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# AUTOCAD ASSISTED TEACHING OF DESCRIPTIVE GEOMETRY AND ENGINEERING GRAPHICS

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**Abstract.** This article will discuss Teaching of the subject Descriptive Geometry and Engineering Graphics in AutoCAD within the framework of laboratory classes The aim of the classes is to learn the methods applied for representation of the three dimensional (3-D) space on the picture plane as well as mastering the ability of creating engineering drawings in the AutoCAD software. To intensify the teaching process a series of tutorials has been developed and uploaded to the Moodle platform and made available on the Internet. It has been emphasized that the introduction of the ICT and multimedia technologies into a teaching process requires not only a careful selection of the visual aids but also careful examination of the problems encountered in didactics.

**Keywords:** descriptive geometry, tutorials, AutoCAD, e-courses

## 1 Introduction

The increasing importance of information technologies in the everyday world and in education makes the question of teaching descriptive geometry with the use of computer software an urgent one [16]. Descriptive geometry has been described in numerous textbooks and among these the following three main streams can be distinguished: books focused on the general aspects of the geometry, books explaining the descriptive geometry with the use of examples and course books with basic knowledge of the geometry and plus a large number of exercises to be solved. As far as the literature in Polish is concerned the first group is represented by Karol Bartel's *Geometria wykreślna* (*Descriptive Geometry*) [2] and course books of Zbigniew Pałasiński *Zasady odwzorowań utworów przestrzennych na płaszczyźnie rysunku* (*The Rules of the Rreproduction of Spatial Aarrangements on the Plane*) vol. 1 and 2 [14,15]. A number of publications can be assigned to the second group, *i.a.* textbooks: *Geometria wykreślna* (*Descriptive Geometry*) by Andrzej Bieliński [3], *Geometria. Przegląd wybranych zagadnień dla uczniów i studentów* (*Geometry, an Overview of Selected Aspects for Students*) [4] and *Inżynierska geometria wykreślna, podstawy i zastosowanie* (*Descriptive Geometry in Engineering, Basics and Application*) [5] by Anna Błach, *13 wykładów z geometrii wykreślnej* (*13 Lectures in Descriptive Geometry*) [6] by Tomasz Bogaczyk and Teresa Romaszkiewicz – Białas, Bogusław Grochowski's *Geometria wykreślna z perspektywą stosowaną* (*Descriptive Geometry with Applied Perspective*) [7] and Wacław Mierzejewski's *Geometria wykreślna. Rzuty Monge'a* (*Descriptive Geometry.* Monge's *Projections*) [8]. To the last category belong the course books Andrzej Korynek, Jerzy Mroczkowski and Teresa Romaszkiewicz – Białas *Geometria wykreślna. Wybrane zagadnienia dla architektów* (*Descriptive Geometry. Selected Aspects for Architects*) [9] and Beata Vogt's *Podstawy rzutów Monge'a w zadaniach* (*The Basics of* Monge's *Projections in Exercises*) [21] and *Kula i bryły obrotowe w zadaniach* (*Sphere and Solids in Exercises*) [20].

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The basics of design in AutoCAD are described in the textbooks by Mirosław Babiuch AutoCAD 2012 i 2012 PL. Ćwiczenia praktyczne (AutoCAD 2012 and 2012 PL. Exercises) [1], Georg Omura Mastering AutoCAD 2010 and AutoCAD LT 2010 [13] and Andrzej Pikoń AutoCAD 2011 PL. Pierwsze kroki (AutoCAD 2011 PL. First steps) [17]. The teaching of descriptive geometry with the use of CAD software is presented in turn by Robert Mazur in Wirtualne metody nauczania w odniesieniu do przedmiotu techniki komputerowe w projektowaniu CAD (Virtual teaching methods in relation to the subject computer techniques in design) [11] as well as by Farid Nassery and Otmar Vogt in Techniki Komputerowe w Projektowaniu (Computer Techniques in Design) [13].

The majority of the authors present various aspects of descriptive geometry without referring them to the specifics of teaching of this subject with the use of CAD software. However, due to the nature of these applications, it is not possible to directly transpose the traditional teaching methods into them.

