TECHNICAL TRANSACTIONS

CZASOPISMO TECHNICZNE

ARCHITECTURE

ARCHITEKTURA

ISSUE 11-A (22)

ZESZYT 11-A (22)

YEAR 2015 (112)

ROK 2015 (112)

WYDAWNICTWO POLITECHNIKI KRAKOWSKIEJ

TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE

ARCHITECTURE | ARCHITEKTURA

ISSUE 11-A (22) | ZESZYT 11-A (22)
YEAR 2015 (112) | ROK 2015 (112)

Basic version of each Technical Transactions magazine is its online version
Pierwotną wersją każdego zeszytu Czasopisma Technicznego jest jego wersja online
www.ejournals.eu/Czasopismo-Techniczne www.technicaltransactions.com www.czasopismotechniczne.pl

Architecture Series
11-A/2015

TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ARCHITECTURE | ARCHITEKTURA
11-A/2015

SZYMON FILIPOWSKI*

PAINTING AN ELEVATION BY LIGHT

ELEWACJA MALOWANA ŚWIATŁEM

A b s t r a c t

Night illuminations of historical architectural objects have been discussed. In order to simulate light effects on the existing object of the Royal Palace in Łobzów, renderings with a defined illumination were made. The author proves that illumination is not only a matter of engineering, but also an art. The possibility to influence the reception of architecture through illumination and the possibilities to simulate illuminations using computer software are investigated. It tries to answer the question whether the method of work, which requires utilization of precise data, deprives the designer of artistry.

Keywords: illumination, light, historical architecture, rendering

S t r e s z c z e n i e

Niniejszy artykuł porusza tematykę nocnej iluminacji architektury zabytkowej. W celu zasymulowania światła na istniejącym obiekcie Pałacu Królewskiego w Łobzowie wykonano wizualizacje komputerowe z przypisanym oświetleniem. Autor wykazuje, że poza przyjętą i praktykowaną często jedynie stroną inżynierską iluminacja to też dziedzina sztuki. Praca ma na celu zbadanie możliwości wpływania poprzez oświetlenie na odbiór architektury oraz możliwości symulowania oświetlenia za pomocą programów komputerowych. Próbuje też odpowiedzieć na pytanie, czy metoda pracy polegająca na wprowadzaniu ścisłych danych pozbawia w tej kwestii projektanta artyzmu.

Słowa kluczowe: iluminacja, światło, zabytkowa architektura, rendering

* M.Sc. Arch. Szymon Filipowski, Division of Descriptive Geometry, Technical Drawing & Engineering Graphics, Faculty of Architecture, Cracow University of Technology; sfilipowski@pk.edu.pl.

1. Aims of illumination, aims of the work

The work is initiated by a thesis classifying illumination as an artwork. This assumption is supported in the further portion of the paper by showing how illumination influences the spectator and how it is created. The Polish dictionary defines art as "…artistic creativity, which manifests itself through works of literature, music, painting, architecture, sculpture etc. that meet the requirements of beauty, harmony, aesthetics and stimulate reflection" [1, p. 997]. During the interpretation of illumination, its feature common with architecture was considered, where "The art is the ability to shape and organize space in real forms in order to fulfill material and spiritual needs of the man; it is also a reflection of social and economical needs of the man's environment, as well as of forms of organized life" [2, p. 12]. The same assumptions, as in, architecture, find application in illumination with a difference that illumination is based on an existing object, where it emphasizes or creates a picture being received by a spectator. Wojciech Żagan specifies the following goals for an illumination "…an increased attractiveness of the object, delivery of a different view, emphasized details, creation of a romantic and mysterious atmosphere around the building, stimulation of the spectator's imagination, improvement of the appearance of cities, districts and streets in the evening and the night, drawing attention to select objects, extends the opening hours of an object by attracting tourists and customers, improved security of the object and its surroundings, an advertisement of the company which has its headquarters in the illuminated building" [3, p. 26]. The work discusses the subject of planning of the overnight illuminations, nevertheless, it is worth mentioning that a majority of existing objects is illuminated, even if only randomly by street lamps or illuminations of other objects [3]. Even though illumination focuses on the building being a subject of an illumination project, its interaction with the surroundings is very important. It is a strictly physical aspect on one end, the dissipation of light in the direct vicinity of its source, and on the other an aesthetical aspect, creation of an image of a larger area – a city or a district and objects in this area. Alojzy Śpik discusses the importance of the context of a building being illuminated: "The matters of illumination of historical and other buildings cannot be treated as a problem separated from street illumination, advertising and neon lights. These relevant types of illumination intersect and supplement themselves, or may in case of incorrect design solutions interfere with each other" [4, p. 27]. In the textbook *The Illumination of Objects* by Wojciech Żagan, a wholesome approach to the illumination of cities is described, with a particular emphasis put on the selection of the object for illumination and the decision process behind deciding whether a given object shall be actually additionally illuminated "The selection of objects intended for illumination is a complex problem which has to be solved through development of a wholesome vision of illumination of a given city or its part, and within this framework a decision shall be made with regards the illumination of a given building" [3, p. 17].The utmost goal of illumination is according to Alojzy Śpik: "Through a properly designed illumination we can create an unforgettable aesthetic impression, we can escape for a short time into the world of beauty, poetry and reflection, detach from the harmful pace of nowadays life, revive long gone times" [4, p. 1].

2. Realizations

The discussion of illuminations would be out of touch with the reality if we were not to consider the conclusions coming from observations of existing realizations. Dominik Mączyński reveals the possible outcomes of the application of light effects [5]. He points out the perfectly designed and executed illumination of the cathedral in Reims: “Contrary to the Romanesque style, Gothic introduced in France an almost unusual invigoration of the so far massive walls, and through its soaring and light forms it created completely new relations between the space and shapes. The walls of Gothic cathedrals make an impression of being unusually light and transparent. This characteristic image of the Gothic architecture was successfully presented in the night view…” [5, p. 245]. As an example of an incorrectly designed illumination, Mączyński points out a tenement house on the Main Square in Krakow, where the sharp illumination neither reproduces the original architectural setting nor emphasizes the details, but in turn, it adds non-existing elements to the reception [5]. As positive examples, the Italian realizations of illuminations of historical buildings are referenced. In the case of the Coliseum in Rome, illumination from the inside, with cold flooding light was applied, resulting in a low illumination of the object. Thanks to the low number of used lights, the curve of the building was retained. The deep arched openings were illuminated with a warm light, which produces an impression of an ongoing spectacle taking place inside. The upper ring was illuminated with an intensive light. A similar approach was used in the case of the illumination of The Papal Basilica of St. Peter in Vatican. The baroque facade was delicately illuminated in its entirety, while a warm light was introduced into the niches with statues. The dome has intensely illuminated colonnades and delicately outlined curvature. These examples indicate that proper solutions are the ones which, through illumination, do not lose their own shape and the natural character of the illuminated object is retained during the night reception [5].

3. Tools

Illumination trials were carried out using a computer. Sketchup Pro7software with the photorealistic renderings add-on V-ray 1.48.89 was used. Having a 3D model available, the following become important: the positioning of the sources of the light, the calculation method, the materials of elements interacting with the light and cameras, as the software during its work reproduces the physics of the light. Each of these stages has an influence on the final effect – i.e. the generated image. Steering is achieved through the introduction or change of parameters in the settings window. The colour of the object has to be set as the actual colour seen in the white light. Before the lights can be “tried on”, one has to first create a physical camera which will enable a complete control of the exposition and frame and will also provide a reference between the generated images and photographs. The most time consuming stage, and also the one having the biggest influence on the final effect of the project, is the positioning of the lights. Aside to a global illumination, the following are available: floodlights for which one can choose such parameters as power, angle of the light beam, dissipation angle, colour of the light, softness of the shadow and parameters according to which the light is being calculated by the software. V-ray has also illuminators which can be uploaded from files in the IES format, spherical and flat lights as well as materials capable of emitting light. The majority of manufacturers of lamps and fixtures make IES files available which, after uploading into the software, provide a faithful simulation of the specific sources of light. One sets up the positioning and parameters, and next, trial renderings are made. In V-ray 2.0, one can observe the changes in real time, thanks to the function Real time rendering. Once the desired effect has been achieved, postproduction in the frame buffer window takes place. The program renders the elements of the picture into channels, the multiplier of which can be changed after the rendering is made. At each stage, the designer can decide on the colour, shape and what is presented. The original assumptions often get out of hand giving thus unexpected results. An important assumption in the designer's work is the selection of the view of the object that is most common to the spectators.

4. Trials

Illumination trails were executed for a facade – typically, the most observed portion of any given building. The work was initiated by a study of the current state of the building and whether there is a need for illumination. The building is lightly illuminated by street lamps situated at the ramp, it also has one spherical lamp over the main entrance and is surrounded by thick greenery, which causes that overall the object is not well exposed despite its considerable size. This indicates a need for an exposition of the building, for instance, with the use of light. At first, trials with flooding light illuminating the facade were made; however, architectural details and characteristic portions of the object were not shown in any way in this case. For this reason, trials with spot lights were undertaken, with the use of which all details were marked, the rhythm was underscored as well as important portions of the facade. This solution gave, however, an image differing from the original look of the object in the daylight – too strong was the articulation of the borderlines, and too the intensive contrasts were producing on the object non-existing forms – as a consequence, the overnight reception of the object was not natural. To obtain a complete simulation of the illumination effect, over the images of the illumination, photographs of the trees blocking the view of the facade were superimposed. The verdure blocking portions of the facade indicated the weak points of the spot illumination. Covering of certain strong elements [2] caused a loss of the rhythm and legibility of the composition. The image of the object illuminated globally was dominated by trees – this is a consequence of high contrast. This is not encountered on facades illuminated in this way. Considering the failure of the first two attempts, another trial was undertaken in order to mitigate the negative effects. The facade was illuminated globally with a relatively low illumination and details and side portals were brought into the picture by illuminating them with floodlights.

The number of operations required during each correction of the illumination is worth mentioning. While the execution of the corrections can be facilitated through the application of components in the Sketchup software, a change of the entire conception calls for a complete reorganization of the elements emitting the light. This indicates that an illumination shall be designed immediately in detail. This approach is however difficult to master and is, at the same time, contradicting the rule of going from a general view to the detail. A solution to this problem is treating a portion of the object's image which contains features present throughout the entire object as a general view. On this portion, the illumination concept is verified with a small number of lights, and hence, adjusting the sources, their positioning and parameters can be done easily. This approach was verified on a close-up of the facade encompassing the left wing with a side portal and decorative barriers of the terrace. Trials for a flooding illumination with adornments, emphasized with the use of a shadow, were carried out. Also, a variant with combined illumination was prepared where the floor of the balcony was illuminated, which through a differentiated illumination highlighted the multilayer nature. The next stage comprises a play with colour, which, if inconsiderate, can however lead to nowhere, a weak in effect showiness. The trail with colours suggested a thought that, if one can influence in the negative way, then it would be worth trying to create or recreate something valuable. The present form of the palace was created mostly during its 19th century reconstruction. An attempt to recreate the atmosphere of those days was undertaken on an image simulating the illumination of gas lamps with regards to their colour, intensity, and dissipation angles. The building remains, in this case, in a warm twilight, and in the background of the thick greenery, it might appear as a sanctuary of quietness. It is also worth illuminating the greenery from underneath, which removes its strong contrasts and includes it in the overall setting.

The aforementioned examples, even though do not attempt to list in an exhaustive way all the possibilities, indicate the multitude of solutions and the potential freedom during creation of images, determination of the overall setting and consideration of detail, as well as utilization of imagery. These features are characteristic to drawing and painting. The universality of the aesthetical solutions and the similarity of the reception by the man irrespectively of the region and the domain shall also be pointed out. Ray Evans presents methods for imagination of architectural objects which base not on photorealistic reproductions of the reality, but on outlining the most important facts for the spectator [6]. In this way, a symbolic image is created that is full of impressions, where only details are underscored, and a general outline of the form is drawn using broad knowledge on the object itself: "Can anyone Draw buildings without knowing something about their construction and history? I doubt it, any more than the human figure can be drawn without a knowledge of anatomy" [6, p. 7].

5. Conclusions

Creating a night image of an architectural object shall undoubtedly be a domain of art, with the same purposes as the ones of the drawing and painting. In this case, it is an art intended for the general public with basic assumptions based on a conscious manipulation of the impression, knowledge of the object, its history and meaning, as well as the needs of the man. This approach yields not only the attraction of the spectator's attention and a clear imaging of the architecture, but also the most important: i.e. creation or reconstruction of the atmosphere of the location. A computer serves merely as a tool, it rather aids the designer in calculations and determination of technical details and enables thus a realization which, in the end, gives an effect as close as possible to the conceived one.

References

[1] Sobol E., *Nowy słownik języka polskiego*, PWN, Warszawa 2002.

[2] Lenartowicz J.K., *Słownik psychologii architektury*, Wydawnictwo PK, Kraków 2010.

[3] Żagan W., *Iluminacja obiektów*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2003.

[4] Śpik A., *Iluminacja obiektów zabytkowych architektury*, Ośrodek Informacji PP Pracownie Konserwacji Zabytków, Warszawa 1976.

[5] Mączyński D., *Iluminacje zabytków − nowe trendy*, Czasopismo Techniczne, 2-B/2009, 243-247.

[6] Evans R., *Drawing and Painting Architecture*, Van Nostrand Reinhold Company Inc, New York 1983.

[7] Bartel K., *Perspektywa Malarska*, tom drugi, Państwowe Wydawnictwo Naukowe, Warszawa 1958.

[8] Żórawski J., *Siatka Prostych*, Wydawnictwo PK, Kraków 2012.

Ill. 1. Daylight visualization of the facade of Palace in Łobzów. Left hand side presents views taking into consideration the existing verdure (author's own design)

Ill. 2. Visualization of the facade illuminated with flooding light

Ill. 3. Visualization of the facade illuminated with spot lights

Ill. 4. Visualizations of the facade illuminated through a combined method

Ill. 5. Combined illumination solution on the left wing of the building

Ill. 6. A proposal for a gas lamp illumination presented on a portion of the facade

TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ARCHITECTURE | ARCHITEKTURA

11-A/2015

RENATA A. GÓRSKA*

GRAPHICACY CAPABILITY AS A FACTOR ENHANCING SUCCESS IN ENGINEERING DISCIPLINES

ROZPOZNAWANIE OBRAZÓW GRAFICZNYCH JAKO CZYNNIK DECYDUJĄCY O SUKCESIE W DYSCYPLINACH INŻYNIERSKICH

Abstract

The analysis of the "state of art" of the research work conducted in Poland and its relation to the foreign research results within the field of "graphicacy" in context of engineering education and gaining success in engineering disciplines is the aim of this work. The pilot study conducted in this respect concerns, in the first stage, the definition of these elements of engineering education which are crucial for graphical subjects to design syllabuses in order to achieve expected learning outcomes. A framework for graphicacy curricula development will be defined while taking into account the element of lifelong learning. In conclusion, the direction of the further research work will be formulated in order to enhance graphicacy capability among engineering students and within engineering studies.

Keywords: graphicacy research, visual literacy, spatial skills development, curriculum planning for engineering studies

Streszczenie

Praca dotyczy badań prowadzonych w zakresie dziedziny o nazwie *graphicacy* (ang.), czyli umiejętności rozpoznawania i rozumienia obrazów graficznych przez studiujących na kierunkach inżynierskich. Pilotażowe badania w przedmiotowym zakresie dotyczą w pierwszym etapie zdefiniowania tych elementów kształcenia w zakresie grafiki, które stanowią istotny czynnik w studiowaniu na tego typu kierunkach, a następnie planowania zawartości sylabusów dla przedmiotów graficznych w takim celu, by uzyskać spodziewane efekty kształcenia. Ostatecznie wskazane zostaną te elementy kształcenia, które mogą być wykorzystane w procesie tzw. kształcenia ustawicznego (ang. *lifelong learning*). W podsumowaniu wytyczono kierunek dalszych badań.

Słowa kluczowe: badania umiejętności rozpoznawania obrazów graficznych, rozpoznawanie obrazów wizualnych, kształcenie wyobraźni przestrzennej, sylabusy dla przedmiotów graficznych

* Ph.D. Eng. Renata A. Górska, Descriptive Geometry, Technical Drawing and Engineering Graphics Section, Faculty of Architecture, Cracow University of Technology; rgorska@pk.edu.pl.

1. Introduction

Research conducted in the field of perception and recognition of graphic images and their correct interpretation have been carried out by psychologists since many years [15]. Just as literacy, numeracy or articulacy play a very important role in the development process of each individual, graphicacy provides the students of engineering specialties the tool that is helpful for gaining success in their professional life as designers and practicing engineers [10, 11, 14]. Individual predisposition to understand and to be able to recognize, and to correctly interpret graphic images has become a major trait required from the future engineer. The theory of perception, image analysis, research on the signal detection and/or interpretation, recognition of the so-called optical illusions have always been the domain of developmental psychology [12]. It must be mentioned here that the Gestalt theory, developed by German scientists: Max Wertheimer, Wolfgang Kohler and Kurt Kofka, plays a crucial role in engineering design. To give an example, let us cite Żakowska [16] who applied some of the Gestalt laws of grouping into the theory of visualization in road design. These laws were: Law of proximity, Law of similarity, Law of closure, Law of common fate, Law of continuity, Law of good Gestalt, Law of Past Experience. Żakowska [16] explained how road perception influences road safety.

Systematic research on graphicacy will result in creating a framework for the subjects that belongs to a group which has been defined as the "visual science" in [3]. The term of "visual science" has never been introduced into the official classification list of research areas specified by the Polish Ministry of Science and Higher Education. The group of subjects within the graphics area at technical universities includes the following subjects: Descriptive Geometry, Computer Graphics, Fundamentals of Computer Aided Design, Technical Drawing, Design Visualization and Rendering, BIM Technology, Visualization in Construction and Road Design. While creating a framework for programs addressing the needs of engineering students it is extremely important to find a common denominator for the research, which is the development of the skills in recognition of graphic images. The subject has been known to researchers in many countries [2, 3, 5, 15] and is also known within the Polish environment [9, 16]. However, in Poland, the research field of the "graphicacy" area has been primarily recognized only by the psychologists.

The aim of this part of research starts with a systematic analysis of literature in the Polish and foreign environment. The research goals (RGs) for the analysis conducted here are as follows:

- to recognize the levels of awareness of the importance of visual literacy development in the frame of engineering studies (RG1),
- to develop relative curricula for the engineering subjects, including the factor of "visual science" (RG2),
- to recognize the possibility of taking a continuum approach in graphicacy development for lifelong learning (RG3).

In recent years, major changes have been introduced into the system of higher education in the common European Higher Education Area [7]. The National Qualifications Framework (NFQ) has assumed that the national curricula will develop and/or reconstruct the curricula by defining and taking into account the so called "learning outcomes". The development of curricula at engineering studies resulted in limitation of teaching hours assigned to particular subjects and to re-arrangement of the so-called "graphical" subjects into common modules.

When creating new programs for “graphical subjects” and their contents, the educators should take into account the element of a potential development of graphicacy capability. It is important that the future engineers should be able to correctly recognize graphic images, to interpret two-dimensional plans and views in a three-dimensional space, to be able to correctly orient the spatial objects and perform manipulation on the three-dimensional objects (e.g. rotation, mirror imaging). Thus, when planning on the content of the lectures at engineering studies, the educators must undertake a systematic and intentional action, which complies with the research results in the field of spatial perception and recognition of graphical images that have been conducted both in foreign countries by Danos and Norman [5, 6] as well as in Poland [9].

2. Graphicacy Research and Taxonomy

Visual literacy, i.e. graphicacy, has been recognized as an everyday life skill and has been identified as the factor playing a substantial role in engineering. Graphicacy, as a personal ability or skills to communicate through visual images, has become the point of interest of many educators around the world.

Bertoline [3], when defining a newly emerging discipline of “visual science”, argued that eighty per cent of our sensory input comes from the visual system. He stated: “There is a tremendous amount of information that is associated with producing good graphics. Colour theory, projection theory, cognitive visualization, and geometry are a few examples of what is needed to plan and to produce graphics. Graphics is used to communicate and store information, solve problems, and affect the senses”. He justifies using the term “visual science” instead of “graphic science” as the word “graphic”, by definition, is limited only to text and pictures, while the word “visual” encompasses not only these two elements, but it is also a broader term including anything that is seen or able to be seen by the eye. Illustration 1 shows a modified diagram of the fields of research that should be included in the discipline of a *visual science*. The original diagram was published by Bertoline in [3] while some new elements have been added by the author to complete the chart by taking into account more broader insight of visual science as graphicacy, the elements such as n-dimensional geometry or kinematic features. Illustration 2 presents the graphical elements included in graphicacy research after Aldrich and Sheppard [1] and examined by Danos and Norman [6].

