailing on each stage	
Information about management	Organization and control of investment processes	

BIM process is complex and involves all parties from architect, structural and MEP engineers, contractors to owners etc. It consists of a technological base and also the layers of social components such as synchronous collaboration, coordinated work practices and

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institutional and cultural framework. In the initial stages a 3D model appears, and then various data is added to its different parts; a 3D model is the axis of the whole process, it is used for cooperation and communication.

These processes require teams to work in a variety of digital environments, the project delivery team collaborate through Common Data Environment (CDE). Technological advances in production and information flow are reflected in BIM maturity stages (Table 2). Currently Level 2 BIM in the industry and education is standard in many countries.

Table 2: Maturity levels of BIM, reflecting technological advancement [5]

Level	Feature	Content	Application in practice
Level 1 BIM	Object-based modelling	- 2D drawings and/or a 3D object-oriented model with basic data attached - seamless visualisation - asynchronous communication	- transition from hand drawing and CAD to BIM
Level 2 BIM	Model-based collaboration	- a managed 3D environment created from separate discipline models - information share and exchange, 4D 5D - clash detection between disciplines - asynchronous communication	- currently Level 2 BIM in the industry and education is standard in many countries
Level 3 BIM	Network-based integration	- a single, integrated, online n-model - complex analysis at early stages: sustainability, constructability, costing, lifecycle - streamlined lean process - synchronise communication - multi-server process for communication	- the new technology providing Unified Modelling Language tools is going to be implemented from 2021 to 2025

Due to its advantages, BIM becomes essential in modern design processes. Universities worldwide include BIM in their curriculum in order to transform students into a BIM-ready graduates who can be competitive on the labour market as they better integrate visualizations and data into their projects. Including BIM content into engineering education can cause restructuring the existing curriculum as BIM is not just an ordinary subject which is to be added to the current curricula. It is a very complex methodology deeply rooted in the advanced technology concepts which requires changes in teaching, especially in terms of collaborative work, integration and coordination methods [1,4]. For these reasons, considering how in the early semester these processes can be supported, the borders among geometry, technology and collaborative work were investigated from the didactic perspective (Fig. 1).

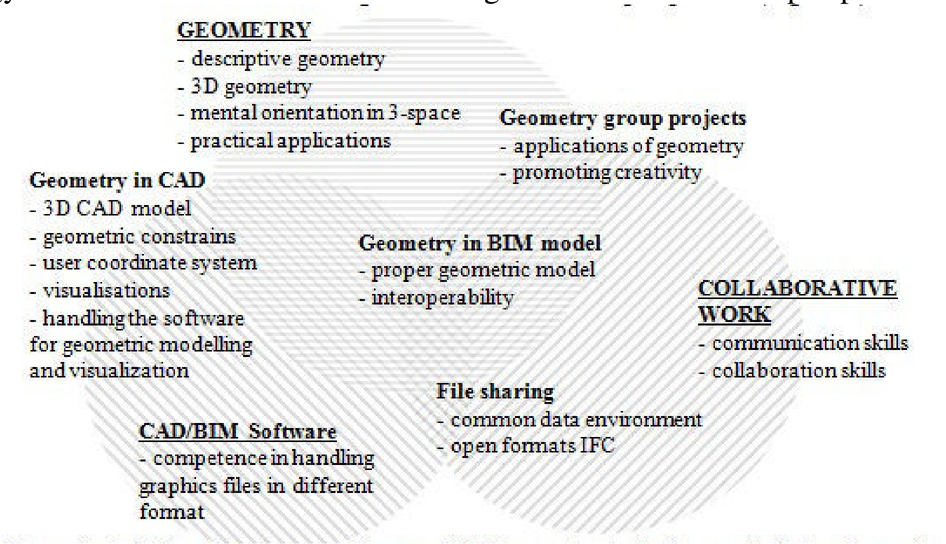

Figure 1: The analysis of three overlapping essential areas of BIM: geometry, technology and collaborative work

In the overlapping areas new fields arise for instant implementation in current education: geometry in CAD, CAD in geometry and group projects for descriptive geometry. It seems that integrating mentioned areas may result in smoother preparation for BIM at later semesters.

2 The descriptive geometry content in CAD education

Academic subjects of descriptive geometry and CAD should support skills of constructing proper 3D models. In both cases the academic aim is to develop competency in effective operation is space. Although the aim is to be obtained with different means, it refers to the same intellectual operations related to the perception of space (Table 3).