## 2 Objectives of the descriptive geometry course and the detailed program of the laboratory

The question of teaching 'Descriptive Geometry and Engineering Graphics in AutoCAD' within the framework of laboratory classes has been discussed in this article. The subject is taught at the Cracow University of Technology at the Faculty of Electrical and Computer Engineering during the first year of the 1st level studies within the specialty of electrical engineering, and it consists of 15 hours of lectures and 15 hours of laboratory classes within one semester.

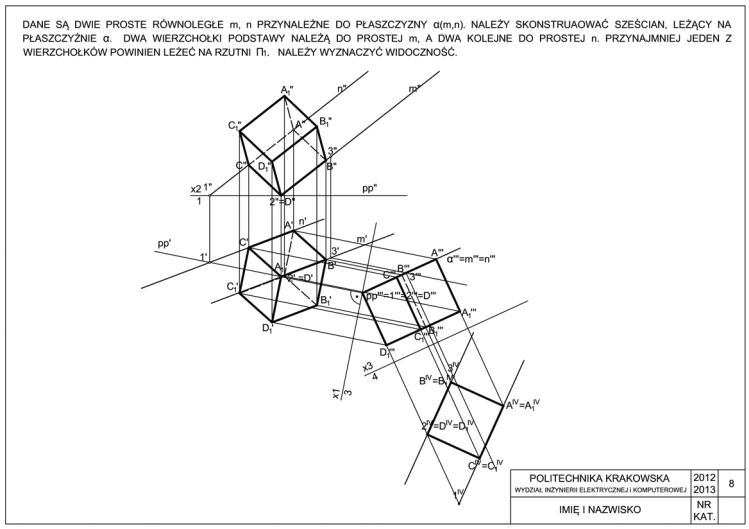


Figure 1: Example work from module 10 – Platonic solids in transformation

The main aim of the subject is to teach the students the methods used in engineering for representation of 3D objects on the two-dimensional (2-D) picture plane of a drawing, and to master skills of creating 2-D drawings and 3-D models in AutoCAD software (laboratory classes). The work, including presentations, is completed within the framework of 45 minute laboratory classes over 12 exercise modules. The exercises are divided into three main groups, namely: 1) exercises related to Monge's projection [21], 2) technical drawing problems and 3) computer aided 3-D modelling.

The first group of problems contains the following modules: Module 2 – examples of ambiguity of two views in Monge's projection, Module 3 - orthogonal projections of a 3-D solid (Fig. 2), Module 5 – an electro-technical detail, Module 6 – basic constructions in

Monge's projection, Module 8 – auxiliary views in Monge's projection, Module 10 – Platonic solids in practical exercises (Fig 1.), Module 11 – sphere and solids in exercises.

The second group of problems is related to the technical drawing: Module 2 – planometric projection, Module 4 – cavalier axonometries or orthogonal isometrics (Fig 2.), Module 7 – dimensioning in a mechanical drawing.

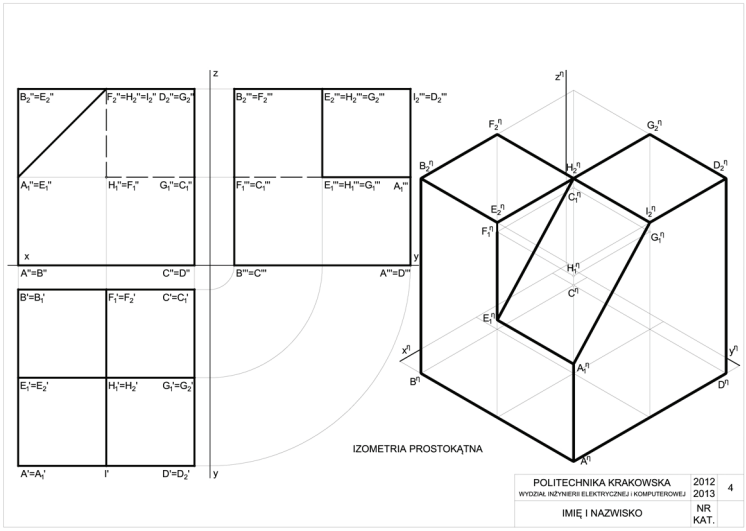


Figure 2: Example work from modules 3 and 4 – solid Monge's projections and axonometry

The last group of exercises focuses on 3-D modelling: Module 9 – a mechanical part in 3-D (Fig. 3) and Module 12 – interpenetration of solids and light analysis in AutoCAD (Fig. 5).