Norman and Seery [11] have recognized the complex relationship between designing and modelling processes, where graphicacy plays the key role for representation of a design project (Illustration 3 after [11]). Danos and Norman [6] developed the new taxonomy for graphicacy, the taxonomy which was originally based on the Fry taxonomy [8] and which has been newly designed, completely remodelled, and updated from a cross-circular textbook analysis in order to become adequately tailored related to the requirements of graphicacy recognition and research. Illustration 4 presents all seven of the graphics categories (after [6]).

At engineering studies, it is important that the students present good levels in graphicacy capability and visualization skills. Numerous research works conducted at the turn of our age showed that many freshmen level students, who were just enrolled into engineering studies, presented low levels of these skills. Sorby and Górska [14] theorized and proved that the special graphics courses in 3-D visualization skills, which were developed for engineering undergraduate studies and addressed to the so called “low visualisers”, had a significant impact on the improvements of visualization/graphicacy skills. As a measure of these skills, various testing instruments have been used, among others, there was MRT (Mental Rotations Test), Purdue Spatial Visualization Test: Rotations, Mental Cutting Test and Differential Aptitude Test: Space Relations Tests. These tests have been administered to the students prior to and after the course. A special textbook on spatial visualization skills training that covered various methods of 3-D object representations on a 2-D picture plane and simultaneously trained the ability to recognize 3-D object based on their 2-D views has been developed by Sorby [13]. In conclusion, after taking the special courses within which the earlier mentioned textbook has been used as a manual, it was possible to state that the stress put on the hand-made sketching and drawing tended to improve spatial skills more than the courses that stressed computer–aided design (CAD) methods.

RG1: The awareness levels of the importance of visual literacy (=graphicacy) development in the frame of engineering studies.

Illustration 3 (after Norman and Seery [11]) presents the complicated role that graphicacy plays to bridge designing with modelling. The model can be supplemented with a rendered visualization of a designed structure. The methods used for visualization today include a wide range of methods starting from preparation of sketchy drawings, creating 2-D and 3-D wireframe representations, using realistic, conceptual or shaded styles for model representation, and finally executing the advanced renderings with proper light, background, materials and textures application.

Graphicacy development within the selected graphical courses that have been specified at engineering studies aims at gaining certain educational goals and learning outcomes, which have been described by Danos et al. [5]. As specified in [5], the commonality in graphicacy outcomes between the two case studies taken from two different countries (the US and Poland) can be summarized as the abilities to: sketch engineering objects in freehand mode, create 2-D geometry, create 3-D solids, create mesh and surface computer geometry, visualize 3-D solid computer models, add dimensions, create section views, generate engineering 2-D drawings from computer models, analyse 3-D computer models.

RG2: Development of relative curricula for the engineering subjects, including the factor of “visual science” and “graphicacy capability” among the students.

The case study presented here will summarize the effects obtained in the three graphical courses: Descriptive Geometry (DG), Technical Drawing (TD), Fundamentals of Civil Engineering (FoCE) and Computer Aided Design (CAD) at two faculties of CUT: Architecture and Civil Engineering.

Nowadays, a concurrent design work performed as a teamwork activity and executed in a common space, which is e.g. a cloud, and it requires application of BIM (Building Information Modelling) technology. Today, the educators must focus on introduction of new technologies and redefinition of the course curricula (=syllabuses) in such a way that the engineering students were trained in new CAD technologies in which graphicacy plays a substantial role.

Within our DG course, the students are mastering the skills and the knowledge on the basics of representation methods used in engineering and they are also trained to be able to provide a freehand sketching of the designed ideas. DG course is the only one where the students do not utilize CAD techniques.

Technical Drawing (TD) course provides the students with a systematic knowledge of the standards used for conveying design ideas in a form of standardized symbols and conventions used within architectural and structural design, they master the conventions how can be added dimensions, provide the "Bill of materials" both for the r.c. (Reinforced concrete) and metal structures, the schedules of doors and windows, etc. The course utilizes AutoCAD software, which is the most common tool used by the designers in Poland today.

Fundamentals of Civil Engineering Course (FoCE) utilizes ArchiCAD software, which has originally been designed as the BIM tool. Starting from a 3-D model construction, each student is able to define an individual type of a wall applied to a structure by defining its attributes to be a composite structure. A composite structure is constructed out of multiple leafs (=skins) and it is possible not only to define thicknesses for each leaf, but also to assign a material from it is constructed and its physical properties. A complete design project provides physical information on the Energy Performance of a building, which complies with the requirements set up by the 2002/91/EC Directive. The tools for creating a 3-D visualization in a form of, either a perspective, or an axonometric view, automatic sectioning, detailing and zones calculation are helpful in a design process.

In frame of Faculty of Architecture, the students who are coming to our university as the "Erasmus" participants, who sign into one of two courses in CAD01 or/and CAD2. In frame of the CAD2 course, they have a chance, among the others, to master another BIM software, which is Revit. There is a high interest shown from the students' side to master this modelling software, even though they are the beginners in the BIM modelling.

In all four courses described above, graphicacy, which is the potential of our students to be able to recognize 3-D objects, to make a 3-D model of a designed structure, to create a technical documentation, is being developed by using various methods and tools. Surprising is the fact that our engineering students tend sometimes to forget the acquired piece of knowledge after they have had completed a specific course. As a good example can serve here dimensioning. Each year it turns out that, after completing a Technical drawing (TD) course and subsequently getting enrolled into the FoCE course, our students forget the application rules they learned in TD.

RG3: Recognition of the possibility of taking a continuum approach in graphicacy development for lifelong learning.

The principle of lifelong learning was adopted as one of the canons of education in the united Europe. Created EQF (European Qualifications Framework − EQF), and on the basis of national qualifications frameworks, where basic qualifications names are defined as follows: a) bachelor and/or an engineer as the Level I of education, b) Master of Science as the level II, c) a Ph.D. – as the level III of education. Presented here results of the research work relate to two qualification levels: I and II. As it has been proved above, a critical factor in studying technical contents is the ability to correctly read and interpret graphic images. For the engineering studies, it is important that the students were able to create designed structures in the mind, and then to be able to construct a computerized model both of the structure and the environment, to create technical documentation in accordance with the recommendations of the Polish and European standards. Obviously, by gaining the learning outcome there is no guarantee that the students preserve the taught material in their minds if they do not continue learning and practicing. Our educational experience provides numerous examples were the students, after having completed one course, seem to "forget" the basics in the following graphic course. To give the simplest example, we may focus our attention on adding dimensions to a designed structure. Therefore, it should be emphasized that technical education requires continuous strategies over the entire course of engineering studies. The elements, which characterize continuity of technical education are: a) the ability to correctly represent a design project with the use of simplified or conventional symbols and the ability to understand and to "read" a symbolic graphic notation, which is equivalent to ability to graphic images recognition. In accordance with the recommendation of the European Parliament and of the Council of 23 April 2008, and for the establishment of the European Qualifications Framework for lifelong learning life, every qualification in higher education is characterized by: a) learning outcomes and b) the workload level for each subject that is expressed in ECTS credits.

6. Conclusions

This paper provides an overview of the current state of the research conducted in the field of graphicacy with the use of newly developed taxonomy by Danos [6]. As graphicacy term has been neither used nor utilized by the educators in Poland, there is the need to define the relation between graphicacy development and general education, but also its relation to engineering education. The author has analysed the elements of her earlier research on the spatial skills in context of graphicacy ability development, and new educational policy that has been introduced in the common European Higher Education Area. The new policy assumes that the universities are given the opportunity to shape individual programs for particular subjects while only specific learning outcomes are expected. In consequence, new syllabuses for graphic subjects have been developed, and these include the factor of graphicacy development and enhancing spatial skills among engineering students. The analysis provided in this paper shows that apart from imagination, graphicacy plays a vital role as a deciding factor on gaining success in engineering studies. The subjects of descriptive geometry, technical drawing, engineering graphics and CAD techniques (visual science) are the fields where the graphicacy skills can be developed, and thus there should be more general guidelines developed for these areas. Further research will be conducted on the graphicacy development and its importance in the engineering education.

References

[1] Aldrich F., Sheppard L., *Graphicacy, the fourth 'R'?*, Primary Science Review, 64, 2000, 8-11.

[2] Barr R.E., Juricic D., Krueger T.J., *The Role of Graphics and Modeling in Concurrent Engineering Environment*, EDGD 58 (3), 1994, 12-21.

[3] Bertoline G.R., *Visual science: an emerging discipline*, Journal for Geometry and Graphics, Vol. 2, (2), 1998, 181-187.

[4] *Autonomia programowa uczelni*, eds. E. Chmielewska, Z. Marciniak, A. Kraśniewski, MNiSzW, Warszawa 2010.

[5] Danos X., Barr R.E., Górska R.A., Norman E., *Curriculum planning for the development of graphicacy capability: three case studies from Europe and the USA*, EJEE, Vol. 39, No. 6, http://dx.doi.org/10.1080/03043797.2014.899324, 2014, 666-684.

[6] Danos X., Norman E., *The Development of a New Taxonomy for Graphicacy*, Laughborough University, https://www.researchgate.net/publication/48353152, 2008, 69-84.

[7] EQF_EHEA 05 a, *European Qualification Framework for Educational Higher Education Area*, Bergen 2005, http://www.ond.vlaanderen.be/hogeronderwijs/bologna/documents/QF-EHEA-May2005.pdf, 2005.

[8] Fry E., *Graphical Literacy*, cited in Journal of Reading, No. 24 (5), 1974, 383-390.

[9] Górska R.A., *Spatial Imagination – an Overview of the Longitudinal Research at Cracow University of Technology*, Journal for Geometry and Graphics, Vol. 9 (2), 2005, 201-208.

[10] Leopold C., Sorby S.A. and Górska R.A., *International Experiences in Developing the Spatial Visualization Abilities of Engineering Students*, Journal for Geometry and Graphics, Vol. 5 (1), 2001, 81-91.

[11] Norman E., Seery N., *Online Conferencing: Designing and Innovation*, [In:] *Graphicacy and Modelling: IDATER 2010*, edited by E. Norman and N. Seery, 5-15. Leicestershire, UK: Design Education Group, Laughborough University, 2011.

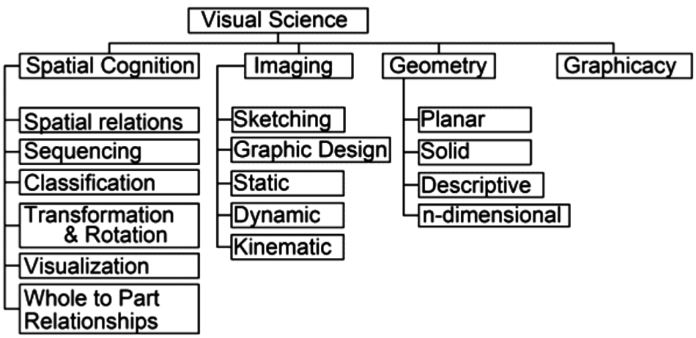
[12] Rużyczka A., *Sensory Impression, Signal Detection and Optic Illusion*. Proc. 21st conf. Geometry Graphics Computer, Gdańsk−Sopot 2014, Gliwice 2014.

[13] Sorby S.A., Manner K.J., Baartmans B.J., *3-D Visualization for Engineering Graphics*, Upper Saddle River, Prentice Hall, New York 1998.

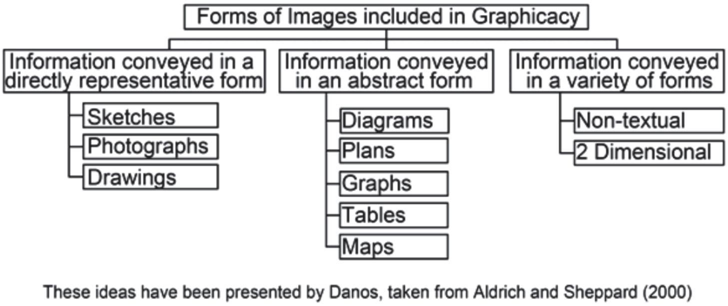
[14] Sorby S.A., Górska R.A., *The Effect of Various Courses and Teaching Methods on the Improvement of Spatial Ability*, Proc. 8th ICEDGDG, Austin, Texas 1998, 252-256.

[15] Wilmot D., *Graphicacy as a Form of Communication*, South African Geographical Journal (Special Issue June) 81(2), 1999, 91-95.

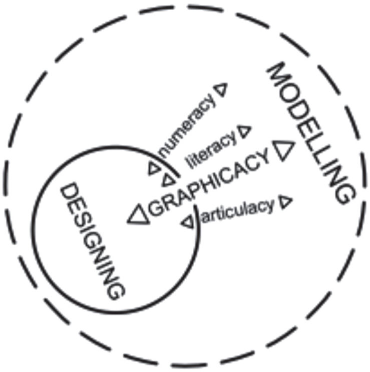
[16] Żakowska L., *Wizualizacja w projektowaniu dróg: Aspekty bezpieczeństwa i estetyki*, Wyd. Politechniki Krakowskiej, Zeszyty Naukowe Architektura Nr 44, Kraków 2001.



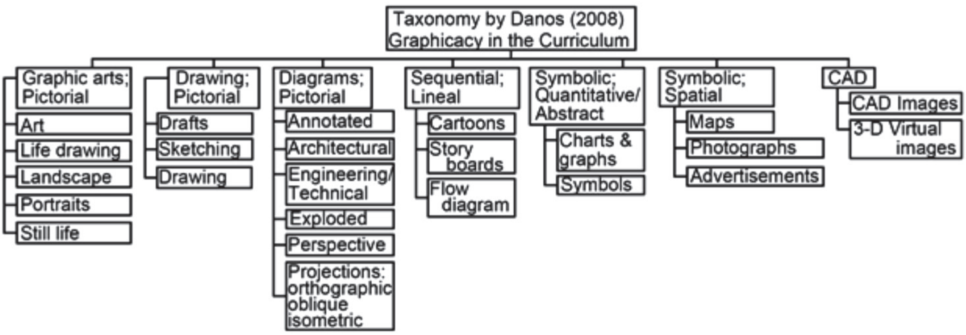
Ill. 1. Modified Visual Science Subject Matter – the ideas represented by Górska and taken after [3] and [6]



Ill. 2. Some of the graphic forms included in graphicacy – illustration taken from [6] and [1]



Ill. 3. Illustration of the complex relationship that graphicacy plays within designing and modeling – illustration taken from [11]



Ill. 4. Examples on how Design and Technology (DT) contributes to teaching and learning graphicacy taxonomy taken from [6]

TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ARCHITECTURE | ARCHITEKTURA
11-A/2015

ANNA KULIG*, KRYSTYNA ROMANIAK**

PERSPECTIVE AS A CONVENTION OF SPATIAL OBJECTS REPRESENTATION

PERSPEKTYWA JAKO KONWENCJA PRZEDSTAWIANIA OBIEKTÓW PRZESTRZENNYCH

A b s t r a c t

In this study perspective was presented as one of the conventions for recording 3D objects on a 2D plane. Being the easiest type of projection to understand (for a recipient) perspective, in its historical context, was presented from ancient times until today[1]. Issues of practice and theory were addressed and examples of precise compliance with the rules and their negation in the 20th century were presented. Contemporary practical applications in architecture were reviewed.

Keywords: linear perspective, computer perspective visualization

S t r e s z c z e n i e

W pracy przedstawiono perspektywę jako jedną z konwencji notowania trójwymiarowych obiektów na dwuwymiarowej płaszczyźnie. Perspektywę, jako najbardziej zrozumiały dla odbiorcy rodzaj rzutowania, zaprezentowano w ujęciu historycznym (od antyku do czasów współczesnych). Odniesiono się do praktyki i teorii, przykładów ścisłego stosowania reguł i negowania ich w XX wieku. Przywołano współczesne zastosowania praktyczne w architekturze.

Słowa kluczowe: perspektywa liniowa, komputerowe wizualizacje perspektywiczne

* Ph.D. Arch. Anna Kulig, Assoc. Prof. D.Sc. Ph.D. Krystyna Romaniak, Faculty of Architecture, Cracow University of Technology; architak@wp.pl, krystynaromaniak@gmail.com.

[1] In his work [21] Michał Sufczyński presents the development of the recording methods in architectural design (Chapter XI, p. 78). The analysis based on works [4] and [11] covers from earliest times up to today.

1. Introduction

Spatial objects are observed in three dimensions – we view them from different sides and directions. „For each look, new shapes of the dimensions sizes and lines are brought. Each look brings a new situation of shapes" [20, p. 212-216]. The process of observation takes place over a certain period of time and, as a consequence, observations made from various points sum up, and objectification of the object being observed takes place. For this reason, a drawing representation of an object is only a partial representation of its actual shape – a record made following a certain convention. An image of an object, a most precise one, can refer to its mirror reflection. Spatial and perspective illusions are then created[2].

The use of perspective to record the space is one of the conventions by means of which we organize the reality. For an average spectator, it is the most understandable method of the record of space. It harmonizes with our way of viewing the world, even if it is not a precise representation or an objective reconstruction of the seeing process.

The reality changes during the observation process[3], and for this reason the rules of perspective are insufficient. The rules of imaging using the perspective were defined over centuries (particular development of the perspective took place in the Renaissance period, in this period its major rules were shaped).

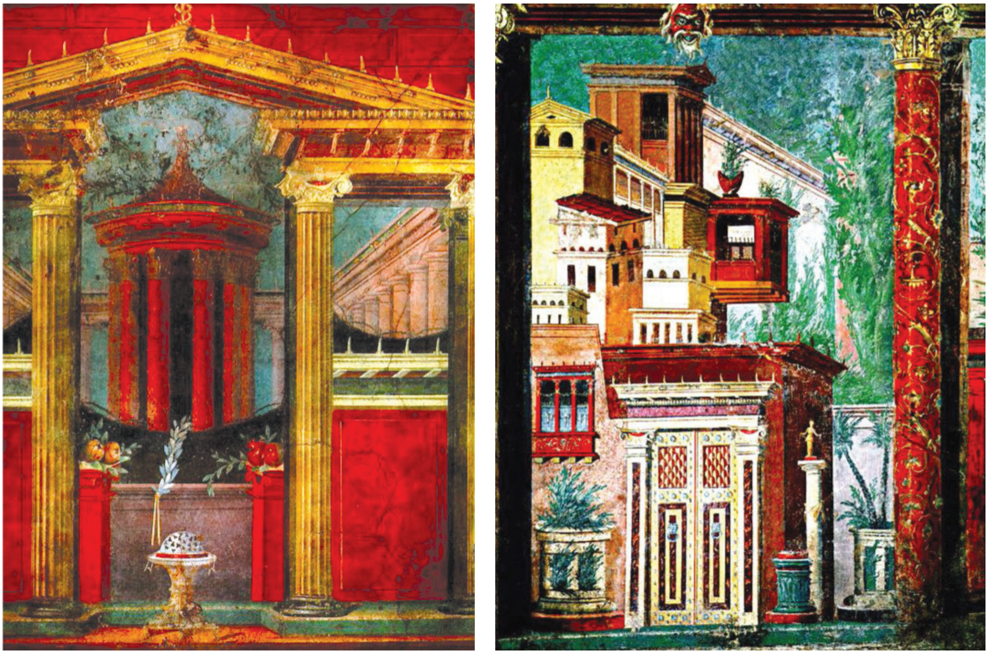
2. Perspective in the historical context

Foundations of the perspective as a discipline in drawing were created by Euclid (the author of the "Elements" and a treaty on the optics) approximately 300 B.C. However, the influence of his theory on artists remains unknown. In the ancient Greece, *scenographia* was used to create an illusion of the reality. One of the oldest paintings of perspective features were preserved in Pompeii. They are fragments of a landscape and views of buildings (Ill. 1). In medieval paintings buildings were represented schematically "in a simplified, general, shortened manner, without attention to proper proportions and style" [22, p. 14]. They played a symbolic function, filled the background and served as a placement of action or as attributes of characters. In the art of Byzantine painters, a dynamic, reversed perspective (the closer to the viewer edges of a building are smaller while the far ones are bigger) was used, which was created from numerous observation points. „Requiring a rational organization of the construction and building tasks, Gothic architecture brought about the emergence of a modern architectural drawing, thus making an architect a true author of a design" [5, p. 54]. Due to the fact that each design had to be approved by persons financing it, therefore "the drawing had to be clear and communicative, even attractive" [5, p. 55].

---

2 **Aerial perspective**, also called **atmospheric perspective**, method of creating the illusion of depth, or recession, in a painting or drawing by modulating colour to simulate changes effected by the atmosphere on the colours of things seen at a distance. Definition after Encyclopedia Britannica on the website [26].

3 J. Ballensted in his work [2, p. 29-30] writes: "Our vision range slightly exceeds 180° whereas the yellow spot vision range is less than 2°… While reading our eyes go over the words in a flowing movement. Each word and each letter has to go through the vision range of the yellow spot. Similarly, while looking at a landscape we spot only a tiny detail despite being convinced that – as we say – with one glimpse we cover the whole. In fact our eyes are performing thousands of small movements".