Table 3: Comparison of aspects of the task performed in the descriptive geometry and CAD

Task Aspect	Descriptive Geometry	CAD 3D
Task objectives	- creating projection views - intersection line, cross-section - building solids/surfaces	- 3D form modelling - getting 2D view documentation - visualization
Workspace	- 2D plane of the drawing - lines, circles, curves	- 3D virtual space - draw, modify applications
Building spatial forms/	- multi-step action - additional construction planes - transformation - rotation - scaling	- often single-click mouse operation - work plane (UCS) - modelling command - solid edit commands - a model without scaling
Intersection, cross-section	- multi-step operation - additional construction planes - transformation on the drawing plane - rotation of the plane	- single-click mouse operation - Boolean Operation; unite, subtract, intersect - intersection - slice command
Views/Visualisation	- constructing orthogonal, axonometric or perspective views	- automatic switching to perspective, orthogonal, axonometric views – Layout, model base

Comparison of task aspects in descriptive geometry and CAD show that:

- the main operations in DG are transformation and rotation, whereas in CAD they are rotation and dynamic UCS,
- the main DG objectives as intersection line and cross-section are available in CAD as a single click operation,
- the main action in DG is creation 2D from 3D imaginary object, whereas in CAD it is the reverse action – building 3D often given 2D views,
- spatial visualization is needed in both DG and CAD.

Many developed constructions in descriptive geometry course are just a single-click mouse operation (e.g. in AutoCAD belonging to a plane, natural size of polygons, distance between points, intersection line, cross-section can be obtained immediately). Therefore the task should be formulated so that multi-step operation would be needed to find the solution of geometric issues. It seems that such issues might be building 3D model from 2D views, creating solids based on spatial relations such as tangency, rotation, alignment, etc.

3 Examples of tasks in AutoCAD

The group of tasks where creating 3D models based on 2D drawing of orthogonal or axonometric projection views was proposed (Fig. 2, Fig. 3). The bases and the polyhedral should be properly rebuild, while the intersection line is automatically obtained.

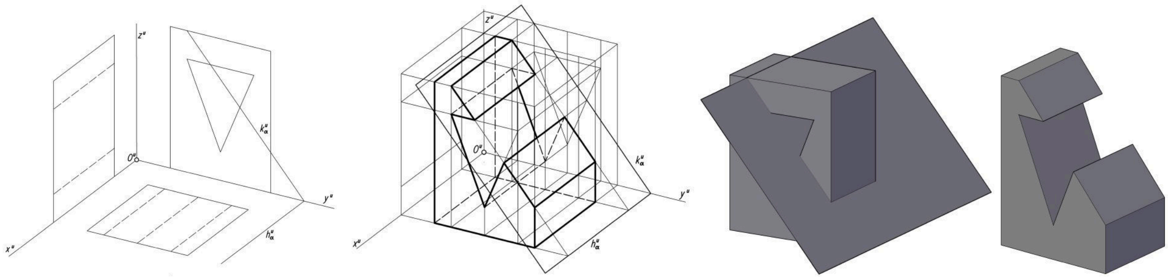

Figure 2: Reconstruction of a polyhedron and an intersecting plane. The intersection is obtained by the slice command (AutoCAD 2017)

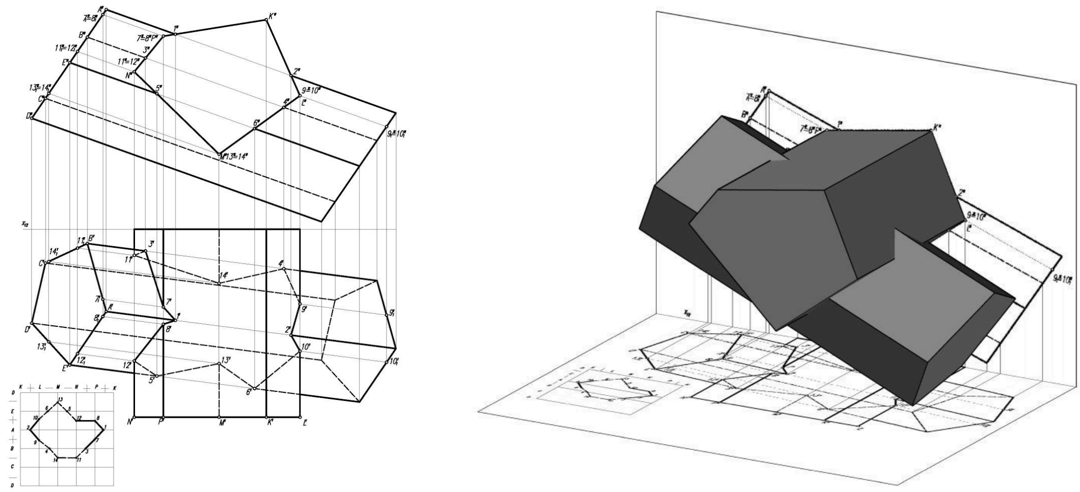

Figure 3: Reconstruction of two polyhedrons given their projection views; intersection appears as an automatic result (AutoCAD 2017)

Another group may be tasks involving tangency: determine a plane tangent to a given solid (Fig. 4), or move one solid, that it would be tangent to the other one (Fig. 5).