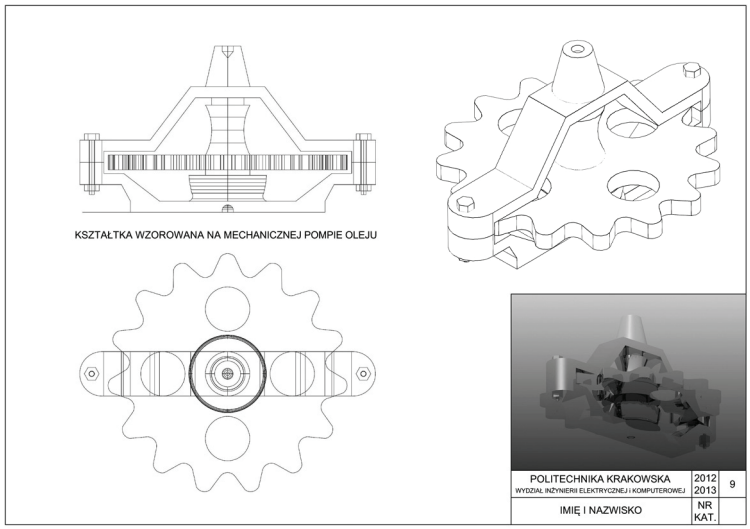


Figure 3: Example work from module 9 – a mechanical part in 3D

## 3 Didactical means and methods

All the modules described above not only teach students how to solve relevant problems but also help them to master AutoCAD commands [17] and introduce them to engineering graphics problems. The selection of subjects aims at extending the knowledge of descriptive geometry as well as of the AutoCAD software. The degree of complexity of problem solutions increases along with gaining the enhanced skills after completing each successive task.

As the exercises are prepared exclusively using the AutoCAD software, both their selection and assignment to students has to be adapted to the possibilities and limitations of the CAD software. All the tasks have been individually assigned to particular students. Variation of the data input usually depends either on the student's individual catalogue number or on his/her name (first name or last name, or both of them). To explain the data assignment to any student, let us say i.e., the student whose last name consists of four letters will be assigned to the problem number 4. In some cases the combination of the letters and the catalogue number was taken as a key assignment. Such procedure of works between particular students and enables them to do individual work. Three examples of various models used within the Modules: 3 and 4 have been presented in Figure 4.

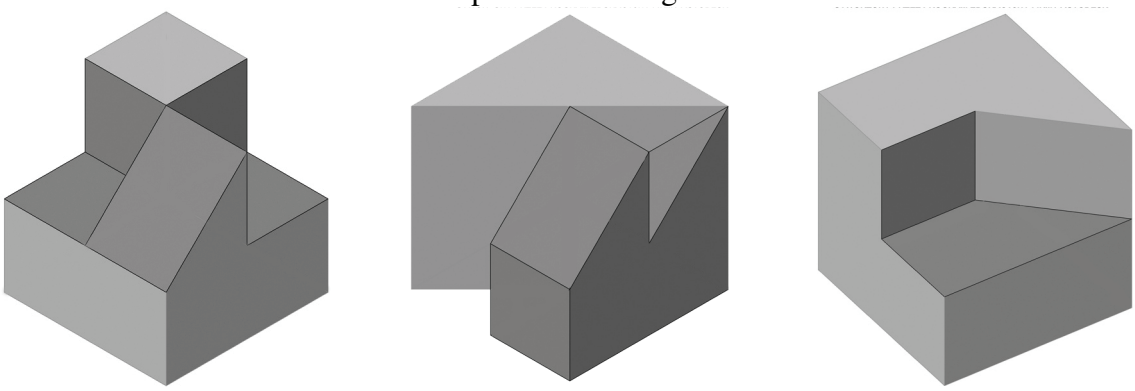

Figure 4: Example works from modules 3 and 4 – shape's Monge's projections and axonometry