Ill. 1. Pompeii paintings of the 1st century *Frescoes from the Villa of P. Fannius Synistor*, currently in Metropolitan Museum of Art, New York (sources: https://pl.wikipedia.org/wiki/Malarstwo_pompeja%C5%84skie#/media/File:Pompeii_Fresco_001.jpg; https://pl.wikipedia.org/wiki/Malarstwo_pompeja%C5%84skie#/media/File:Pompeii_Fresco_002.jpg, online: 27.11.2015)

As one of the first artists, the classical rules of the perspective implemented Giotto di Bondone (1266–1337). A characteristic feature in his works was the assumption of one observation point, referred to as "point of view". Architectural objects presented in perspective were serving merely as a background for characters which were represented in preternatural dimensions – to emphasize their importance in the religious and symbolic sense (Ill. 2a). On a wall painting in Siena, Ambrogio Lorenzetti (1290–1348) assumed numerous observation points. He unfolded a vision of a late medieval city, being an architectural fantasy (Ill. 2b).

In the 15th century, artists were trying to faithfully portrait the reality following the rules of the perspective. A subject of particular interest was urban development in relation to the economical and political growth of cities during this time. Painters were creating virtually portraits of the architecture, which became a valuable source of historical forms of various objects [12]. Pierro della Francesca (1420–1492) was the leading perspectivist, theoretician and painter of the Renaissance period. He wrote several treaties where he explained the assumptions of the perspective. He presented the method of the intermediate perspective, which nowadays is referred to as the architectural perspective. His fluency in operating this convention is visible in his works (Ill. 3a). Another leading artist of Renaissance, who was fascinated with optics, was Leonardo da Vinci (1452–1519). He determined the rules of perspective, based on the laws of optics. Aside from linear perspective, he developed the aerial perspective, which employs variations in the intensity and sharpness of outlines, as well as curvilinear perspective,

a)

b)

Ill. 2. Perspective in paintings of the 14th century:

a) Giotto di Bondone, *St Francis Renounces His Fathers Goods and Earthly Wealth,* fresco in the church of St. Francis in Assisi (ca. 1300) (source: https://en.wikipedia.org/wiki/Giotto#/media/File:Giotto_di_Bondone_-_Legend_of_St_Francis_-_5._Renunciation_of_Wordly_Goods_-_WGA09123.jpg, online: 27.11.2015),

b) Ambrogio Lorenzetti, *The Allegory of Good Government*, Palazzo Publico in Siena (1339) (source: https://en.wikipedia.org/wiki/The_Allegory_of_Good_and_Bad_Government#/media/File:Ambrogio_Lorenzetti_-_Effects_of_Good_Government_in_the_city_-_Google_Art_Project.jpg, online: 27.11.2015)

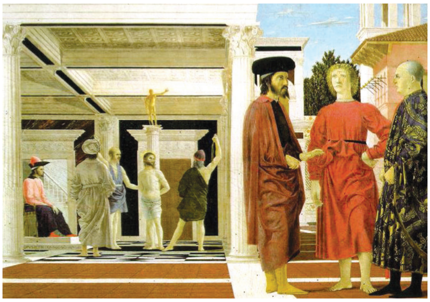
which utilizes the natural curvature of the human field of view. Through saturation and colour dynamics, he was able to obtain an impression of moving away and closing in. Creation of a painting was most often preceded by drawings and handmade sketches serving the study of the building elements of a given painting. These works were not published by the artists and even purposefully destroyed. Currently sought and discovered, they are a rich source of information on the artist's workshop. An example here can be the sketch „Perspective Study For the Background of the Adoration of the Magi" (Ill. 3b). Leonardo da Vinci used the works of the Italian architects, perspectivists, such as: Filippo Brunelleschi or Leon Battista Alberti[4]. He used *i.a.* the introduced by them grid of squares, the so-called – perspective grid.

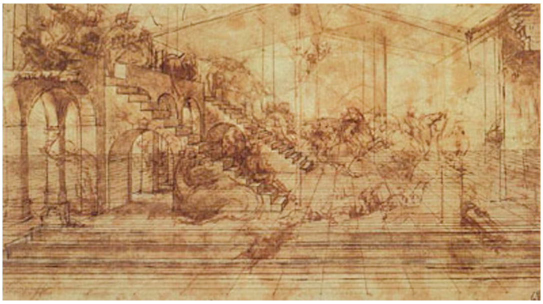
The discovery of geometrical perspective allowed an unequivocal method for presenting architectural designs to be developed. Not only could an architectural form be presented in its real dimensions with the use of orthogonal drawings, but also in its precise perspective [5, p. 56].

Baroque was a period in which the methods of drawing of various perspective views were developed, for instance, with several points of view, from underneath, from a side, from bird's eye view. Investigated and applied were the phenomena of the perspective illusions. For example, in vault paintings, a fictional floor being a continuation of the existing interior elements used to be created (Ill. 4a). At the end of the 17th century, Andrea Pozzo (1642–1709), who practiced architecture and painting side by side, wrote an extensive work on perspective [16]. Being a skilful drawer, Pozzo created exquisite copperplates which illustrated two types of projections discussed in the book [4, p. 549]. There was another book written by Johann Jacob Schübler [19] and published in 1719 which surpassed that of Pozzo. Richly illustrated,

[4] L.B.Alberti is the author of the treatise on perspective *De Pictura* which he most likely wrote in 1435. This work has been digitalised and is available on-line at the Research Library website https://archive.org/stream/dellapitturaedel00albe#page/134/mode/2up.

a) b)



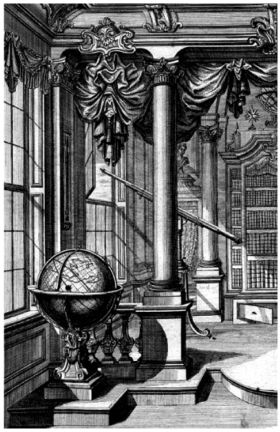


Ill. 3. Perspective in paintings of the 15th century:

a) Piero della Francesca *The Flagellation of Christ* (1460) – Gallery Nazionale delle Marche, Urbino (source: https://en.wikipedia.org/wiki/Piero_della_Francesca#/media/File:Piero_-_The_Flagellation.jpg, online: 27.11.2015),

b) Leonardo da Vinci *Perspective Study for the Adoration of the Magi,* (~1481), Gallery degli Uffizi, Florence (source: https://pl.wikipedia.org/wiki/Leonardo_da_Vinci#/media/File:Studium_perspektywiczne_do_Pok%C5%82onu_Trzech_Kr%C3%B3li.jpg, online: 27.11.2015)

a) b)



Ill. 4. Perspective views in 17th and 18th centuries: century:

a) Andrea Pozzo, *Apoteose de Sante Inacio cropped* Roma, (ca. 1694) (source: https://upload.wikimedia.org/wikipedia/commons/8/84/Andrea_Pozzo_-_Apoteose_de_Santo_Inacio.jpg, online: 27.11.2015),

b) J.J. Schübler, *Proposals for baroque architecture and inside decoration. A study* (ca. 1730) (source: https://de.wikipedia.org/wiki/Johann_Jacob_Sch%C3%BCbler#/media/File:Schuebler_Studierzimmer.jpg, online: 27.11.2015)

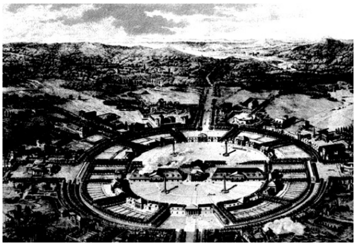
the work bears witness to the author's craftsmanship in developing views from different perspectives. Schübler presents the principles of the bird's-eye perspective with its several spectacular exemplary drawings (III. 4b). K. Bartel considers the work as one of the most beautiful in the subject literature [4, p. 552].

A masterful use of perspective is visible in the 18th century paintings. During this period, "portraits" of architecture were created. Bernardo Belotto known as Canaletto (1721–1780) would use a darkroom referred to as “camera obscura” to construct perspective, achieving an unusual precision and accuracy in reproduction of details of building objects. His panoramas, in particular the one of Warsaw, were used in the post-war period, during reconstruction of the destroyed historical objects (Ill. 5a).

Equally perfect craftsmanship in mastering linear perspective is evident in the works of architects of that period. A design of an industrial city drawn by a French architect Claude Nicolas Ledoux (1736–1806) (Ill. 5b) was quoted as an example. Karl Fridrich Schinkel (1781–1841) was yet another well-known architect of that period. He studied art and, like other artists, travelled all over Europe creating outdoor paintings and drawings (Ill. 5c).

a)

b)



c)

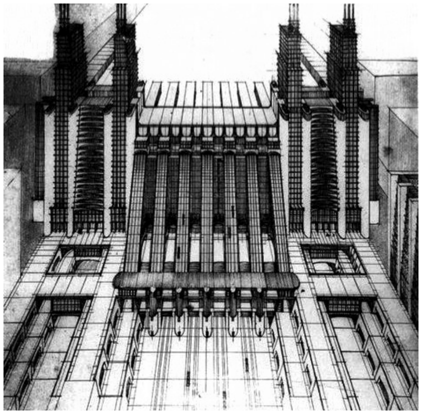
Ill. 5. Perspective views from the turn of the 18th and 19th century:
a) Bernardo Belotto known as Canaletto, *St. Anne's Church in Warsaw* (1774) – Royal Castle in Warsaw (source: https://pl.wikipedia.org/wiki/Bernardo_Bellotto#/media/File:Canaletto_Ko%C5%9Bci%C3%B3%C5%82_%C5%9Bw._Anny.JPG, online: 27.11.2015),
b) Claude-Nicolas Ledux, *Projet pour la ville de Chaux* (1804) (source: *L'Architecture considérée sous le rapport de l'art, des moeurs et da la législation*, http://gallica.bnf.fr, online: 27.11.2015),
c) Karl Fridrich Schinkel *Medieval Town by Water*, (1815) (source: https://upload.wikimedia.org/wikipedia/commons/c/ca/Karl_Friedrich_Schinkel_-_Medieval_Town_by_Water_-_WGA21002.jpg, online: 27.11.2015)

In the following century, a departure from the strict application of perspective rules takes place. Impressionists were using, most often, the colour and aerial perspective to reproduce the space (Ill. 6a).

In the 20th century, the convention of realistic pictorial representations is abandoned. Paintings and realistic drawings are replaced by photography and film, which record the three-dimensional reality in accordance with the rules of the perspective. Painters of this period were experimenting with new representations of the space, with different perspectives. For example, cubists (Pablo Picasso, Georges Brague) were constructing another space by representing an object simultaneously from several points of view (P. Picasso *Dora Maar Seated*, 1937 – Musée Picasso in Paris). They rejected the rules of the traditional perspective. They would subject the forms to geometrization. In turn, the futurists were presenting a space in which everything is in motion, the objects run or spin. The major theme of their works was the city in a geometricalized form (Umberto Boccioni *The noise of the street enters the house,* 1911 – Sprengel Museum in Hanover). Expressionists (Vincent van Gogh, P. Gauguin) were deforming the shapes and colours, braking up with the objectivism and presenting in this way subjective visions (Paul Gaugin *Yellow Christ*, 1889 – Albright-Knox Art Gallery, Bufallo, New York). Surrealists (Salvador Dali, Rene Magritte) were paining objects in a trompe l'oeil form, they were arranging them in unusual combinations,

a)

b)



Ill. 6. Perspective images of architecture in XIX and XX century:
a) Alfred Sisley *Kanał Saint-Martin*, (1872) – Museum d'Orsay Paris (source: https://pl.wikipedia.org/wiki/Alfred_Sisley#/media/File:Alfred_Sisley_001.jpg, online: 27.11.2015),
b) Antonio Sant'Ellia *Stazione d'aeroplani e treni ferroviari con funicolari e ascensori su tre piani stradali* (1914) (source: https://en.wikipedia.org/wiki/Futurist_architecture#/media/File:Santelia03.jpg, online: 27.11.2015)

achieving in this way surprising impressions (S. Dali *The Temptation of St. Anthony,* 1946 – Royal Museum of Arts, Brussels). Thus, the breaking up with the objectivism and copying of the nature took place. Unconventional approach towards the perspective (assumption of several points of view) and its application to produce unrealistic representations of the reality can be observed in the works of Maurits Cornelis Escher, Giorgio de Chirico, Rene Magritt, Carlo Carra, and others (G. de Chirico *The Disquieting Muses*, 1917 – Mattioli Collection, Milano).

The 20th century is considered a golden era of traditional hand-made architectural drawing [7, p. 7]. Perspective drawings of that period were made to delight and charm investors. To that purpose, not only was the drawing craftsmanship harnessed, but also other means which are used by artists to make their works become artworks. Hence architectural drawings are made with the use of a variety of techniques and materials. Many architects perceive designing as art and search inspiration in painting. Born in 1950, Zaha Hadid found her inspiration in the works of vanguard artists. The works of Frank Lloyd Wright (1867–1959) manifest his fascination with Japanese art and one of his perspectives *La Miniatura Mrs. George Madison Millard House*, bears resemblance to Claud Monet's paintings [7, p. 70].

In the 50's of the last century, hand-made sketches were included as a means for presenting architectural concepts, which served designers for communication. From that period came famous sketches of Le Corbusier (1887–1965), in which the new Modulor-system-based proposals were introduced.

At the end of the 20th century, the development of computer technologies, and consequently, relevant graphic computer software resulted in computer-assisted architectural design, whereby architects were equipped with a tool that opened for them new possibilities of presenting their concepts.

It is worth highlighting here that, amongst architectural designs, there are several examples of so-called 'drawn architecture' that have never materialised. However, these had their share in the development of theoretical thought and inspired the imagination of many artists [13, p. 40][5].

3. Perspective, as one of the conventions for the record of spatial objects

Nowadays, we know that linear perspective is only one of numerous possibilities to structure the space on an image, and that it contains certain assumed elements. Realistic paintings of the three-dimensional reality with the classical perspective view are a rarity nowadays. The ability to draw in perspective is not immediately needed. The tedious, manual work has been replaced by digital techniques. This method of presentation prevails over the other presentation possibilities. Computer-made visualizations and photographs took over the role of the documentation, while the role of the "portrait" has been taken by the photography and film. Virtual observation, modelling and presentation take place. Computer-made images of architecture can be transformed number of times by altering the position of the camera, lightning, texture, colour etc. One can thus experiment and obtain, in a short period of time, numerous views and striking perspectives of an object. The authors are trying to surprise the spectator with unusual views, sharp convergence of the perspective, intensive contrasts of the colour and light. Computer visions are simulating photographs of existing objects, "in computer visualization diminishes the border between the interior and the exterior, between a drawing and the reality" [3, p. 10].

Only a few years ago, hand-made, drawn and painstakingly time-consuming perspectives of architectural objects were created in the final stage of the execution of a design. Nowadays, modern technologies enable the design and the perspective observation of a building at each stage of its construction. Computer software provides a variety of possibilities for presenting the structures in perspective. Buildings and what they look like depend on the possibility of performing a rendering. The SketchUp software can be used for modelling 3D objects, creating perspective views (Ill. 7a) as well as the renderings with the V-Ray software, the frontend of the SketchUp (Ill. 7b–d). In the SketchUp software the user establishes the position of the observer and the direction, at a standard visibility angle. The V-Ray (handling) relates to traditional Photography – the visibility angle is focal-length-dependant at a default small-format. It is possible to obtain the depth and the high definition adjusted to the digital equivalent of a diaphragm, which can affect the exposition. Like in camera lenses, a picture with a different degree of distortion can be obtained (Ill. 7d).

A mechanically created linear perspective is objective, ideally accurate, in perfect harmony with the rules of the geometry. However, due to routinization, it lacks the expression of a perspective drawn by hand.

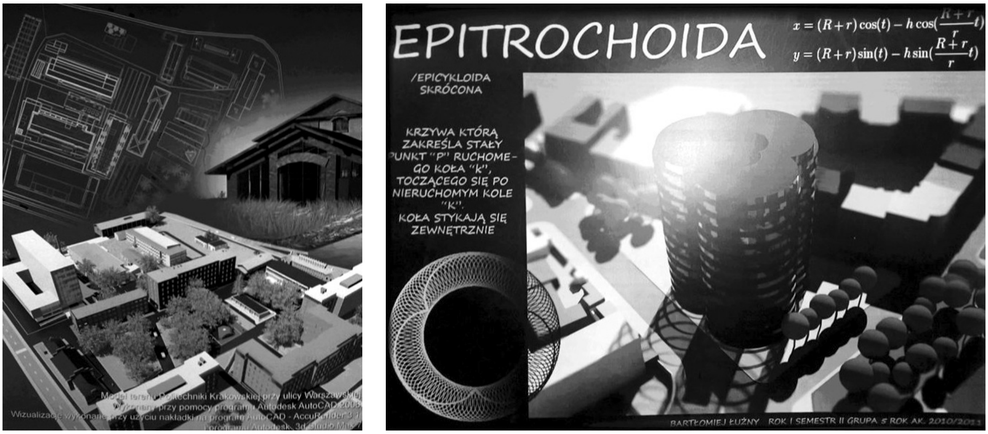
[5] The author classified the following designers as architect-theorists: Giovanni Battista Pirranesi (1720–1778), [from the period of French Renaissance] Étienne-Louis Boullée (1728–1799), Claude Nicolas Ledoux (1736–1806), [from 19th century] Joseph Michael Gandy (1771–1843), Karl Friedrich Schinkel (1781–1841), [from 20th century] Antonio Sant'Elia (1883–1916), [an expressionist] Wenzel Hablik (1881–1934), [constructivists] El Lissitzky (1890–1941) i Yakov Chernikhov (1889–1951).

Ill. 7. Perspective views/images made with the use of the following software: a) SketchUp, b, c) V-Ray; object renderings at different visibility angles, d) V-Ray with distortion 0.5 – the ‘fish-eye’ effect (by: Szymon Filipowski)

The geometrical theory of the perspective, reduced to its basics, remained in the curricula of architecture, engineering (civil engineering) and arts studies[6]. The theory is conveyed using modern information technologies though. This affects both the lectures and the laboratory classes (an example here is a set of exercises developed by the Faculty of Architecture of Krakow University of Technology). Within the framework of the geometry classes interactive courses and presentations were prepared using the Moodle platform. The platform allows the students to return to the lecture materials at any time and at any pace. The knowledge from these lectures is then brought into practice during laboratory classes on the subject Computer Techniques in Design (Ill. 8a). The materials constitute a basis for preparation of a proper modelling rendering and next of a photorealistic rendering in both

[6] Perspective, and air perspective in particular, is a subject of numerous studies and written works. For the purpose of the academic subject of Descriptive Geometry the chapters on perspective can be found in textbooks and many works on the topic are available [16, 18]. Yet still one of the most remarkable pieces of work on this type of projection remains the work of K. Bartel [4] in which the author subjects paintings to the analysis in terms of perspective.

a) b)



Ill. 8. 3D objects in AutoCAD software: a) Model of the area of the Cracow University of Technology at Warszawska Street in Krakow, prepared by the students of the Imago Science Club (graphical study by: Piotr Vogt), b) Epitrochoide (Bartłomiej Łużny) – student's work prepared within the framework of Mathematics classes

architectural and developmental design. Such visualizations and models are created using the following computer programs: Graphisoft ArchiCAD, Autodesk AutoCAD, Autodesk 3dStudioMax, Accurender, Artlantis, Autodesk Architectural Deskop, Adobe Photoschop, ScechUp, Lumion, Revit, RhinoCeros, Grasshopper etc.

A kind of marketing, in which computer graphics and perspective are used, belongs to the basics of education of specialist workforce also in such subjects as mathematics (Ill. 8b). It is recommended to strictly follow the rules of the perspective in the end of semester projects (in mathematics). These rules are not observed as strictly in the handmade drawing, as long as the suggestion or the implication is of higher importance[7]. Handmade sketches on a location, as well as based on recollections and imagination, have a cognitive purpose; they stimulate the spatial imagination, perceptiveness, memory, and when made based on imagination, they constitute an initial record of an idea, a notice of a future design.

A sketched drawing can also serve the purpose of reaching intellectual focus, supporting creative thinking, raising questions and searching for solutions. The analytical function of sketching involves two elements:

– a set of symbols that distinguish an architectural design in a unique way,
– a narrative expressed by images that interpret these symbols, i.e. composition, articulation, arrangement and line density [8].

---

[7] „The rules of projecting, comprehending the subject in the category of geometry as a discipline of science, in handmade drawing constitute only a general guideline on the construction of an image. The perspective does not have to be strictly followed. Numerous circumstances exist where it is virtually required to omit some of its rules in the handmade perspective drawing. It is done due to different properties of the space to plane relationship, if they prove more important for the drawing as a measure of expression which shall move the imagination and form not only information but also a spatial suggestion" [10, p. 267].

Sketching, as such, still remains needed, as an exercise in drawing and design, as a method for a record of a concept and as a communication mean[8]. An impression is present that nowadays perspective is more widely used by architects and civil engineers than artists painters though. "Once the methods for the construction of a perspective have been developed, the workshop of an architect, to a certain degree, became closer the workshop of the painters. In paintings, architecture was presented and perspective became an art of its kind" [6]. The works of architect Michał Suffczyński demonstrate his artistry in presenting the reality and mastering perspective[9]. His watercolours are displayed at numerous exhibitions and available for viewing on his own website [27].