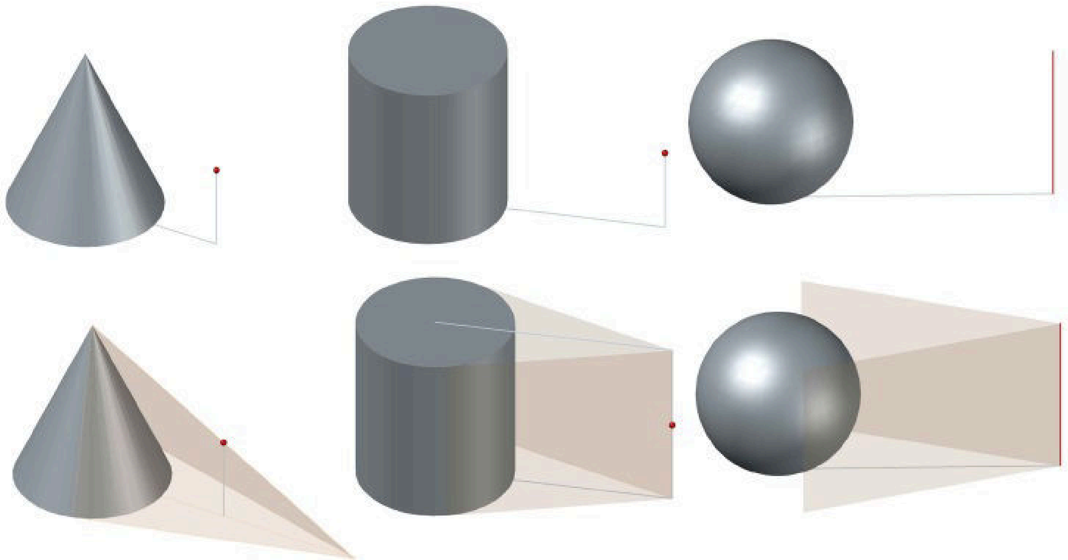

Figure 4: Creating planes tangent to given solids passing through a point or a line (AutoCAD 2017)

In another task it was necessary to set the positions of the octahedron in the model space, that the views obtained through automatic creation of documentation in the paper space would be the same as required (Fig. 6). The octahedron should be repeatedly rotated in various ways.

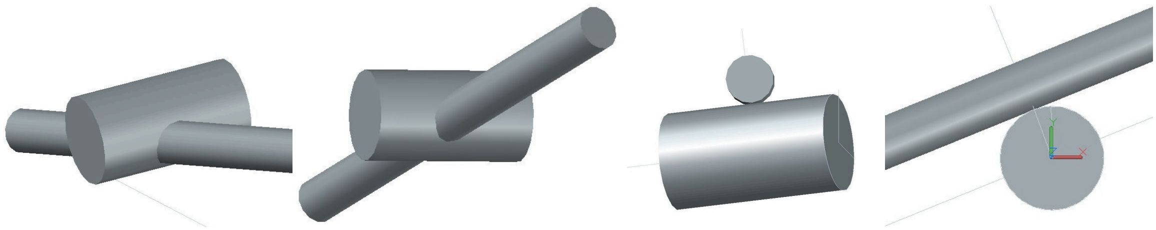

Figure 5: Moving the cylinder to the position tangent to the second cylinder (AutoCAD 2017)