It needs to be emphasized that, considering the limited number of laboratory classes, the problems have been developed in such a way that the students did not need to start the drawing from scratch, but they were rather supposed to finish it by using the selected elements, commands and skills. To give an example let us look at the task where the interior of a room has been represented in a 3-D space as three views of the horizontal, frontal and profile planes in a 3-D space (Fig.5a). Firstly two 3-D solids, a right hexagonal prism and a sphere, have been created based on their two views. Secondly, an interpenetration between a prism and a sphere has been executed with aid of AutoCAD command. Finally, the light source has been added and the light analysis has been performed in AutoCAD environment. Thus, the student's only task was to create a 3-D model of a houseroom with two elements of furniture and to analyse the room illumination (Fig. 5b).

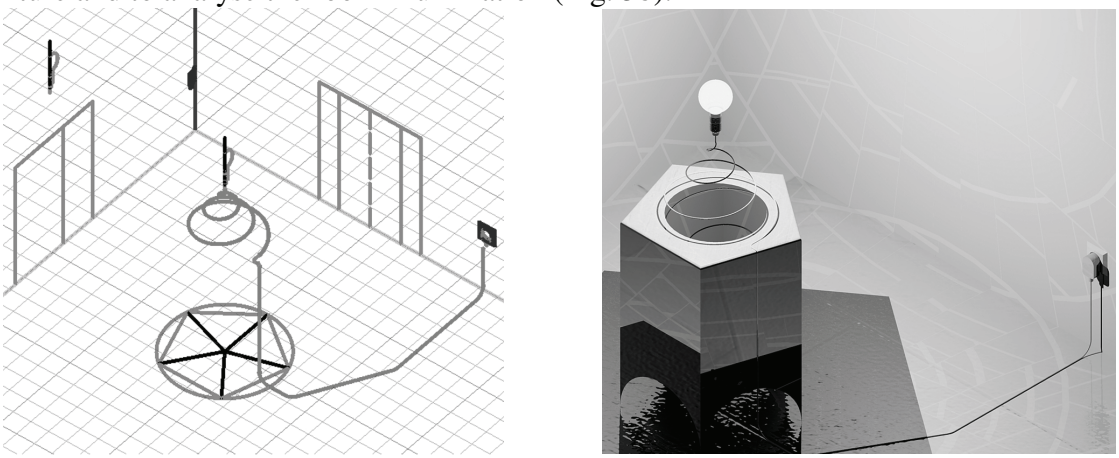

Figure 5: Example work from module 12 – interpenetration of solids and light – the subject and visualization
a) The horizontal, frontal and profile planes in a 3-D space
b) Model of a houseroom and to analyse the room illumination

Each problem assigned to the student very often becomes a base for subsequent work. To give an example we can take the task related to Platonic solids (Fig.1) for which the auxiliary view of a square positioned on a given plane is used as a base face of the later-to-be- constructed cube. For this reason the subsequent groups of problems are assigned in time intervals which allows the students to complete their own tasks.

The schedule and arrangement of the laboratory hours comprises the overall procedure needed for preparation of the technical documentation of the design project which is created within AutoCAD environment, starting from 2-D drawings to 3-D models creation, through 2-D layouts preparation and visual presentation.

Modern training aids [16] have been created and introduced into the laboratory classes thus creating new possibilities to facilitate the teaching and learning processes. A series of tutorials have been developed. They have the form of a sequence of slideshow in which commands and step-by step instructions how one element should be drawn are presented as graphical aids (Fig. 6). These instructional tutorials are making the mastering of AutoCAD software easier and present possible applications of the selected commands during the completion of the assigned tasks. Each of the tutorials has been developed as a Power Point presentation and made available in a pdf file format.


Figure 6: Building elements of slides used in the tutorials

The tutorials show how to complete a given exercise; however, they do not provide a ready solution as this could lead to a mechanical execution of the task without having understood it first. For this reason the tutorials have been elaborated for the modules related to axonometric projections, dimensioning and constructing 3D models in AutoCAD only. They have not been developed for the exercises related to Monge's projection. It has also been assumed that any reference to a previously presented command will only contain its name and basic parameters.