At present, perspective is the most popular convention for presenting spatial objects. The development of graphic computer software made perspective available to laymen who do not necessarily have to know the principles of its creation. Are drawn and painted perspective views going to survive in the age of the digital technology? Looking at the workshop of famous contemporary architects, who do utilize modern computer software, we can still see that they are drawing, sketching and painting by hand. They value this method of work and publish their first, general sketches of designs[10]. Handmade perspective drawings presenting sketches of conceptions are still present at the end of semester works made by students and also in dissertations and competition works. Naturally, a dominating majority of designs is made using a computer (Ill. 9). However, during the selection of the proper perspective and of the view point, the knowledge of the perspective is still applied. „Despite the development of computer techniques, hand-made drawing still remains a fast, effective and convenient design tool" [9, p. 5-14].

And what can be taken away from the traditional painting representations of architecture? What values remained up to date for the nowadays creators of images who are using the computer graphics?

Painting representations of architecture constitute and interesting material from the standpoint of the workshop of the old masters. In the masterpieces, we observe a coexistence of the nature and architecture, setting of the latter in the surroundings and terrain, consideration of the landscape values, the greenery and water. Authors were seeking interesting and harmonizing views, favourable from the compositional standpoint, as well as standpoint of the light, which would enrich the vividness (at the right time during a day). They would often synthesize the theme by eliminating excessive details and giving up pedantry, by means of which they would emphasize the lead motive and would draw the spectator's attention towards the key elements. Artists were selecting objects and were purposefully moving away from a detailed record of reality, omitting thus unaesthetic and defacing elements. The harmony of shapes and colours is also worth attention. An interesting feature is a reduction of the number of colours, sometimes limitation of the palette to an almost monochromatic set.

[8] On 29–30 May 2015 in Kraków the III International Conference on *Challenges of the 21st century: To Draw, to Paint or to Use a Computer* took place. The conference was one of the series on Teaching Drawing, Painting and Sculpture in Architectural Education. The review of conference articles, published in both the Technical Transaction, 2015, and two monographs, shows that perspective is still one of the most popular methods of recording the ideas and the thoughts of a designer. The works contain many hand-made sketches which are unceasingly considered as the 'simplest and fastest method for recording images and thoughts [14].

[9] This work [21] is addressed to those who are interested in methods of space visualisation. It is accompanied by a CD in which the author recorded the process of creating a drawing 'step-by-step.

[10] Architectural drawings of famous architects, can be viewed at the websites: [23–25, 28, 29].

a)

b)

Ill. 9. Design of a house: a) garden side view, b) interior (license to use the graphical materials obtained from the ARCHON company on 15.09.2011)

It turns out that such approach facilitates the play of the chiaroscuro, vividness and mood. Masterful wield of the perspective is visible in the smooth and delicate transitions between the close and the distant plans, variable intensity of colours, diminishing outlines in the distance. A perspective captured with a painter's brush constituted a spontaneous expression, which was based on a feel of a moment and highly individualized.

4. Conclusions

Referring to the sources of the art of perspective allows to observe subsequent achievements of creators in the field of interpretation of the third dimension. Perspective was fascinating artists since the Renaissance, in particular the painters of landscapes and panoramas. Gaining knowledge on the history is an opportunity to touch the art of painting and to discover the relationships between the painting and architecture, as well as to get to know the workshop of the old masters and its modern interpretation. The linear perspective, which is still in use, is a wonderful discovery of the human mind. ”The same way a photographic image documents, to certain extent, the artistic effect of the object realisation, a correctly constructed perspective image can be an objective test of the spatial and artistic concept of a design before its realisation. From this, among others and most of all, springs the purposefulness and the necessity for designers to become familiar with geometrical laws that rule the perspective image, so that the designer could perform the role of such an objective test of forthcoming realisation. The familiarity with these laws can assist a full use of information contained in a photographic image as an objective stocktaking record which in fact is a central projection of a situation in space onto the plane of the photo” [15, p. 16].

References

[1] Alberti L. B., *De Pictura*, 1435.

[2] Ballenstedt J., *Architektura: historia i teoria*, PWN, Warszawa 2000.

[3] Banek B., *Wizualizacja perspektywiczna projektowanych obiektów a wizualizacja drogą programu komputerowego*, Biuletyn PTGiGI, Gliwice 5/1998.

[4] Bartel K., *Perspektywa malarska*, T. 2, PWN, Warszawa 1958.

[5] Białkiewicz A., *O rysunku architektonicznym*, Teka Kom. Arch. Urb. Stud. Krajobr. – OPL PAN 2006, 53-60.

[6] Białkiewicz A., *Rola rysunku w warsztacie architekta*, Wyd. Politechniki Krakowskiej, Monograph 315, Krakow 2004.

[7] Bingham N., *100 lat rysunku architektonicznego*, Wydawnictwo TMC, Raszyn 2013.

[8] Bonenberg W., *Importance of Freehand Drawing in Architectural Design*, Monograph 485, *Challenges of the 21st century: To Draw, to Paint or to Use a Computer*, Wydawnictwo Politechniki Krakowskiej, Kraków 2015.

[9] Bradecki T., Stangel M., *Freehand Drawing for Understanding and Imagining Urban Space in Design Education*, Architecture Civil Engineering Environment, 2/2012, 5-14.

[10] Bruzda J., *Niektóre zagadnienia zależności między formami w przestrzeni a ich obrazami na płaszczyźnie. Przyczynek do zasady rysunku odręcznego w architekturze*, Teka Komisji Urbanistyki i Architektury, T. XXII.

[11] Kemp M., *The Science of Art*, Yale University Press, New Haven and London 1990.

[12] Kulig A., Romanak K., *Perspective Images of Architecture in the Past and Today – Part I*, The Journal of Polish Society for Geometry and Engineering Graphics, 18/2008, 69-85.

[13] Maluga L., *Autonomiczne rysunki architektoniczne*, Wydawnictwo Politechniki Wrocławskie, Wrocław 2006.

[14] Maluga L., *Architectural drawing and professional culture,* Monograph 484, *Challenges of the 21st century: To Draw, to Paint or to Use a Computer*, Wydawnictwo Politechniki Krakowskiej, Kraków 2015.

[15] Pałasiński Z., *Zasady odwzorowań utworów przestrzennych na płaszczyźnie rysunku,* cz. 1, Wydawnictwo Politechniki Krakowskiej, Kraków 2001.

[16] Pałasiński Z., *Zasady perspektywy, Skrypt dla studentów wyższych szkół technicznych*, Wydawnictwo Politechniki Krakowskiej, Kraków 1998.

[17] Pozzo A., *Perspectivae pictorum atque architectorum*, Augustae Vindelicorum, Augsburg 1719, http://dx.doi.org/10.3931/e-rara-369 (online: 16.12.2015).

[18] Romaszkiewicz-Białas T., *Perspektywa praktyczna dla architektów*, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2006.

[19] Schübler, J.J., *Perspectiva pes picturae, das ist: kurtze und leichte Verfassung der practicabelsten Regul zur perspectivischen Zeichnungs-Kunst* (Band 1) Nürnberg 1719, http://digi.ub.uni-heidelberg.de/diglit/schuebler1719ga (online: 16.12.2015).

[20] Strzemiński W., *Teoria widzenia*, Wydawnictwo Literackie, Kraków 1969.

[21] Suffczyński M., *Rysunek Akwarela Sztuka komunikacji wizualnej*, Wydawnictwo Hokus-Pokus Marta Lipczyńska, Warszawa 2010.

[22] Wallis M., *Noakowski*, Warszawa 1965.

[23] http://archigram.westminster.ac.uk (online: 16.12.2015).

[24] http://archiwebture.citechaillot.fr (online: 16.12.2015).

[25] http://library.columbia.edu/indiv/avery (online: 16.12.2015).

[26] http://www.britannica.com/art/aerial-perspective (online: 16.12.2015).
[27] http://www.suffczynski.art.pl/ (online: 16.12.2015).
[28] www.moma.org/collection/search.php (online: 16.12.2015).
[29] www.ribapix.com (online: 16.12.2015).

TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ARCHITECTURE | ARCHITEKTURA
11-A/2015

FARID NASSERY, RAFAŁ ZIELIŃSKI*

3D COMPUTER MODELLING OF ARCHITECTURAL DETAILS BASED ON THE MODERN BIM INVENTORY SYSTEMS

MODELOWANIE KOMPUTEROWE 3D DETALI ARCHITEKTONICZNYCH W OPARCIU O NOWOCZESNE SYSTEMY INWENTARYZACYJNE BIM

A b s t r a c t

The article presents the 3D computer modelling of architectural details based on the modern BIM inventory systems. It discusses the methodology of architectural inventory, which employs laser measurements in the ArchiCad programme interconnected with the FlexiJet system. The use of this method allows one to create elements of a virtual building (BIM model) with great precision, thanks to its very high measurement accuracy and appropriate software. The application of this system is exemplified by the specified elevation detail of the Royal Palace in Łobzów, currently housing the Faculty of Architecture of Cracow University of Technology.

Keywords: Flexijet inventory, 3D modelling, architectural detail, ArchiCAD

S t r e s z c z e n i e

Artykuł prezentuje modelowanie komputerowe 3D detali architektonicznych w oparciu o nowoczesne systemy inwentaryzacyjne BIM. Przedstawiono metodę inwentaryzacji architektonicznej wykorzystującej pomiary laserowe w sprzężonym z programem ArchiCAD systemie FlexiJet. Zastosowanie tego sposobu inwentaryzacji umożliwia tworzenie z niezwykłą precyzją elementów wirtualnego budynku (model BIM) dzięki bardzo dużej dokładności pomiarowej i odpowiedniemu oprogramowaniu. Zaprezentowano działanie tego systemu na przykładzie wybranego detalu z elewacji dawnego Pałacu Królewskiego w Łobzowie, obecnie mieszczącego Wydział Architektury Politechniki Krakowskiej.

Słowa kluczowe: inwentaryzacja Flexijet, modelowanie 3D, detal architektoniczny, ArchiCAD

* Ph.D. Arch. Farid Nassery, M.Sc. Arch. Rafał Zieliński, Division of Descriptive Geometry, Technical Drawing & Engineering Graphics, Faculty of Architecture, Cracow University of Technology; fnassery@pk.edu.pl, rzielinski@pk.edu.pl.

1. Introduction

The article presents 3D computer modelling of architectural details based on modern BIM inventory systems. For this purpose, laser measurements in ArchiCAD-connected Flexijet system have been used. The details on the facade of the former Royal Palace in Łobzów (currently housing the Faculty of Architecture of Cracow University of Technology) have been chosen as an example.

The article presents particular stages of work: from the operating functions of the Flexijet system, through measuring stage, until final modelling of architectural detail in ArchiCAD. The methodology of creating particular elements enabled the authors to examine the most common problems encountered in the virtual renditions of details. The article also discusses various ways of adding up the measured details using certain advanced functions of ArchiCAD. Particular focus has been given to options which compress the files being created which directly influences the speed of working on the model and time required for visualization. The comparison of certain functions of ArchiCAD allows for making optimal choices in the process of modelling.

The concept of creating inventory systems in BIM technology has to begin with the analysis of computer assisted designing. The ways of creating inventory of buildings have been evolving inparallel with the constantly-improving tools needed for this process. In the past, the two dominant solutions used by designers and architects were hand-drawn sketches and perspective drawings as well as Monge's perspectives – plans, facades and cross-sections. Nowadays, drawings are predominantly made with the help of digital technology, the knowledge of which may directly influence the methods being used and the ultimate quality of the produced architectural designs.

More and more often architectural designing is based on working with virtual objects. In order for the graphics editor to generate the required two-dimensional drawings, it is enough to request the appropriate method of projecting the 3D model. The graphics editor will create floor plans, facades, cross-sections, perspectives and axonometric projections, all in accordance with the rules of descriptive geometry [2].

In computer aided designing, three main methods of defining space can be distinguished:

– digital form definition,
– computerized form finding,
– computational form generation [13].

The article discusses the issues relatedto digital form definition based on CAD (Computer Aided Design) and BIM software. A great deal of publications dealing with these problems hasalready come out. They present the optimal methods of using computer aided designing software, creating technical drawings and modelling virtual reality [12] together with methods of visualization.

Introduction to BIM technology can be found in the following: BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors by Chuck Eastman, Paul Teicholz, Rafael Sacks, Katleen Liston [8] as well as in BIM Content Development: Standards, Strategies, and Best Practices by Robert Weygant [25].

The usage guidelines for the program are provided, among others, in the following publications: ArchiCAD by Jesse Russell and Ronald Cohn [21], Начали! ArchiCAD by Andrej Orlov [18] as well as ArchiCAD 17 – Grundkurs by Bernhard Binde [3], and

ArchiCAD 17: Praxiseinstieg by Detlef Ridde [20]. The notion of BIM has been discussed in the following publications: ArchiCAD.Wprowadzenie do projektowania BIM by Rafał Ślęk [23], ArchiCAD 17 BIM Modelling und Dokumentation by Bernhardt Binde [4], Building Information Modeling for Construction Using ArchiCAD by MohdShiratuddin, Shane Germany, Tulio Sulbaran [22], as well as in Основы BIM Введение в информационное моделирование зданий by Vladimir Talapov [24].

2. BIM Technology

Digital form definition dates back to mid-1970s. It was then that technical drawings were beginning to be created with the help of vector graphics software. In the late-1990s, applications based on creating virtual buildings were introduced [8]. Such model constitutes the base on which later 2D drawings are made. This method is represented in such computer programs as: AutoCAD Architecture by Autodesk, Revit by Charles River Software (later Revit Technology Corporation), ArchiCAD by Graphisoft [6], ArCADia-Architektura by Polish company INTERsoft [7], Bentley Architecture by Bentley, or IDEA Architecture by 4M Software. The increasing popularity of designing in BIM technology was connected with the introduction of IFC format (Industry Foundation Classes) [6], which constituted the platform for exchanging data between BIM-class computer software and various participants of the designing process. IFC, being an independent format of files, is compatible with most BIM applications.

Design in BIM technology involves building a 3D model, which is the 'preliminary realization' of the object. The system relies on 3D elements which are defined by means of parameters. It enables registering all the necessary data required by all participants of the prospective building process. The digital form of the object reflects its physical and functional characteristics. All data stored in BIM format is internally consistent – particular parts of documentation contain interrelated information. Any changes made to the BIM model are automatically visible in all drawings, perspectives, facades or cross-sections [23].

3. ArchiCAD Software

ArchiCAD application, developed by the Hungarian company Graphisoft, is the program which implemented the very idea of BIM right from the start. It was the year 1982/1983 when the first version 1.0 appeared. It was based on creating structures in 3D geometry, on the basis of which 2D drawings were generated – floor plans, facades, cross-sections etc. The 'Virtual Building' concept, which to a large extent realized the BIM idea, was introduced in the program as early as in 1987 [6]. The distinctive feature of this application is the way of creating 3D model, similar to the architectural approach to designing and constructing buildings. The idea of the program is based on drawing in the system which is close to WYSIWYG (What You See Is What You Get), so whatever appears on the screen, will closely correspond to what is printed out. Modelling begins with the selection of floor plans in which the designer defines geometrical and material parameters of walls, window and door frames, openings etc., on the basis of which the program is able to produce expenditure estimates. This process may be called 'preliminary construction' because the model of the future building is being created from the objects which correspond to real construction elements (walls, ceilings, beams, etc). Any changes made to the virtual building are transferred to floor plans and vice versa [1]. All the technical and designing documentation has been prepared in this way starting from the 9.0 version of the program. Before, it had to be prepared in a separate program called PlotMaker. Moreover, ArchiCAD application allows storing data in the format of IFC files, which makes it compatible with other computer software involved in the designing and construction process [9].

4. Flexijet – conducting inventory of historical buildings in BIM system

Flexijet system consists of two elements: hardware (tripod, laser distance meter, touch sensor and rotatable device (Ill. 2–4)) and software which manages the measurement process (Ill. 1). Currently, it is compatible with the following programs: ArchiCAD, Rhino, Compass CAD10, Scala, PaletteCAD, PythaCAD [9].

In the area of inventory systems for buildings, Flexijet works best with the ArchiCAD application. It conducts laser measurements and simultaneously creates standard ArchiCAD elements in BIM technology. The resultant model may contain complete detailed data of the building undergoing inventory thanks to very precise coordinates. The accuracy of measurements is 2 mm, which guarantees a very faithful rendering of the object. Understandably, it is especially crucial with historical buildings and their technical documentation. During the measuring stage, such complex elements as windows, doors, stairs, balustrades, etc.,may be created. As they are parametric objects, their models constitute ideal basis for planned modernisation. It is a very important aspect of the Flexijet system especially in Poland, where adaptations, rebuilding and building extensions account for over half of all building activities conducted in urban areas. The information stored in the BIM model may also serve for various simulations and analyses [10].

Standard range-finders provide us with a set of points that are defined spatially. Creating inventory requires a rather time-consuming process of linking these points and their interpretation. The Flexijet system allows for instant modelling of particular elements of the virtual building (Ill. 6). Therefore, the first step in conducting measurements is choosing which part of the building will be measured and recreated in ArchiCAD program. Flexijet laser range-finder is positioned on a point by hand or with the help of a touchpad. We get the reading of the range and, on the basis of three points in space (at least 3 in case of a wall), a BIM model of an element is created. Further measurements enable us to model particular interiors. Measuring elements invisible for the range-finder is executed by metering and indicating 3 base points that are visible from both positions in which the Flexijet device was installed. Next, the device needs to be repositioned and the previously established reference points must be located, which enables us to continue conducting measuring operations and create the virtual model [15–17].

5. Modelling details

When modelling architectural details in ArchiCAD assisted by Flexijet, one should get acquainted with possibilities of obtaining data and possible applications. Flexijet measuring system can provide very important information about a given structure. Having this data before the start of actual modelling effectively saves time and facilitates adding details later on. The output data can be divided into the following categories:

- photographic documentation of the building, particular details, ledges, etc.,
- spot metering with the use of Flexijet system and ArchiCAD program executed on the views of the facades, cross-sections and in 3D view mode,
- measurements defined by lines, polygons, arches and circles using Flexijet and ArchiCAD in facade and cross-section views.

Although laser distance-measuring is very precise, it cannot provide all the necessary information. It has to be remembered that, during the inventory, very complicated shapes may not be possible to be modelled straight away. Reconstruction works should be preceded by photographic documentation since multiple elements must be created during a separate stage in the studio. Thanks to the photographs, we get comparative material and there is no need to come back to the place of inventory. The next step is spot metering executed with the help of a Flexijet device. It begins with establishing fixed marking spots, which define the position of the object irrespective of the position of the distance measuring device. The coordinates obtained in this way are very precise. In this way, it is possible to measure a particular detail, establish points defining its length and width as well as characteristic elements. Another possibility is using the tool which allows for drawing straight and curved lines. It is possible to define essential divisions of a detail, axes and geometry of a particular element. In order to do this, one need to open the view mode of appropriate facades or cross-sections in ArchiCAD and start drawing in them. It is done by the means of spot metering with Flexijet the first and last point of a straight line, or three points in the case of a curved line, circle or a rectangle. If an object has an axis of symmetry, it is not necessary to contour all its elements, only the ones which will be replicated by its mirror image (Ill. 7).

This very method was used for measuring and defining the front facade of the former Royal Palace in Łobzów. The team of architects, including Farid Nassery, Szymon Filipowski and Rafał Zieliński, prepared documentation together with a virtual model and details. (Ill. 9–13). One thing which is especially worth mentioning here is the modelling of portals on the basis of the obtained data. The first and fundamental step was modelling profiles of walls and balustrades. The greater the density of the metering spots, the more precise profiles geometry will be. The same effect can be obtained using lines and arches. After entering the profile into the ArchiCAD library, it is possible to draw a balustrade with the ‘wall’ tool. The 3D image created in this way will display all the details and ledges which have been measured earlier. A clear advantage of this method is its precision and the possibility to define the geometry from a large distance with no need to use scaffoldings (Ill. 7).

The same element may be created with the help of the ‘Morph’ panel, which was further developed in ArchiCAD 16. Apart from building morph objects from scratch, it is possible to transform the already-existing elements. For this purpose, one needs to draw the contour and trace with the ‘Fill’ tool, and change into the morph element with the help of the socalled “magic wand” (pressing and holding the spacebar). After rotating it in appropriate position, the ‘tube command’ may be used, which may be a straight line, a curve or a polygon (Ill. 8).

The next stage is refining the details. Depending on the scale of a building, additional measurements may be required. Before starting the inventory, it is worth establishing how detailed it should be and what exactly constitutes the focus of our interest. Laser measuring with Flexijet enables us to obtain a huge amount of data, including the curvature of the walls, vertical deflections, or small changes in the profiles of the analysed elements. Hence the need for establishing the level of detail refinement of our inventory measurements as well as the amount of time we want to devote to it.