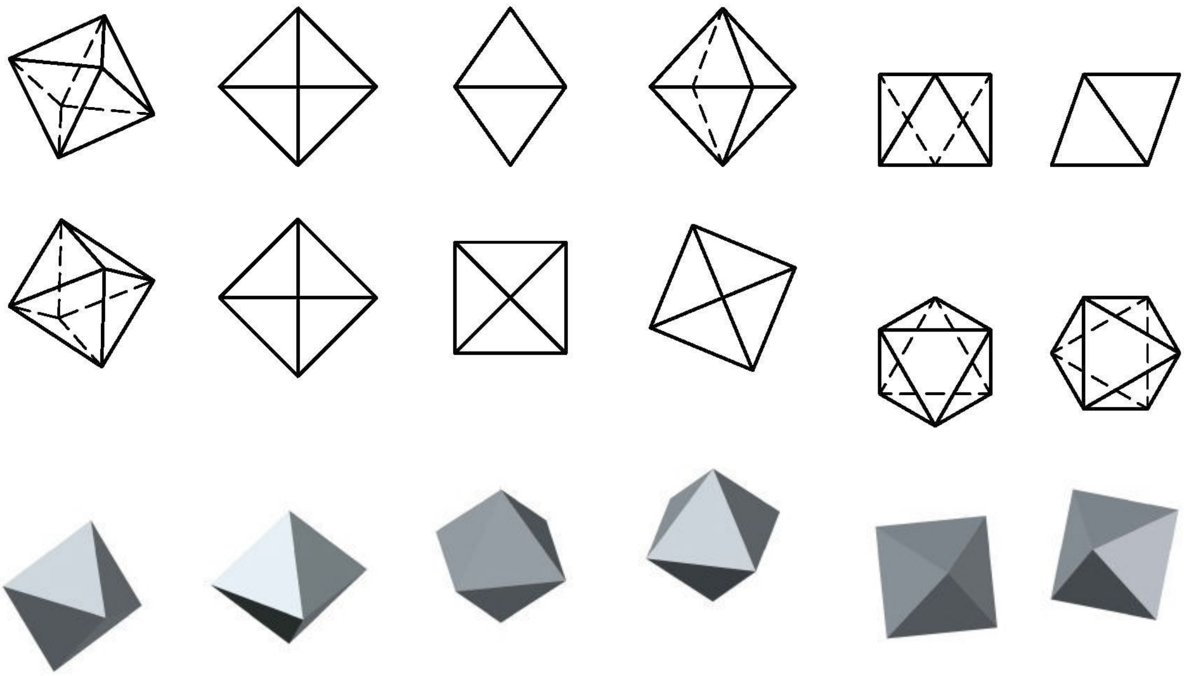

Figure 6: Obtaining predefined views of the octahedron by using Base Views command (AutoCAD 2017)

4 Conclusions

BIM changes engineer’s work and soon it will become a standard in education; for Civil Engineering Faculty teaching CAD as two-dimensional drawings is already insufficient. As BIM increases the importance of modelling, the education of descriptive geometry and CAD needs to be adjusted. At the current stage, it seems that the value enhancing modelling is to find a connection between DG and technology - the geometry course can be supplemented with CAD, and CAD course should include elements of descriptive geometry. From the presented analysis, it is apparent that the essential skills for CAD course which are taught in DG are: creating 2D views from 3D model and vice versa, rotation-UCS, spatial relations. The introduction to 3D modelling can relate to those skills which should not be available automatically. The BIM workflow requires cooperation; therefore, the geometry curriculum should introduce group projects which would also relate to practical issues.

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POMIĘDZY GEOMETRIĄ WYKREŚLNĄ A CAD 3D

Przedmiot geometria wykreślna dostarcza metod do działania w przestrzeni trójwymiarowej poprzez dwuwymiarowe rysunki i przygotowuje do tworzenia rysunków technicznych. Nadchodząca era technologii BIM przynosi zmiany procesu zapisu formy przestrzennej projektu. Wizja projektowanego obiektu wprost z umysłu projektanta przenosi się na model 3D powstający w środowisku cyfrowym. Główne działania projektanta dotyczą więc bezpośrednio tworzenia modelu; dokumentacja 2D jest uzyskiwana w sposób automatyczny.

Obecnie studenci kierunków inżynierskich poznają geometrię wykreślną dostosowaną do specjalności, jednocześnie w toku studiów poznają także programy do modelowania obiektów 3D. W obu przypadkach celem edukacyjnym jest wykształcenie kompetencji do skutecznego działania w przestrzeni. Chociaż cel ten jest uzyskiwany za pomocą różnych środków, to jednak dotyczy tych samych operacji umysłowych. W artykule podjęto próbę przedstawienia takiego wprowadzenia do modelowania, które uwzględniałoby zdobyte wcześniej doświadczenie z geometrii wykreślnej. W tym podejściu działania wykonywane są bezpośrednio na modelu, operacje takie jak obroty czy transformacje można obserwować tylko w momencie ich tworzenia, a później ślad po nich znika. Konstruując treści takiego wprowadzenia należy więc dobierać zadania które generują geometryczne myślenie oraz przywołują poznane wcześniej konstrukcje i algorytmy. Nie sposób także zignorować faktu, że wiele problemów kluczowych dla geometrii wykreślnej, w środowisku cyfrowym można rozwiązać jednym kliknięciem, bez żadnych konstrukcji; przykładowo dotyczy to zagadnienia przekrojów czy przenikania. Trzeba zatem formułować takie zadania, których nie można uzyskać automatycznie, i których rozwiązanie wymaga utworzenia pewnej strategii konstrukcyjnej.