In order to achieve better learning outcomes an additional course in this subject has been made available in the Internet on the Moodle e-learning platform [18] and published at the Cracow University of Technology through e-learning website (www.elf2.pk.edu.pl - e-learning framework). This course has been created due to the fact that there are only a limited number of laboratory classes assigned to the subject.

The course has been divided into an introductory part, 12 laboratory modules and two presentation modules [11]. The subsequent modules present the relevant groups of the

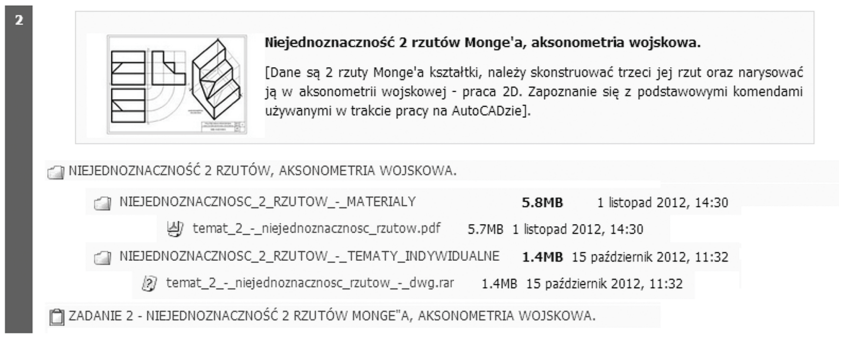


Figure 7: Example laboratory modules on the e-learning platform – the course: Geometry and Engineering Graphics in AutoCAD

laboratory classes. Each of them is accompanied by a short description of a problem, an icon related to the given subject (Fig. 7) and contains the following elements:

- didactical aids – laboratory classes tutorials,
- sets of individual, randomly assigned problems,
- option for electronic submission of individual tasks in the form of an electronic file.

The last two modules are a recapitulation of the entire course in the form of a presentation of all assigned projects and each student is expected to produce a poster as a presentation of selected tasks that relate to 3-D modeling in AutoCAD. An important element of the e-learning course is a possibility to submit the assignment onto the platform which allows remote revision of the projects.

## 4 Summary

Thanks to such development of the scope of laboratory classes, students master more precisely basic skills related to the preparation of engineering projects with the use of the AutoCAD software. These didactical aids are not aimed at substituting the laboratory classes, instead they are focused on helping the students to rehearse the material, recall commands and their applications. They also help those who were absent from classes. Their introduction has made it possible to improve the quality of assignments and eliminate previously observed errors related to technical drawing. The schedule and topics of laboratory work has been accepted in accordance with the syllabus and qualifications they should have graduated from this course.

The application of the e-learning platform has enhanced the student-teacher interaction and gives the students an unlimited access to information resources related to the subject. In the academic year 2012/2013 an average grade for this subject was 4.5 (B), which may indicate that the newly-introduced solutions are efficient. Nevertheless, the introduction of multimedia and information technologies into the course still requires a careful design of the course structure and visual aids, as well as careful approach to the selection of topics.

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[21] *Rozporządzenie* Ministra Nauki i Szkolnictwa Wyższego z dnia 25.09.2007 *w sprawie warunków, jakie muszą być spełnione, aby zajęcia dydaktyczne na studiach mogły być prowadzone z wykorzystaniem metod i technik kształcenia na odległość.*
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**Figures:**
Author's own illustrations: 1-7.

# NAUCZANIE GEOMETRII WYKREŚLNEJ I GRAFIKI INŻYNIERSKIEJ WSPOMAGANE APLIKACJĄ AUTOCAD

Artykuł prezentuje zagadnienie nauczania w ramach przedmiotu Geometria Wykreślna i Grafika Inżynierska w AutoCAD, w części obejmującej zajęcia laboratoryjne. Przedmiot prowadzony jest w wymiarze 15 godzin wykładów i 15 godzin laboratoryjnych na 1 roku