In the case of the balustrade of the portal in the Łobzów Palace, profile, metering, and division measurements were conducted with the accuracy of 5 mm. However, the details, such as roses and pilasters, were defined only by marking their main geometry. Modelling of these elements was based on the 'Morph' tool and its additional functions thanks to which various morph elements can be joined into one or removed. It has to be remembered, though, that in case of using such operations on morph elements, their result is permanent. It means that such operations cannot be 'undone' at a later stage, and returning to the original shapes is not possible. Such option exists only with 'Wall' type elements. Additionally, The 'Morph' tool has the option of 'Smooth & Merge Faces', texturizing separate each face and 'Modify Segmentation'.

During the process of modelling, it is crucial to remember about the following:

- checking the correctness of the morph elements – many elements may contain mistakes which are invisible on the screen and, consequently, the program is unable to 'close' the morph element. Such an object is empty and will have no cross-sectional filling. It may also result in the incorrect edition of polygons it is made up of in some other computer programs as well as during the attempt of visualization of a given element. If possible, the morph element should be checked after each operational step. In order to do that, one needs to choose DESIGN > MODIFY MORPH > CHECK SOLIDITY,
- switching off layers which are not being used at a given moment – with very complicated objects, it is advisable to only leave the layers which are being worked upon at a given moment visible, since it speeds up working in the 3D view,
- editing layers in the 3D window in 'wireframe' view – this option is useful when using functions for solids; editing objects in such situation does not overload the scene, which enhances considerably the process of modelling.

6. Conclusions

Digital tools developed for inventory systems in BIM technology can be used extensively in architectural research and conservation works. The precision of measurements and modelling results in a better description of both the state an object is in as well as a possible range of required renovation works or modernisation. Unlike most 3D scanners, the systems like Flexijet are not based only on a point cloud, which needs to be reinterpreted and converted in order to get 2D images. A project executed in BIM technology resembles building a detailed virtual 3D model, together with simultaneous preparation of designing documentation. The result of such inventory is a 3D model of the whole building or its part, which can be freely edited with all changes made to floor plans, facades and cross-sections remaining consistent throughout. Thanks to the ArchiCAD interface, BIM allows preparation of very accurate cost estimates on the basis of obtained data and, consequently, facilitating scientific research as well as influencing possible future renovation decisions. Therefore, it is an extremely useful tool in reducing costs of the renovation or conversion of a building. Moreover, 3D models of architectural details may constitute the basis for detailed comparative analyses, and possibly the basis for recreating them with the use of 3D printers. Constantly advanced computer techniques result in innovations and improvements of inventory systems, designing and renovation methods, contributing to their greater accuracy and widening the scope of applications.

References

[1] *ArchiCAD 18. 30 lat projektowania BIM*, AutoCAD i ArchiCAD – Serwis eCad, http://www.ecad.boo.pl/?p=1402 (online: 02.04.2015).

[2] Bertoline G.B., Wiebe E.N., Hartman W., Ross W.A., *Fundamentals of Graphics Communication*, McGraw-Hill Higher Education, New York 2011.

[3] Binder B., *ArchiCAD 17 − Grundkurs*, Mironde, Auaa, Niederfrohna 2012.

[4] Binder B., *ArchiCAD* 17 BIM Modelling und Dokumentation, Mironde, Auaa, Niederfrohna 2013.

[5] *Building Information Modeling and Green Design*, Brattleboro, BuildingGreen, Inc., http://www2.buildinggreen. com/article/building-information-modeling-and-greendesign #ABrief HistoryofDigitalDesign (online: 11.04.2014).

[6] Dejer M., Grzymała-Kazłowski M., Handzei R., Kaszania D., Nogaj P., Szymanik W., Tomana A., *BIM − kosztowny czy opłacalny*, Builder, Wydawnictwo PWB MEDIA, Warszawa, nr 1, 2014, 96-99.

[7] Dudek P.,*BIM dla Polski*, Builder, Wydawnictwo PWB MEDIA, Warszawa, 1/2014, 102-104.

[8] Eastman C., Teicholz P., Sacks R., Liston K., *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, Wiley, Hoboken 2011.

[9] *Flexijet 3D*, FLEXIJET 3D. Flexijet.pl, http://www.flexijet.pl/index.php?option=com_ content &view =article&id=4& Itemid=114 (online: 29.04.2014).

[10] *Inteligentne inwentaryzacje w systemie BIM!*, Warszawa, WSC Witold Szymanik Sp z o.o., http://www.archicad.pl/obrazki/Flexijet_ulotka_podglad.pdf (online: 29.04.2014).

[11] Januszkiewicz K., *Systemy i narzędzia generatywne, „*Archivolta", 2012/4, 44-51.

[12] Kadłuczka A., *Rekonstrukcja architektoniczna - realne czy wirtualne modelowanie rzeczywistości historycznej*, [In:] *Doktryny i realizacje konserwatorskie w świetle doświadczeń krakowskich ostatnich 30 lat*, ed. B. Krasnowolski, Wyd. WAM, Kraków 2011, 209-223.

[13] Menges A., *Nowe synergie: integracja procesu projektowania dzięki metodzie morfogenezy numerycznej*, Architektura, 4/2008.

[14] *Messen und modellieren*, Sontheim, BIMm GmbH., http://www.bim-measurement.com/Dokumente/ Produktfolder-Flexijet4architects-DE-klein.pdf (online: 20.04.2014).

[15] Nassery F., *BIM Technology in Preservation of Historical City Buildings*, [In:] *Tradition and Heritage in the Contemporary Image of the City, Vol.3, Practise and Process*, eds. T. Jeleński, S. Juchnowicz, E. Woźniak-Szpakiewicz, Wydawnictwo Politechniki Krakowskiej, Kraków 2014, 57-64.

[16] Nassery F., *Edukacyjny aspekt kreowania rzeczywistości wirtualnej w konserwacji zabytków*, Wydawnictwo Politechniki Krakowskiej, Kraków 2011, 313-320.

[17] Nassery F., Vogt B., *Trójwymiarowe komputerowe modele obiektów jako sposób na zachowanie obiektów zagrożonych destrukcją oraz odtwarzania zniszczonych budowli na przykładzie cerkwi w Bełżcu i innych obiektów sakralnych*, Wydawnictwo Politechniki Krakowskiej, Kraków 2000, 575-578.

[18] Orlov A., Начали*! ArchiCAD*, Inter, Sankt Petersburg 2008.

[19] Pęczek G., *Architektura w dobie cyfrowej*, Architektura, Wydawnictwo Murator, 12/2009, 102-106.

[20] Ridde D., *ArchiCAD 17: Praxiseinstieg,* MITP Verlag GmbH, Bonn 2013

[21] Russell J., Cohn R., *ArchiCAD*, Book on Demand Ltd., Stoughton 2012.

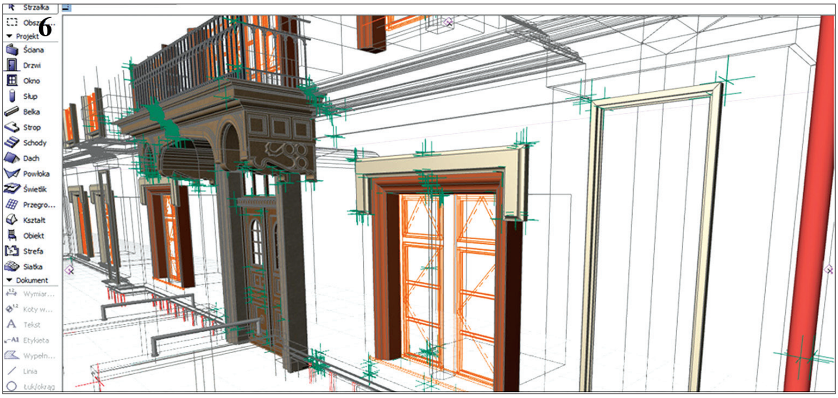
[22] Shiratuddin M., Germany S., Sulbaran T., *Building Information Modeling for Construction Using ArchiCAD*, Cengage Learning, Inc, Clifton Park 2010.

[23] ŚlękR., *ArchiCAD. Wprowadzenie do projektowania BIM*, Wydawnictwo Helion, Gliwice 2013.

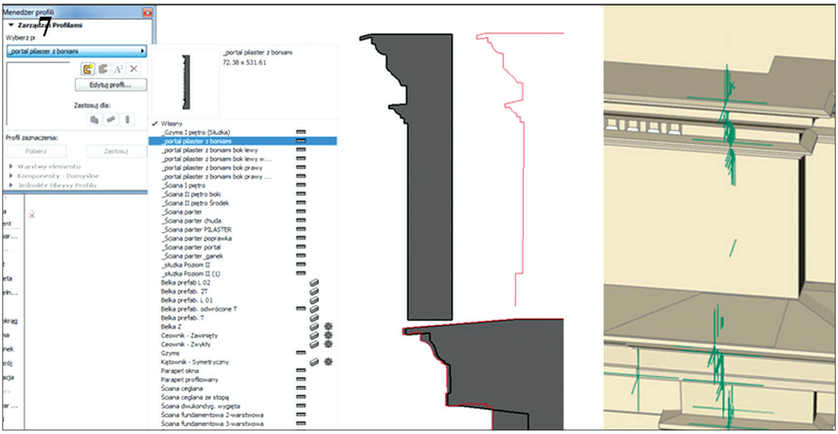
[24] Talapov V.V., *Основы BIM Введение в информационное моделирование зданий*, DMK Press, Moskwa 2011.

[25] Weygant R.S., *BIM Content Development: Standards, Strategies, and Best Practices*, Wiley, Hoboken 2011.

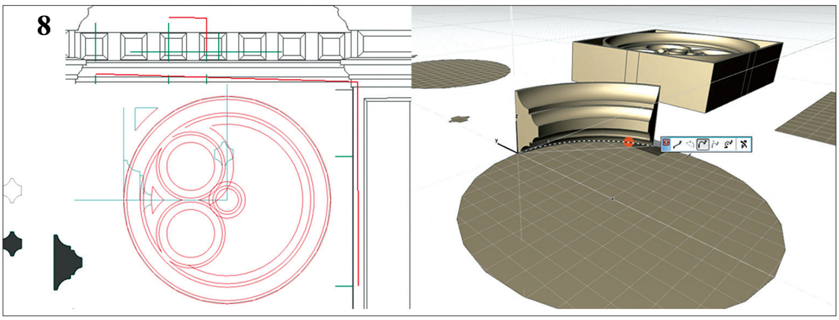
Ill. 1–5. Flexijet device (photos by Rafał Zieliński, 2015)



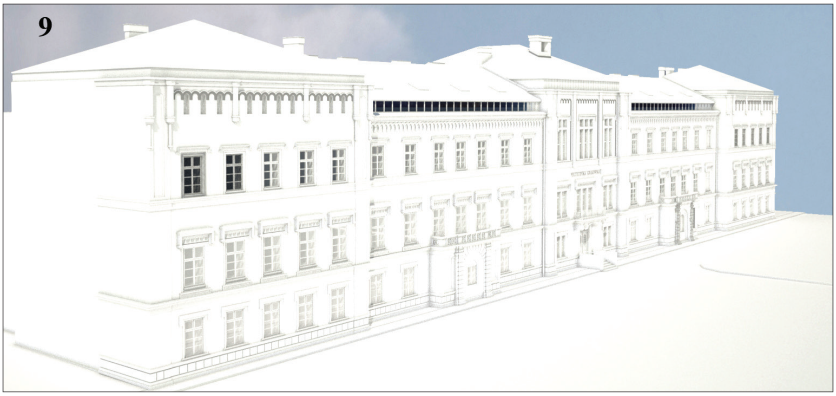
Ill. 6. The measurement of the Royal Palace in Łobzówwhich employs FlexiJet system (photo by Rafał Zieliński, 2015)



Ill. 7. The example of profile measurement and their use in FlexiJet system (photo by Rafał Zieliński, 2015)

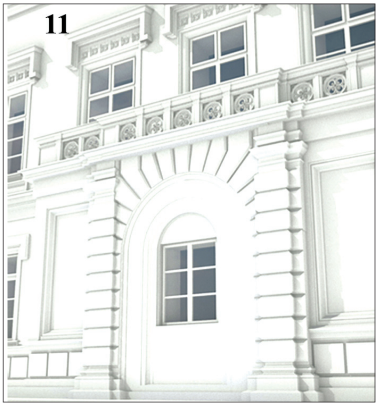


Ill. 8. The example of detail measurement and their use for 3d modelling (photo by Rafał Zieliński, 2015)

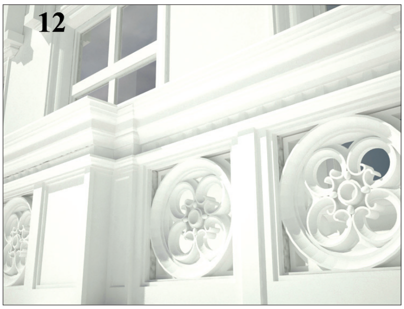


Ill. 9. 3D visualization of the Royal Palace in Łobzów (photo by Rafał Zieliński, 2015)

Ill. 10. 3D visualization of the Royal Palace balcony in Łobzów (photo by Rafał Zieliński, 2015)



Ill. 11. 3D visualization of the Royal Palace archway in Łobzów (photo by Rafał Zieliński, 2015)



Ill. 12. 3D visualization of the Royal Palacebalcony rose detailin Łobzów (photo by Rafał Zieliński, 2015)

Ill. 13. 3D visualization of the Royal Palacedetailin Łobzów (photo by Rafał Zieliński, 2015)

TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ARCHITECTURE | ARCHITEKTURA

11-A/2015

ANITA PAWLAK-JAKUBOWSKA*, KRYSTYNA ROMANIAK**

THE ARCHITECTURE OF SOLID AND RETRACTABLE ROOFS

ARCHITEKTURA DACHÓW STAŁYCH I RUCHOMYCH

A b s t r a c t

One element that impacts the visual perception of retractable roofs is their geometrical construction. A quest to find new and attractive forms for buildings' roofs presents a challenge for architects and designers. In this study, an attempt has been made to classify the roofs in terms of their architectural form. The roofs covered in the research are solid as well as moveable. Solid roofs are divided into three categories i.e. plane, curvilinear and freeform. Two criteria apply when classifying retractable roofs. One is the type of motion that the roof is performing (rotational and sliding) and the other is the type of material that roof panels are made from (roofs with rigid and variable panels).

Keywords: membrane, plane, curvilinear, freeform, with rigid and variable panels roofs

S t r e s z c z e n i e

Jednym z elementów wpływającym na odbiór przekryć ruchomych jest ich budowa geometryczna. Poszukiwanie nowych form zadaszeń obiektów architektonicznych to jedno z ważniejszych zadań stawianych projektantom i architektom. W niniejszej pracy podjęto próbę uporządkowania i sklasyfikowania przekryć dachowych pod kątem ich formy geometrycznej. W obszarze badań znalazły się zarówno zadaszenia stałe, jak i te, które wykonują ruch. Dachy stałe podzielono na przekrycia o połaciach: płaskich, krzywoliniowych i złożonych. W zakresie ruchomych zadaszeń przyjęto dwa kryteria ich podziału: rodzaj ruchu wykonywanego przez dach (obrotowy i przesuwny) oraz rodzaj materiału tworzącego panele dachowe (wyodrębniono dachy z panelami sztywnymi i zmiennymi).

Słowa kluczowe: przekrycia membranowe, dachy z połaciami płaskimi, krzywoliniowymi i złożonymi, zadaszenia z panelami sztywnymi i zmiennymi

* M.Sc. Eng. Arch. Anita Pawlak-Jakubowska, Geometry and Engineering Graphics Centre, Silesian University of Technology; anita.pawlak@polsl.pl.

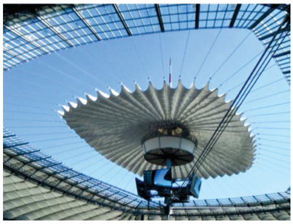
** Assoc. Prof. D.Sc. Ph.D. Krystyna Romaniak, Faculty of Architecture, Cracow University of Technology; krystynaromaniak@gmail.com.

1. Introduction

A rapid progress in new technologies brings about new challenges for designers and architects and, at the same time provides them with virtually unlimited possibilities in terms of shaping architectural buildings. Computer-aided design software allows for creating and modelling of solids and surfaces of any shape. It leads to new, original and spectacular solutions. According to the trio: Firmitas (Firmity), Utilitas (Utility), Venustas (Beauty), the three principles that define architectural features, coined by Vitruvius and still very much in use [1], it is the shape of an architectural building that determines its beauty. The form is the element that attracts attention, has emotional impact, and as a result, conveys the sense of beauty.

a)

b)



c)

Ill. 1. PGE Narodowy in Warsaw – roof as seen:
a) from outside (source: https://ro.wikipedia.org/wiki/Stadionul_Na%C8%9Bional_din_Var%C8%99ovia#/media/File:Warszawa,_Stadion_Narodowy_-_fotopolska.eu_%28331614%29.jpg, online: 06.12.2015),
b) from inside (source: https://pl.wikipedia.org/wiki/Stadion_Narodowy_w_Warszawie#/media/File: POL_Stadion_Narodowy_Warszawa_09.jpg, online: 06.12.2015),
c) from inside with a variety of illumination (source: https://pl.wikipedia.org/wiki/Stadion_Narodowy_w_Warszawie#/media/File:Narodowy-otwarcie16.JPG, online: 06.12.2015)

The roof is the part of the building that has a considerable impact on its perception. Roof shapes can be flexibly modelled and formed. In this study, an attempt has been made to classify the roofs of architectural buildings in terms of their architectural form. Roofs that are solid and those that can move were covered in the research. A movable roof can significantly change the shape of a building, and there is a different perception of the roof in its open or shut form. What distinguishes solid and retractable roofs is their construction which for the latter, is visible not only from the outside, but also from the inside of the building. The changing shape of the roof attracts the attention of the viewers, hence particular care is taken by architects and designers of its aesthetics and form. The PGE Narodowy in Warsaw is a typical example of that. It is one of the biggest textile rooftops in the world, covering in the area of eleven thousand square metres. Pictures in Ill. 1a and 1b show the Stadium viewed with its roof open and shut; from the outside and inside respectively. If not covered or obstructed by any object, the roof part of the building constitutes an integrated element of the interior, and during cultural or sports events, plays a decorative role (Ill. 1c). Being flexible and adaptable [2], retractable roofs enhance buildings with a variety of possible uses for outdoor or indoor activities, due to their ability to react swiftly to changing weather conditions. The multi-functionality of retractable roofs is undeniably their greatest asset [5].

The main purpose of the study is to determine the retractable roofs whose shape changes several times during the movement. The researches begun with the classification of the retractable roofs based on their geometry. Because their shape is often determined by the solid roof (it is often a part of the solid roof), a review of the solid roofs shapes was done.

2. Solid roofs

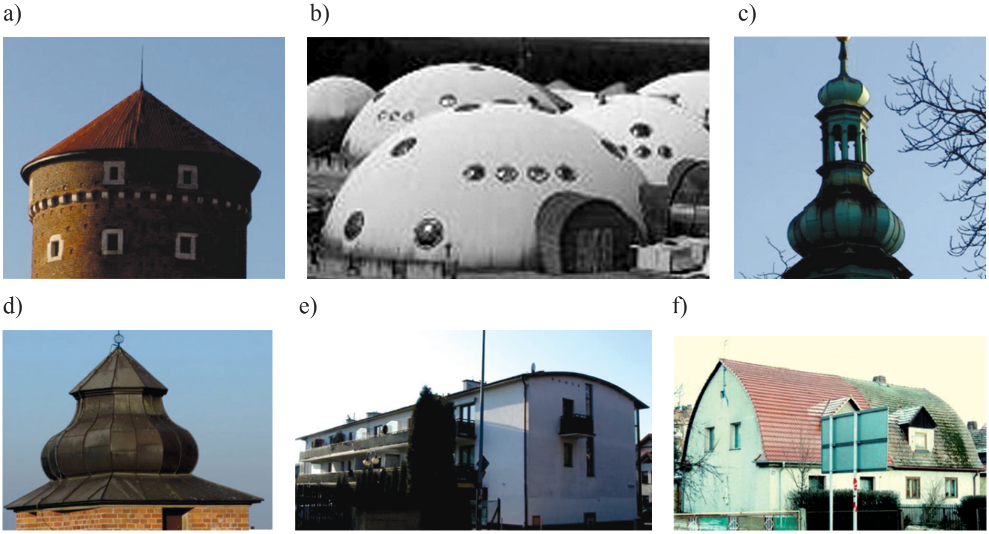
Basic classification divides solid roofs into two categories i.e. plane or curvilinear [8]. The plane category includes: flat, shed, gable, hip, half-hip, gablet, mansard, monitor (Polish), pavilion, helm, butterfly and saw-tooth roofs. Ill. 2 presents selected examples of this type of roofs.

The curvilinear category takes the following: conical, dome, onion-shaped, bell, barrel, saddle, barrel, rainbow, vaulted, corrugated and parabolic roofs (Ill. 3).

Ill. 2. Plane roofs:

a) flat (source: https://pl.wikipedia.org/wiki/Zielony_dach#/media/File:20080708_Chicago_City_Hall_Green_Roof.JPG, online: 06.12.2015),

b) gable, c) half-hip (photos by K. Romaniak), d) gablet (source: https://pl.wikipedia.org/wiki/Dach_p%C3%B3%C5%82szczytowy#/media/File:Zakopane_Droga-do_Rojow_2_dom_drewniany_02_A-1100_M.JPG, online: 06.12.2015), e) mansard, f) monitor, g) pavilion, h) butterfly, i) saw-tooth (photos by K. Romaniak)

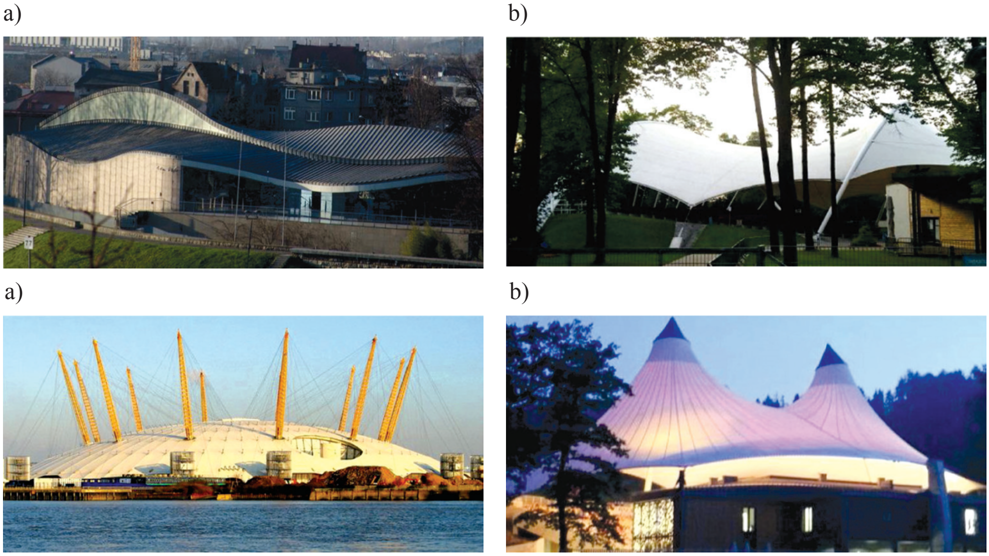


Ill. 3. Roofs of curvilinear planes: a) conical (photo by K. Romaniak), b) dome (photo by A. Pawlak--Jakubowska), c) onion-shaped, d) bell, e) barrel (photos by K. Romaniak), f) rainbow (source: https://pl.wikipedia.org/wiki/Dach_kr%C4%85%C5%BCynowy#/media/File:Kluczbork,_zabudowa_ul._Byczy%C5%84skiej.JPG, online: 06.12.2015)

This classification, in which the dividing criterion is the shape of the rooftop area, does not exhaust all possible solutions. Roofs within each group are subject to further divisions. Mansard roofs, for example, may appear in an apex/ pitched (gambler) (Ill. 4a) or a hip form (Ill. 4b). Neither does the classification cover elements that can change the form of the roof such as dormers (Ill. 4c).

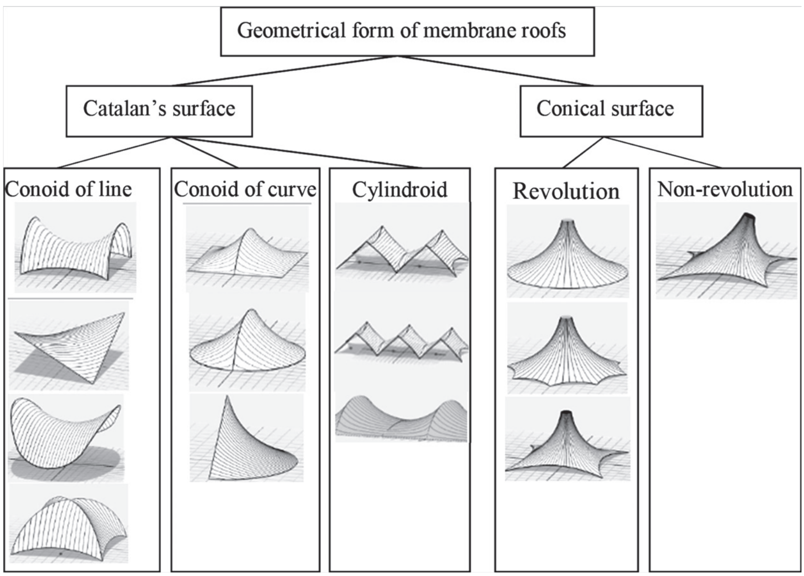
The development of computer technologies and progress in the building material industry provides a vast number of opportunities for designing roofs that escape any classification. The form of such roofs is, more frequently than not, very complicated and difficult to classify under any category. Hence a new group of solid roofs has been determined and referred to as roofs of complex areas [7]. These mainly appear in a form of membrane rooftops with panels made from fabric (Ill. 5 a–c).

Ill. 4. Examples of roofs: a) gambler roof, b) mansard hip roof with dormers (photos by K. Romaniak), c) roof with plane and curvilinear areas (source: https://pl.wikipedia.org/wiki/Cerkiew_Narodzenia_Przenaj%C5%9Bwi%C4%99tszej_Bogurodzicy_w_Choty%C5%84cu#/media/File:Chotyniec_cerkiew2.JPG, online: 06.12.2015)



Ill. 5. Examples of roofs of the following shapes: a) hyperbolic paraboloid [10] (photo by K. Romaniak), b) parabolic conoid (photo by A. Pawlak-Jakubowska), c) dome (source: https://en.wikipedia.org/wiki/Millennium_Dome#/media/File:Millennium_Dome_1.jpg, online: 06.12.2015), d) cone (photo by A. Pawlak-Jakubowska)

In terms of geometrical form, membrane rooftops often take spectacular and unique shapes featuring softness and plasticity. They fall into two fundamental groups i.e. Catalan’s surface and conical planes (Ill. 6) [3, 4].



Ill. 6. Most common geometrical forms of membrane construction (by A. Pawlak-Jakubowska)

Shaping a rooftop with the use of digital technology results in obtaining freeforms of the B-Spline type and NURBS (Ill. 7).

a) b) c)

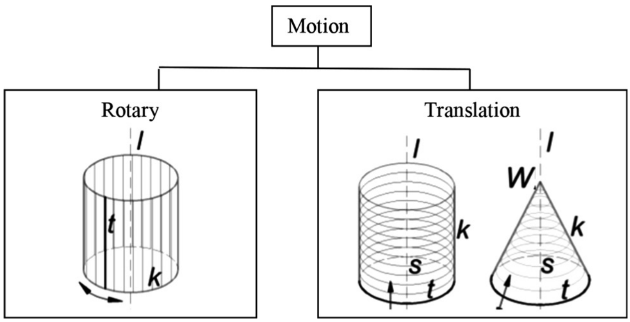
Ill. 7. Free forms of NURBS type: a) Salvador Dali Museum in St. Petersburg in Florida (source: https://commons.wikimedia.org/wiki/File:St._Pete_Dali_Museum03.jpg, online: 06.12.2015), b) Centre Pompidou-Metz in Metz (source: https://de.wikipedia.org/wiki/Centre_Pompidou-Metz#/media/File:Metz_Centre-Pompidou_2011-3_2.JPG, online: 06.12.2015), c) Złote Tarasy in Warsaw (source: https://en.wikipedia.org/wiki/Z%C5%82ote_Tarasy#/media/File:Zlote_tarasy_zima2011.JPG, online: 06.12.2015)

Roof architecture includes not only his shape, but also building technology and the function of the roof and object. Among the solid roofs, the flat roof creates special opportunities in terms of changing its function. It can be used as additional living space, in the form of a terrace or garden. This space is especially valuable in the cities, creating the opportunity to be among the greenery and outdoors. The roof then has leisure and recreational functions.

3. Retractable roofs

Two criteria apply when classifying retractable roofs. One is the type of motion that the roof is performing [6] and the other is the type of material that roof panels are made from. Within the first criterion, there are roofs that perform the following:

– rotary motion – rotation of the generatrix around the axis of the plane,
– advance motion – translation ‘extension’ of the generatrix along the straight line plane directrix (Ill. 8).

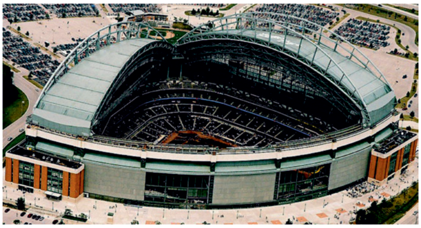


Ill. 8. Retractable roofs divided by the type of motion (by A. Pawlak-Jakubowska)

Illustration 8 presents rotary and translation motions performed on cylinder and cone planes. Similar translation takes place on other planes, such as sphere or torus. In Table 1, there are examples of selected buildings in which the above-mentioned types of motions are performed. Each rooftop is shown in its open and shut form.

Table 1

Retractable roofs performing rotary and translation motions

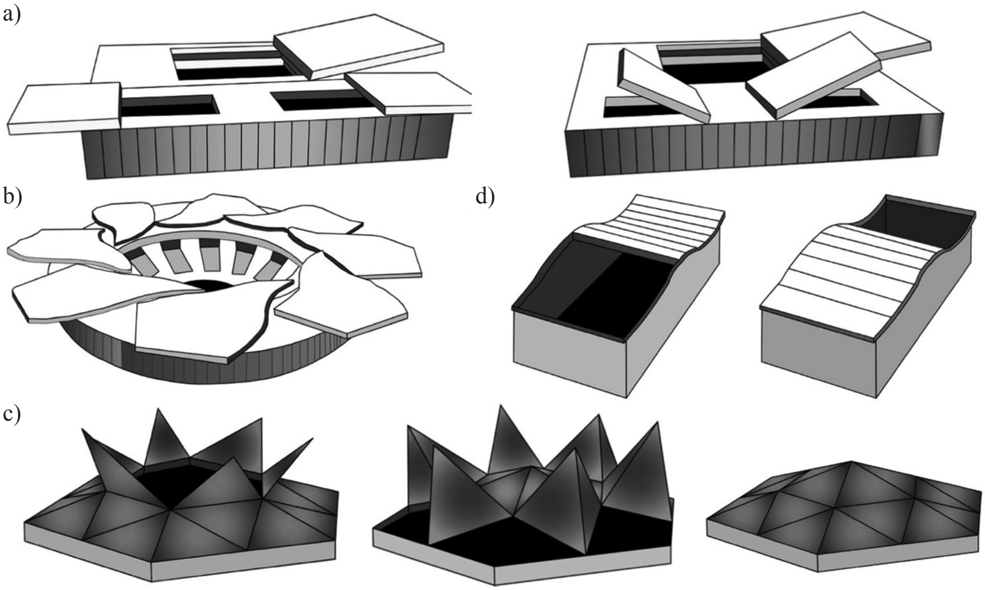
No.	Plane	Motion	Roof
1	Torus	rotation	
			Miller Park, Milwaukee, USA (2001), capacity – 41,900 people (source: https://fr.wikipedia.org/wiki/Miller_Park_%28Milwaukee%29#/media/File:Miller_Prk.jpg, online: 06.12.2015)
2	Cylinder	rotation	
			Millennium Stadium, Cardiff, England (1999), capacity – 74,500 people (source: https://en.wikipedia.org/wiki/Millennium_Stadium#/media/File:Millennium_Stadium_%28aerial_view%29.jpg, online: 06.12.2015)
3	Cylinder	translation	
			Seagaia Ocean Dome in Miyazaki, Japan (1993) (source: https://en.wikipedia.org/wiki/Seagaia_Ocean_Dome#/media/File:SeaGaia_-_Miyazaki_Ocean_Dome_-_outside.jpg, online: 06.12.2015)

Similarly to the one for solid roofs, this classification of retractable roofs does not cover all possible solutions. Examples of rooftops that escape the classification are presented in Ill. 9 as follow:

– rooftop Caja Magica in Madrid performs a rotary as well as a translation motion (Ill. 9a),
– individual elements of the rooftop of Qi Zhong Stadium in Shanghai move along a circular runner, hence the motion performed is called rotary (Ill. 9b),
– panels of the Duisburg Theatre rooftop advance along a smooth curve (Ill. 9c),
– triangular panels of the Media Park roof in Sapporo rotate around straightforward axes (Ill. 9d).

In the next classification, the retractable roofs are divided into roofs with rigid or variable panels. The classifying criterion is the material that the panels are made from. Rooftops with rigid panels are invariable in shape during translation, whereas roofs with other panels, made of textile material, vary in shape while moving.

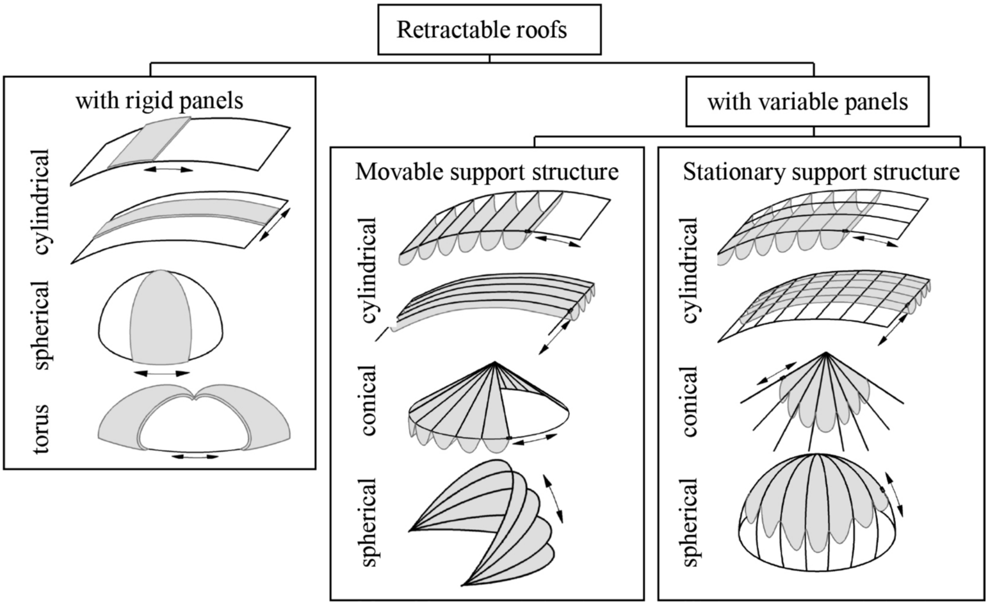
a) b) c) d)



Ill. 9. Various shapes of retractable roofs (diagrams): a) Caja Magica, Madrid, Spain, b) Qi Zhong, Shanghai Stadium, China, c) Duisburg-Nord Theatre, Germany, d) Media Park, Sapporo, Japan [9] (by K. Romaniak)

Two more groups of roofs with variable panels were determined, which differ in the manner of construction. First, with a stationary support structure along which the traction moves (Kadzielnia, Kielce, Poland), and the other with a movable support structure which itself performs the movement itself (Toyota Stadium, Japan).

This work presents the examples of rigid and movable roofs which represent only a fraction of actual real-life solutions. Nonetheless even those examples point out to an extraordinary diversity in terms of geometrical forms, which can be obtained. Membrane roofs and those modelled with computer software (NURBS surfaces) take a very important place amongst the roofs discussed.



Ill. 10. Geometrical classification of retractable roofs with rigid and variable panels (by A. Pawlak--Jakubowska)

4. Conclusions

One element that impacts the visual perception of retractable roofs is their geometrical construction. A quest to find new and attractive forms for architectural buildings presents a challenge for architects and designers. Classifications of roofs, both rigid and retractable, show their unlimited diversity and richness in terms of shapes and solutions regarding construction and materials they can be made from. The process of making retractable rooftops requires not only the creativity of the designer, but also the technical innovativeness of engineers and constructors. Each one of such undertakings is a synergy of tasks performed by specialists of architectural design, construction and the structure of mechanisms. The next stage of research will be the analysis of roof building technology and functionality associated with the type of roof. The classification of roofs, both solid and retractable, organizes information with respect to their geometry. Classification criteria of retractable roofs adopted in this paper are related to the movement, because the main purpose of the research is to find the roofs with different geometries, which change during the movement.

References

[1] Bigaj P., *Ponadczasowość teorii Witruwiusza w kontekście architektury współczesnej,* Czasopismo Techniczne, Architektura, 7/2009, 173-178.

[2] Bögle A., Schlaich M., Hartz C., *Pneumatic structures in motion*, Proceedings of IASS Symposium, Valencia 2009.

[3] Krzemiński J., *Konstrukcje powłokowe. Kształtowanie geometryczne przekryć*, Wydawnictwo Biuro Studiów i Projektów Typowych Budownictwa Przemysłowego, Warszawa 1962.

[4] Lewis W. J., *Konstrukcje napięte. Ich forma i praca*, Wydawnictwo Instytut Śląski, Opole 2008.

[5] Masubuchi M., *Conceptual and structural design of adaptive membrane structures with spoked wheel principle – folding to the perimeter*, Praca doktorska Technischen Universitat Berlin Institut fur Bauingenieurwesen zur Erlangung des akademischen Grades, Berlin 2013.

[6] Otto F., *IL 5 Convertible Roofs. Institut for Lighteweight Structures (IL)*, University of Stuttgart, Stuttgart 1972.

[7] Pottmann H., Asperl A., Hofer M., Kilian A., *Architectural Geometry*, Bentley Institute Press, Exton, Pennsylvania 2007, 361.

[8] Skowroński W., *Ilustrowany Leksykon Architektoniczno – Budowlany*, Wydawnictwo „Arkady", Warszawa 2008, 58-60, 273.

[9] Uni-System, www.uni-systems.com (online: 18.12.2015).

[10] http://manggha.pl/architecture (online: 18.12.2015).

TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ARCHITECTURE | ARCHITEKTURA
11-A/2015

BEATA VOGT*

AUTOCAD AND E-LEARNING IN TEACHING DESCRIPTIVE GEOMETRY

AUTOCAD I E-LEARNING W NAUCZANIU GEOMETRII WYKREŚLNEJ

A b s t r a c t

The world is changing constantly and inexorably, and the new technologies enter all of the fields of our lives. The changes also affect the ways of teaching traditional subjects, such as descriptive geometry. Until recently, this subject, being the basic communication language for engineers all over the world, had only been taught with traditional methods – using paper, pencil, compasses and ruler. Currently, instruction on solving geometric problems begins to use computers with the AutoCAD software as well as e-learning platforms with a full range of possibilities. An essential issue in the course of instruction is to make the student realise that a computer can only do what it is told to do by its operator, and it is necessary to have theoretical knowledge to be able to use one in order to solve a given problem.

Keywords: descriptive geometry, AutoCAD, e-learning

S t r e s z c z e n i e

Świat się nieustannie, nieubłaganie zmienia, a nowe technologie wkraczają we wszelkie dziedziny naszego życia. Również sposoby nauczania klasycznych przedmiotów, takich chociażby jak geometria wykreślna, ulegają zmianie. Ten przedmiot, będący podstawowym językiem porozumienia inżynierów na całym świecie, do niedawna był nauczany wyłącznie klasycznymi metodami – przy użyciu papieru, ołówka, cyrkla i linijki. Obecnie do nauki rozwiązywania problemów geometrycznych zaczyna się wykorzystywać komputer z programem AutoCAD oraz platformę e-learningową z całym wachlarzem jej możliwości. Ważną rzeczą jest uświadomienie studentowi w trakcie nauki, iż możliwości komputera zależą wyłącznie od jego wiedzy teoretycznej i umiejętności rozwiązywania problemów.

Słowa kluczowe: geometria wykreślna, AutoCAD, e-learning

* Ph.D. arch. Beata Vogt, Department of Descriptive Geometry of Technical Drawing and Engineering Graphics, Faculty of Architecture, Cracow University of Technology; bvogt@pk.edu.pl.

The dynamic development of new technologies is changing the face of the contemporary world. All fields of life are affected by changes, including ways and methods of teaching young people at all stages of education. Subject to the process of changes are even the most traditional subjects, such as mathematics or descriptive geometry. Descriptive geometry was chosen an example illustrating the progress in teaching students of technical colleges. Until recently, this subject, being the basic communication language for engineers all over the world, had only been taught with traditional methods – using paper, pencil, compasses and a ruler. These instruments were used both at lectures and in classes, and the geometrical constructions were recorded in the form of drawings. Teaching aids for this type of tutorials comprised of textbooks and other academic manuals. Currently, computer technology is more and more frequently used in the teaching of descriptive geometry, along with relevant software. The computer is used by students as an advanced drawing board requiring them to master a suitable graphics program. Access to the Internet, and thereby to the e-learning platform, makes it possible to take advantage of the resources stored there. E-learning courses supplement classroom activities. Students can access the materials stored there at any time during the course. This enables them to repeatedly revise the topics covered during the lecture and to do the exercises provided there. The e-learning platform provides a close equivalent to the constant contact with the tutor.