studiów stacjonarnych, I stopnia, kierunku Elektrotechnika na Wydziale Inżynierii Elektrycznej i Komputerowej Politechniki Krakowskiej im. T. Kościuszki. Celem zajęć jest poznanie metod odwzorowania przestrzeni trójwymiarowej na płaszczyźnie rysunku (wykłady) oraz opanowanie umiejętności tworzenia ich w programie AutoCAD do celów inżynierskich (laboratoria). W ramach cyklu 45 minutowych zajęć laboratoryjnych wykonywanych jest 12 ćwiczeń oraz ich prezentacja w programie PowerPoint. Ćwiczenia podzielono na trzy główne grupy: dotyczące klasycznie rozwiązywanych zadań rzutów Monge'a [21], rysunku technicznego oraz komputerowego modelowania trójwymiarowego. Kolejne zadania ćwiczą poszczególne zagadnienia, zarówno związane z opanowaniem poszczególnych komend AutoCADa [17], jak i z nauką rysunku inżynierskiego. Następujące po sobie zagadnienia rozbudowują wiedzę i pozwalają na utrwalanie zasad, zarówno z geometrii wykreślnej, jak i z obsługi programu AutoCAD. Stopień trudności rośnie wraz z umiejętnościami nabywanymi w kolejnych pracach. Efektem tak ułożonego harmonogramu laboratoriów (zgodnego z sylabusem i kwalifikacjami jakie powinien mieć absolwent tego kierunku) jest opanowanie podstawowych umiejętności z zakresu wykonywania projektów inżynierskich przy użyciu AutoCADa, poczynając od dokumentacji technicznej, poprzez model 3D, aż do prezentacji w formie wizualizacji [1]. Artykuł prezentuje dobór ćwiczeń, a także sposób ich zadawania, który został przystosowany do możliwości i ograniczeń, związanych z pracą w AutoCADzie. Wszystkie tematy zostały zindywidualizowane poprzez wprowadzenie zmiennych zależnych od numeru albumu, imienia, nazwiska lub ich kombinacji, co pozwoliło zapobiec kopiowaniu prac.

W ramach zajęć laboratoryjnych wprowadzono różne współczesne środki dydaktyczne [16], stwarzające nowe możliwości wspomagania nauczania. Opracowano serię samouczków mających formę ciągu slajdów prezentujących wprowadzane komendy i sposoby rysowania w postaci opisu kolejnych faz wykonania zadania oraz ich graficznej prezentacji. Pokazują one sposób wykonania ćwiczenia, lecz nie prezentują gotowego rozwiązania, ponieważ mogłoby to spowodować mechaniczne wykonanie zadania. Z tego też powodu przygotowano samouczki wyłącznie do modułów dotyczących aksonometrii, wymiarowania i budowy obiektów 3D w AutoCADzie, pomijając rozwiązania zadań z rzutów Monge'a.

W celu intensyfikacji efektów kształcenia, , wprowadzono dodatkowo wspomagający kurs z tego przedmiotu w intrenecie. Został on opracowany w oparciu o platformę Moodle [18] i zamieszczony na stronie e-nauczania Politechniki Krakowskiej – ELF (www.elf2.pk.edu.pl e-learning framework). Artykuł prezentuje również możliwości zastosowania platformy Moodle do wspomagania nauczania. Kurs podzielono na: informacje wstępne, 12 modułów laboratoryjnych i 2 moduły prezentacji. Wykorzystanie platformy e-learningowej pozwoliło na wzmocnienie interakcji pomiędzy prowadzącym zajęcia, a studentami. Przedstawiono także architekturę kursu oraz zwrócono uwagę na nieograniczone ramami czasowymi, korzystanie z zasobów informacji, związanych z zagadnieniami z tego przedmiotu. Wykorzystanie nowoczesnych metod wizualnych wspomagających nauczanie przedmiotów inżynierskich może, jak w zaprezentowanym przypadku, podwyższyć efektywność procesu dydaktycznego, o czym świadczą wyniki uzyskane przez studentów w roku akademickim 2012/2013. Wprowadzenie technologii multimedialnych i informatycznych wymaga jednak dokładnego zaprojektowania, zarówno samych pomocy wizualnych jak i szczególnej uwagi przy wyborze tematów.