At the Faculty of Electrical and Computer Engineering of the Technical University of Krakow, first-year courses include the subject of *Geometry and Engineering Graphics in AutoCAD*. The objective of the course is to shape the students' spatial imagination and instruct them in methods of representing a three-dimensional space in the drawing plane. The subject is accomplished according to the following timetable: 1 hour of lecture and 1 hour of laboratory classes (using mainly the AutoCAD computer program) - it has the value of as many as 5 ECDL credits. In its scope, it includes Monge projections, axonometric projection, affinity and collineation, technical drawing with dimensioning principles and AutoCAD basics for creating 2D drawings (technical documentations, assembly drawings) and shaping 3D objects (modelling of spatial objects).

Within the framework of the course, students must master the basics of descriptive geometry and technical drawing, and learn the computer program with the aid of which they perform all the tasks (AutoCAD). This forces both students and teachers to get significantly involved in the teaching process. Due to the relatively small number of classes, students have access to an internet service run by the course instructor as well as constant contact with him via email. This way, additional consultations and corrections are provided (outside of the time provided for in the consultation schedule). On the e-learning platform, they receive tutorials and drafts for each of the topics being covered. They also take advantage of animations and instruction films (performed in real time), the purpose of which is to show step-by-step the manner of action, especially when introducing new AutoCAD program commands. The e-learning course also includes quizzes that check and consolidate the knowledge concerning each of the issues. Furthermore, students use sets of descriptive geometry problems published by the Technical University of Krakow, such as: *Rudiments of Monge Projections in Exercises*, *Affinity and Collineation in Exercises*, or *Sphere and Solids of Revolution in Exercises*. These sets constitute a compendium of knowledge within the given scope of material, indispensable to students of technical faculties, as well as a sets of topics to be studied by students on their own (beside the problems themselves, they contain the solutions thereof along with a scheme of reaching correct solution to the problem posed). These textbooks provide students with the possibility to reanalyse the patterns and constructions that they learnt during the lecture, and to use them for solving engineering problems, while at the same time, they enable them to prepare themselves properly for laboratory classes.

The basis for participation in the descriptive geometry course is knowledge acquired by students at the earlier stages of education, mainly in the scope of Euclidean geometry. Course instructors prepare tasks, the purpose of which is for students to recall and consolidate information concerning plane figures and their properties, tangents to circles, the intercept theorem, Thales' theorem, etc.

In the course of studying the subject, the student acquires the ability to work in the AutoCAD environment, both in the scope of 2D and 3D. He is able to make planar drawings of various mechanical objects, including their sections, dimensioning and creating assembly tables. He can build spatial models of these objects, selecting appropriate material indispensable for the visualisation thereof and saving in the form of raster images. Further skills relate to drawing, reading and supplementing technical documentations (collaboration between different sectors). Learners acquire the ability to combine vector images with raster images and to prepare materials for print. Towards the end of the semester, each student creates their own poster that presents a solution to a given geometric problem. The project consists of a problem solution with the use of descriptive geometry methods as well as images representing a spatial model of the existent situation.

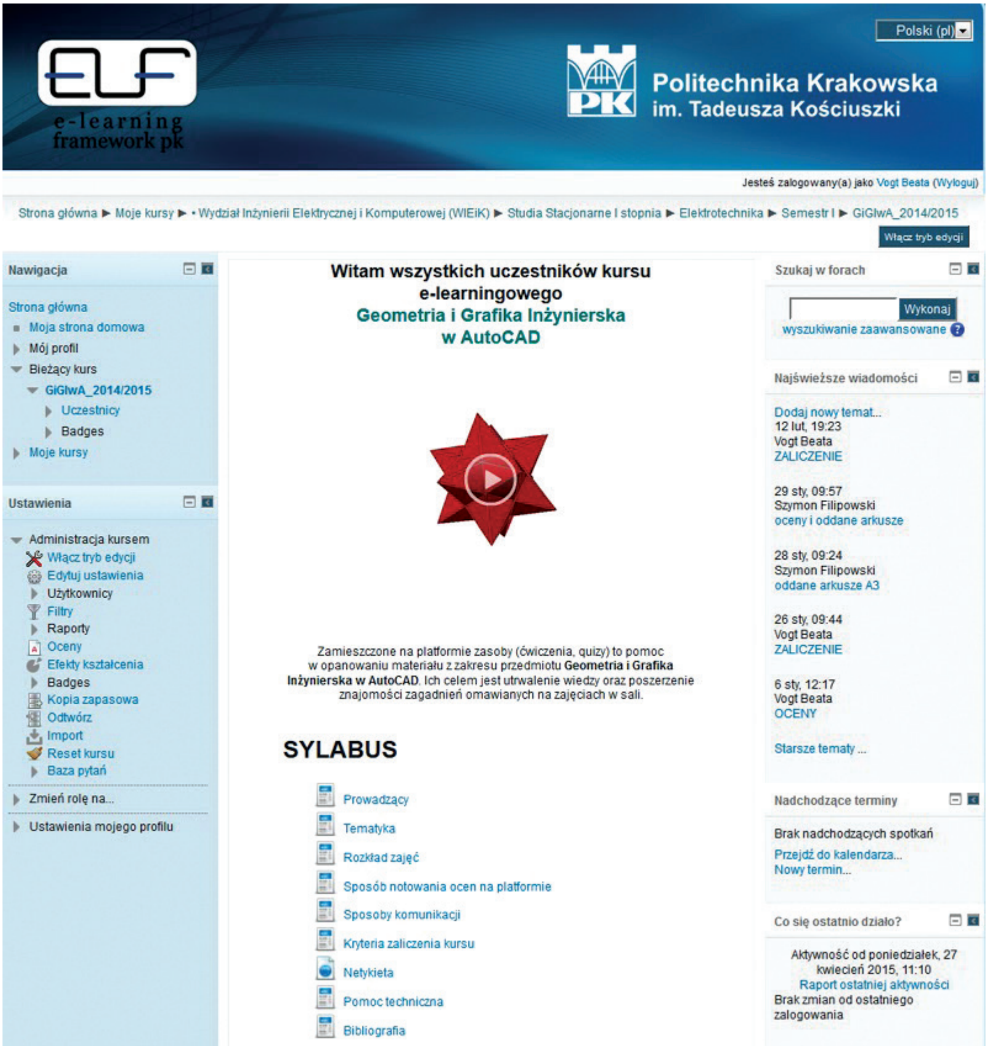
Within the scope of descriptive geometry, students learn what geometry deals with and what are the basic ways of representing space. They learn the principles of orthographic projection (ambiguity of images from two projections) as well as the differences between the European first-angle projection and the American third-angle projection. Further on, they learn axonometric acquainting themselves with each of its kinds. They practice constructing military axonometric, cavalier axonometric, orthogonal isometry, orthogonal dimetry and orthogonal anisometric. Another method of representing three-dimensional objects in the form or two-dimensional drawings that the students learn is the method of Monge projection. Beginning from the general information, that is the way of representing points, straight lines and planes in this kind of projection as well as singular straight lines and planes, they proceed to the 5 basic constructions (affinity, common element, parallelism, orthogonality and metrical constructions, sections and rotations). The next stage is becoming familiar with the method of transformation that is the ability to deal with consecutive projection planes perpendicular to one of the previous ones[1].

After becoming familiar with the basic "alphabet" in the form of basic constructions and transformations, students proceed to three-dimensional objects, that is to say problems related to solids. They find out about regular and half-regular polyhedrons, pyramids, prisms, the sphere, cones and cylinders. They solve problems involving the topics of piercing points, sections, intersections and developments of solids. They learn about the relation of collineation and affinity with respect to some engineering problems. They construct conic sections: ellipse, parabola and hyperbola. At the end, they learn various engineering problems that are solved using geometric methods.

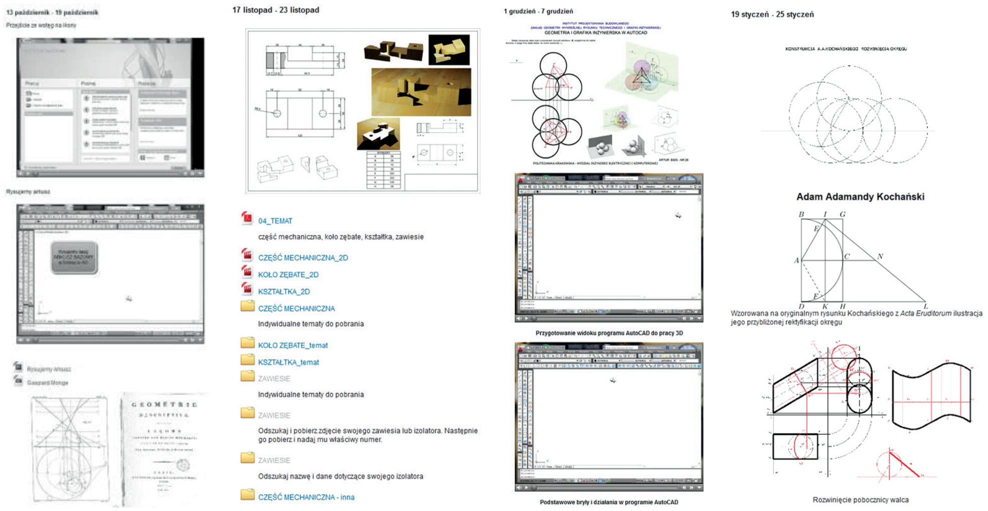
---

[1] When teaching descriptive geometry in the traditional way (with the aid of pencil, ruler and compasses), due to the decreasing number of classes of this subject, the tutors often depart from teaching the 5 basic constructions and proceed directly to the method of transformation. In the case of classes conducted with the use of a computer, students more frequently choose to solve a geometric problem using the basic constructions (section) than transformation. Moreover, they make fewer errors in these exercises.

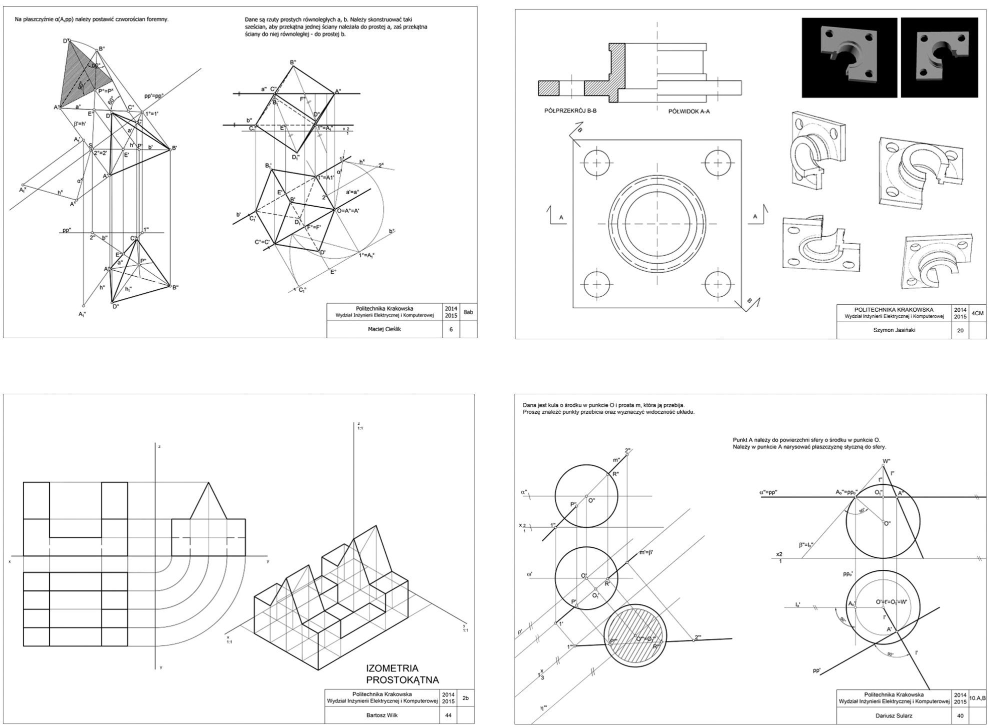
The introduction of modern teaching techniques [computer programs and e-learning] was intended to streamline and improve the efficiency of teaching, and at the same time, to facilitate the direct contact between students and lecturers, which would enable an individual approach to the problems arising in the course of the teaching process. However, as in the saying “there are two sides to every coin”, even here there is the other side, as these methods are more time-consuming, to both the students and the lecturers. It is also necessary to have access to broadband internet [which is still not so easy outside big cities] as well as computer hardware of sufficient parameters. Despite these disadvantages, it seems that this way of conducting classes is going to be more and more common.



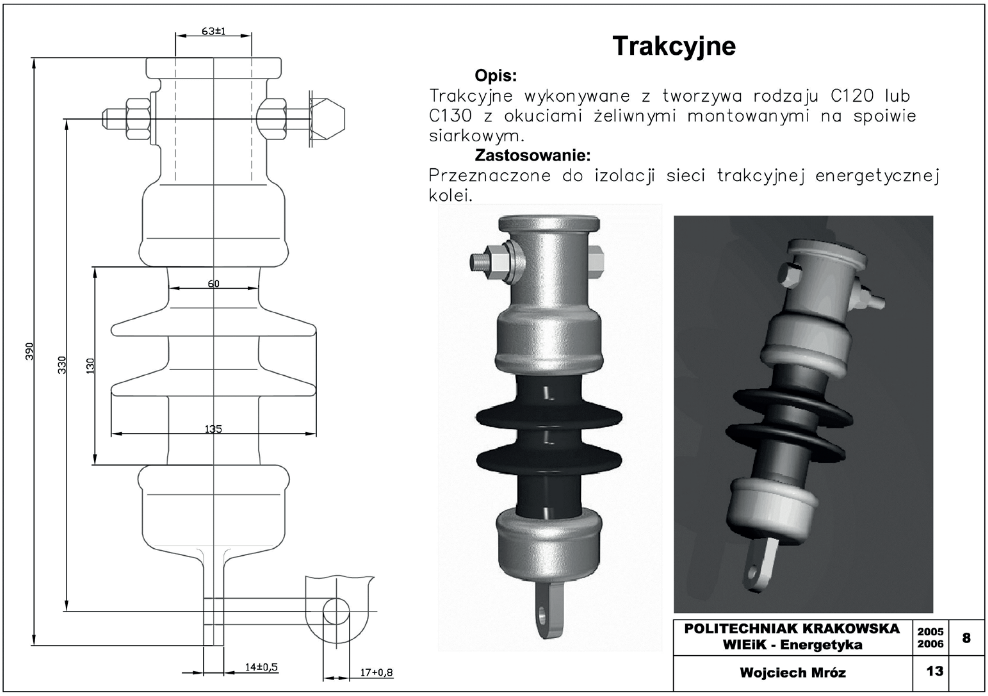
Ill. 1. View of the e-learning site of the course Geometry and Graphics in AutoCAD



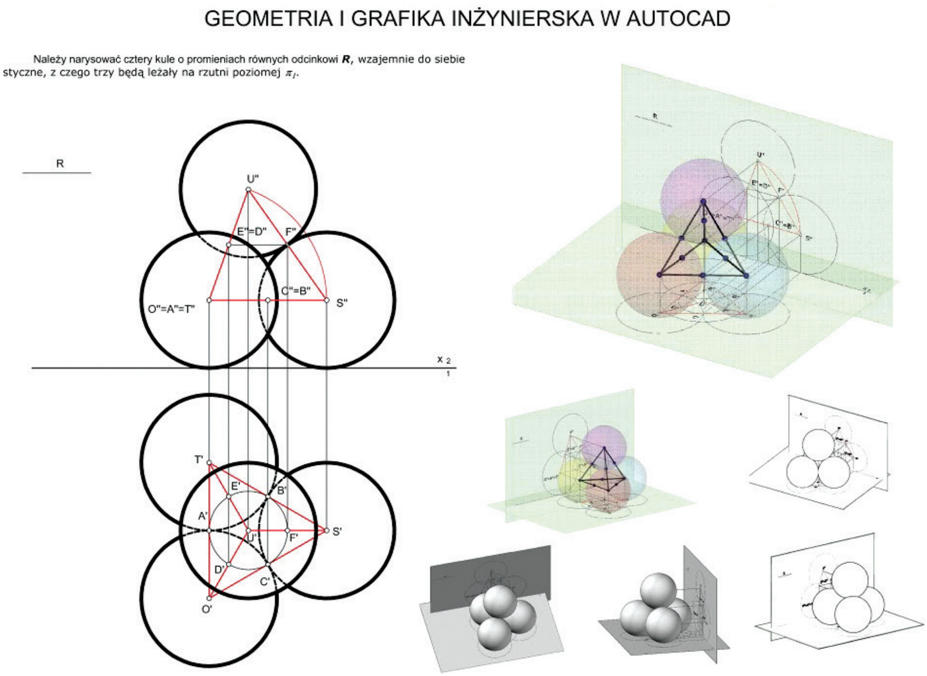
Ill. 2. View of the e-learning site of the course Geometry and Graphics in AutoCAD

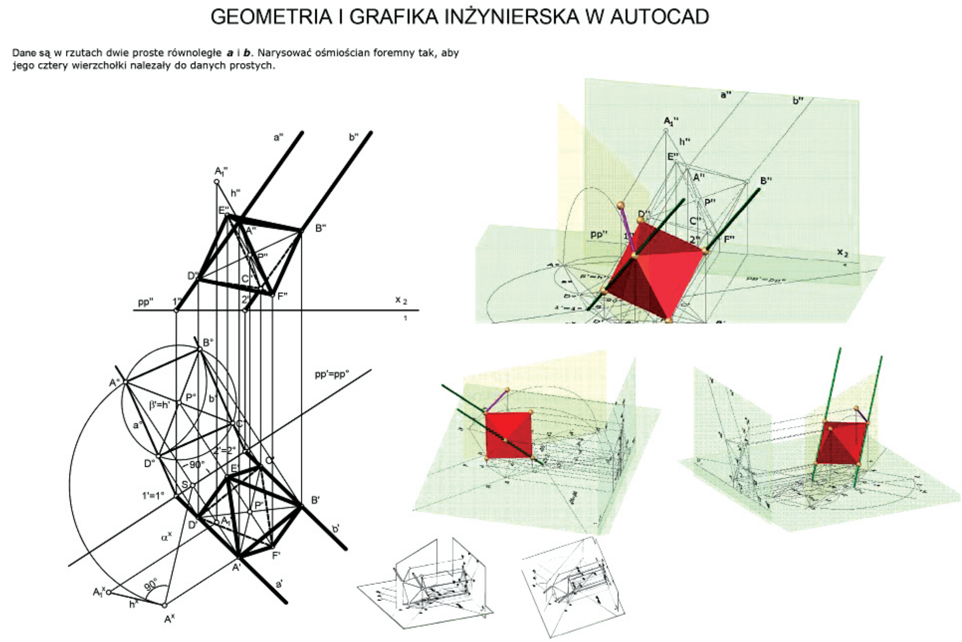


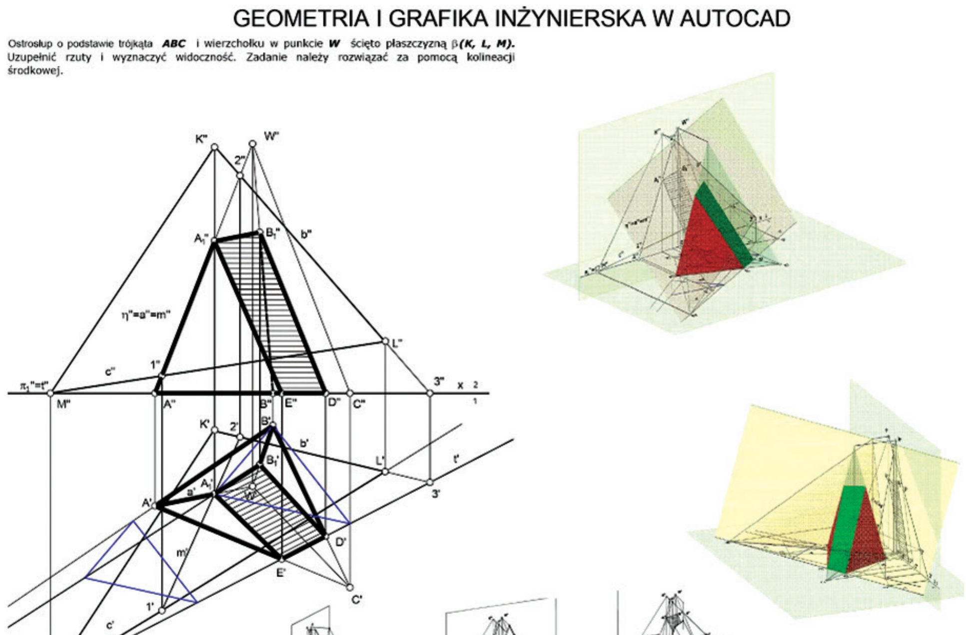
Ill. 3. Examples of various geometric-engineering problems solved during the classes



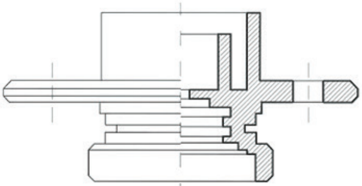
Ill. 4. Traction – a 2D drawing along with dimensioning and a raster image of a 3D model created by a student



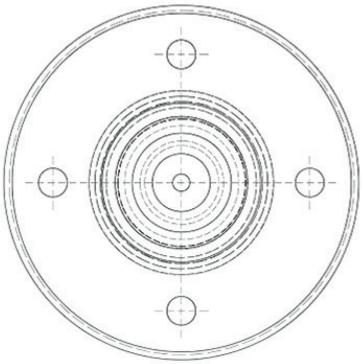




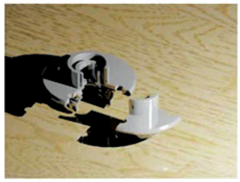
Ill. 5. Specimen posters made by students. Each one contains the topic of the problem, geometric solution as well as a representation of the 3D model showing the existent system

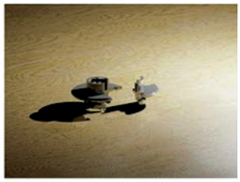


PÓŁWIDOK-PÓŁPRZEKRÓJ

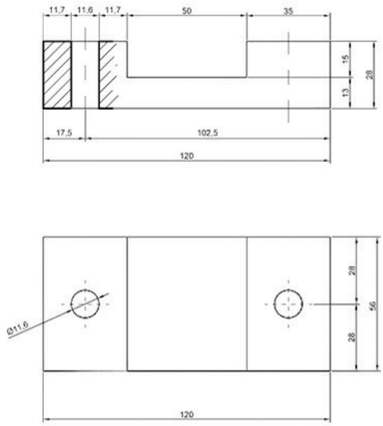


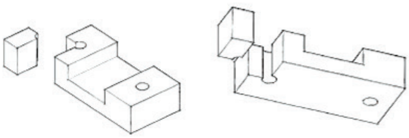
RZUT

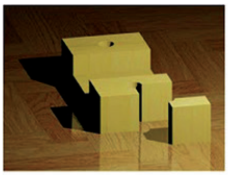


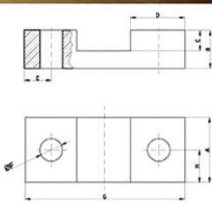


Politechnika Krakowska Wydział Inżynierii Elektrycznej i Komputerowej	2014 2015	4CM
Michał Gliński	15	



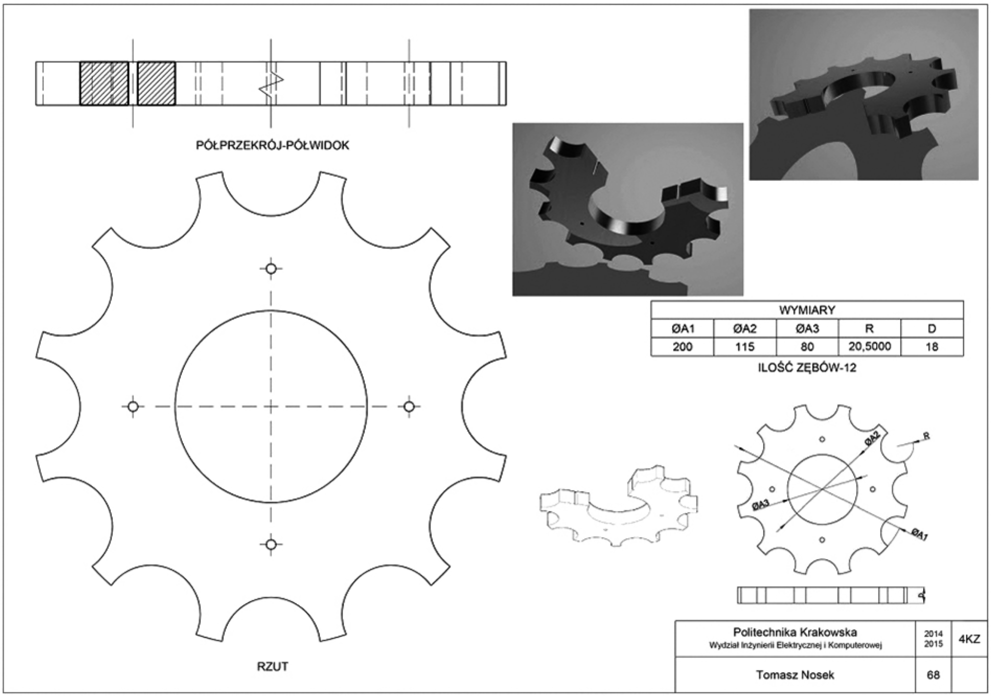




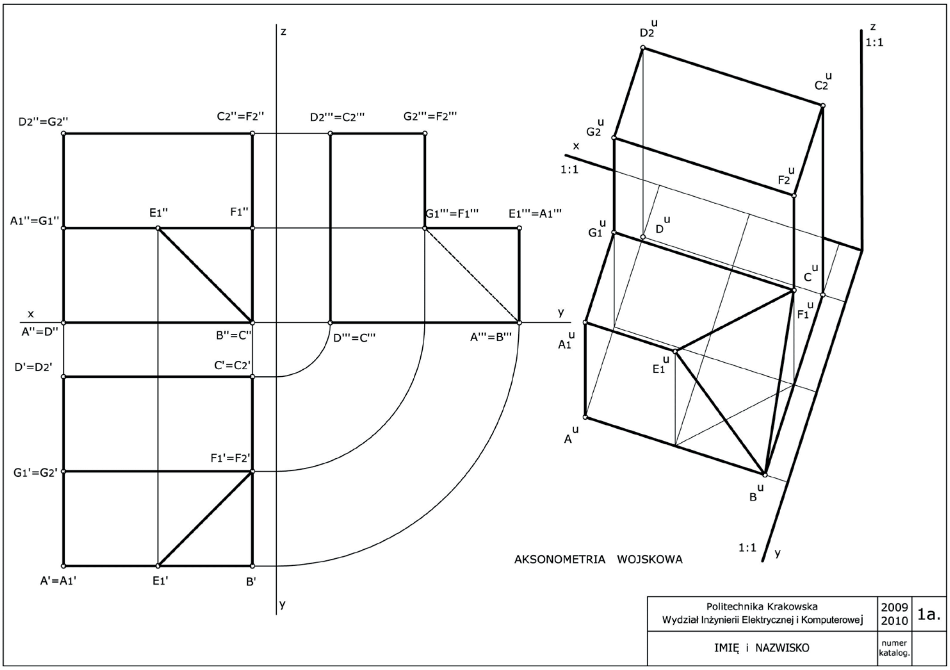


WYMIARY	
A	56
B	28
C	15
D	35
E	17,5000
F	11,6000
G	120
H	28

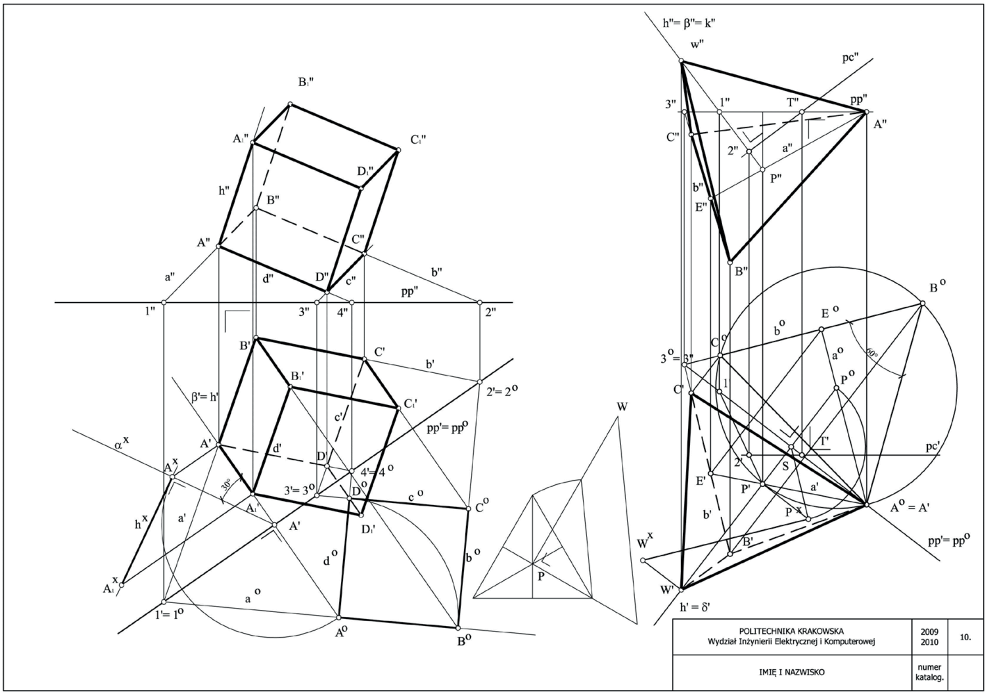
Politechnika Krakowska Wydział Inżynierii Elektrycznej i Komputerowej	2014 2015	4K
Michał Gliński	15	



Ill. 6. Various mechanical part developed by the students



Ill. 7. Based on two existing projections students construct a third one, label appropriately all the vertices, and then draw the axonometry of the system (developed by Beata Vogt)



Ill. 8. Exercises with polyhedrons solved with the traditional methods (developed by Beata Vogt)

References

[1] *Geometria i Grafika Inżynierska w AutoCAD* [Wydział Inżynierii Elektrycznej i Komputerowej > Studia Stacjonarne I Stopnia > Elektrotechnika > Semestr I]; http://elf2.pk.edu.pl/course/view.php?id=578 (online: 26.02.2015).

[2] *eLearning − nowe możliwości*, http://www.learning.pl (online: 15.03.2015).

[3] *E-learning*, https://pl.wikipedia.org/wiki/E-learning (online: 15.03.2015).

[4] *Educational technology*, https://en.wikipedia.org/wiki/Educational_technology (online: 30.11.2015).

[5] *E-learning (Theory)*, https://en.wikipedia.org/wiki/E-learning_%28theory%29 (online: 30.11.2015).

TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
ARCHITECTURE | ARCHITEKTURA
11-A/2015

AGNIESZKA WOJTOWICZ *, BARBARA WOJTOWICZ**

THE PERSONAL NEED FOR STRUCTURE AS A FACTOR AFFECTING THE UNDERSTANDING AND PROJECTING OF COMPLEX SPACIAL STRUCTURES

POTRZEBA STRUKTURY JAKO CZYNNIK WPŁYWAJĄCY NA ROZUMIENIE I PROJEKTOWANIE ZŁOŻONYCH STRUKTUR PRZESTRZENNYCH

A b s t r a c t

Creativity and understanding of complex spatial structures are required from architects. Thereat, avoiding the uncertainty and the necessity of simplifying complex structures may, in consequence, lead to an inadequacy of the effect of their work. Employing the scales of Personal Need for Structure (PNS) and PNS-Geometry served to determine if the individuals with strong intensity of these qualities will have problems with understanding construction of complex spatial structures and correct solving of geometrical problems. The results of the preliminary research appear to validate the thesis.

Keywords: Personal need for structure, architecture, geometry

S t r e s z c z e n i e

Od architektów wymaga się kreatywności oraz zdolności rozumienia konstrukcji struktur przestrzennych. Z tego powodu unikanie niepewności i konieczność upraszczania złożonych struktur mogą powodować, że efekt pracy architektów nie będzie odpowiedni. Wykorzystując skale Indywidualnej Potrzeby Struktury (PNS) i PNS-Geometria, starano się określić, czy rzeczywiście osoby, u których natężenie tych cech jest wysokie, będą miały problem z rozumieniem konstrukcji złożonej struktury przestrzennej i prawidłowym rozwiązywaniem zadań geometrycznych. Wyniki pilotażowego badania wydają się potwierdzać tę tezę.

Słowa kluczowe: potrzeba struktury, architektura, projektowanie, geometria

* Ph.D. Agnieszka Wojtowicz, Psychology Department, Faculty of Physical Education and Sport, University of Physical Education in Krakow; agnieszka.wojtowicz@awf.krakow.pl.

** Ph.D. Barbara Wojtowicz, Division of Descriptive Geometry, Technical Drawing & Engineering Graphics, Faculty of Architecture, Cracow University of Technology; wojtowiczbm@gmail.com.

1. Introduction

Every individual has to deal with the complexity of the environment that he/she lives in. No matter whether we examine the biological or the social environment, the amount of analysed data is enormous, whereas our cognitive resources are limited [9]. Therefore, it has become necessary to find ways to reduce the information load. Two types of strategies used for this can be distinguished [10].

First of all, there is the avoidance strategies, which limits the amount of information to which individuals are exposed. Included here are all of the behaviours creating the barriers between an individual and the environment e.g., putting on earphones and listening to music while using public transportation, or building high fences around houses, gardens or housing developments [10]. These strategies can also be observed in the case of people who intentionally ignore social stimuli e.g., by avoiding eye contact.

The other way of reducing the cognitive load are the strategies allowing to organize the world into a simplified, more manageable structure. Cognitive structuring refers to creating and using abstract mental representations, like schemas, scripts, attitudes, and stereotypes, which are simplified generalizations of previous experiences [15, 1, 8].

The need to simplify the structure will also manifest through difficulties in integrating multiple pieces of information at the same time, which might explain why integrating mathematical data or dealing with constructional geometrical tasks may be more difficult for some people.

Even in case of planar geometrical constructions, which we execute in the image plane and which are graphical representations of complex three-dimensional structures, require the designer to have the ability to correctly understand spatial relations existing between the spatial objects. Being one of the primary elements of spatial orientation, the perception of shape depends heavily on the integration of sensory information in cortical centres [7]. Despite the fact that the image on the retina is two-dimensional, the reality is perceived as three-dimensional, and the spatial relations between objects are precisely determined [16][17]. However, while performing constructional geometrical tasks, we do not rely on experience; instead we need to read the projections of spatial elements correctly. The ability to analyse the information related to the objects, which are mathematical structures, is essential. One has to visualise the principles of projecting separate elements, which do not emerge from the intuitive, automatic processing of the visual stimuli. Individuals who avoid complexity in social situations and who impose an incorrect, simplified structure on these experiences may also have a tendency to oversimplify mathematical (and also geometrical) complexity, which will lead to inappropriate integration of information and drawing false conclusions [13]. Neuberg and Newsom performed a study pertaining the ability to categorise (based on abstracting) with reference to a non-social environment overstimulating with information [10]. The Participants were presented with various images, which they were to group at their own discretion. The individuals with a stronger need for simple structure created larger, less complex categories, simultaneously demonstrating lower flexibility and associating each of the elements only with one category, as opposed to the individuals with a lower need for simple structure. This might suggest that the ability to analyse the qualities of objects, in the case of individuals with a strong need for simple structure, is constrained by the inability to deal with too many stimuli, and by the necessity to reduce cognitive overload.

Architects need to have a theoretical background in architectural design, construction and building. On the other hand, the final effect of their work is an individual architectural composition, which should express their emotions, experiences, which has to be open for the mutual understanding with the recipient, and which should have a personality [11]. The need for a simple structure and reluctance to go beyond clichés might prevent projecting on this level of proficiency, which will cause the design to reflect neither the individualism of the architect nor the personality of the client. It is explained by the fact that creativity requires some doze of tolerance for ambiguity, which the subjects with a high need for structure lack [3, 4]. Neuberg and Newsom [10] suggest that the Personal Need for Structure is related to the lower level of Openness to Experience – a trait strongly associated with creativity [6]. In Rietzschel's, Slijkhuis' and Van Yperen's studies [12], the negative correlation between creativity and the need for simple structure was observed, especially in case of tasks without a detailed, step-by-step instruction.

The aim of the research presented here was to determine whether high level of Personal Need for Structure is related to the lower performance on tasks in terms of understanding the construction of complex spatial structures. The secondary goal was to answer the question, if high level of Personal Need for Structure reduces the level of creativity in the architectural design process.

2. Method

2.1. Participants

The participants comprised of forty undergraduate students of the first year at the Faculty of Architecture of Cracow University of Technology (30 women and 10 men).

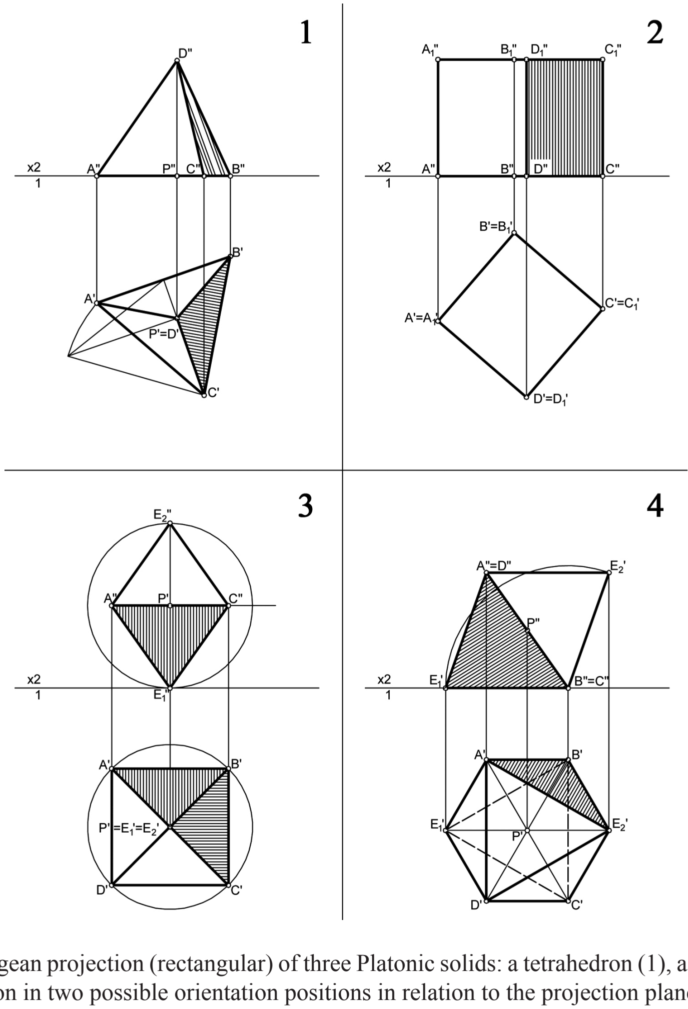
2.2. Research tools

The Polish version of Personal Need for Structure scale (PNS) [14, 15] was used. The scale consists of 12 statements (e.g.: "I become uncomfortable when the rules in a situation are not clear", "I don't like situations that are uncertain" – full scale in Neuberg and Newsom [10]), to which participants ascribe numbers from 1 ("strongly disagree") to 6 ("strongly agree"). The higher the score, the higher the motivation to create simple structures. Beside the general result, the scale allows to describe two qualities: the need for structure in everyday life (PNS Desire for structure – items: 3, 4, 6 and 10) and the way of reacting to the lack of structure (PNS Response to lack of structure – items: 1, 2, 5, 7, 8, 9, 11, 12). Due to its weaker connection with other statements, item no. 5 was not included in the general result, nor in any of the sub-scales [10]. The scale allows to determine the extent to which an individual prefers structuralization and organizing experiences, without referring to social or political issues.

For the purpose of the study, an additional tool was devised: the Personal Need for Structure – Geometry (PNS-Geometry). It was based on the English version of PNS scale, which was adapted for the purpose of measuring the need for structure with a reference to mathematical data [13]. In the primary version, the scale had 12 items, to which participants were to answer using a six-item scale, analogical to the original PNS scale. However, during the statistical analyses it was decided that only 11 items would be used.

2.3. Geometrical tasks

The study has used the construction of three Platonic solids (Mongean projection method): a tetrahedron, a cube and an octahedron in two possible orientation positions in relation to the projection plane (with one position to choose from two options). The participants were to draw two views (a front view and a top view) of each of the Platonic solid, with one of the solid's faces lying in the horizontal picture plane. In the case of a tetrahedron, the task boiled down to constructing its height in the top view, which in sequence allowed to draw the front view of the tetrahedron. During the construction of a cube, it was necessary to take into account the fact that its edge length equals the length of the square's side. In the case of an octahedron being placed in the position in which one of its faces belongs to the horizontal picture plane, it was required to construct the distance between its two opposite faces in the top view and then to draw the front view. In the second position, in which one of the apexes



Ill. 1. The Mongean projection (rectangular) of three Platonic solids: a tetrahedron (1), a cube (2) and an octahedron in two possible orientation positions in relation to the projection plane (3, 4)

of the octahedron is lying in the horizontal picture plane while simultaneously one of its diagonal planes, which is a square, is parallel to the horizontal picture plane and its other diagonal square is parallel to the frontal picture plane, it was required to consider the fact that the distance between the opposite apexes is equal to the diagonal of the square. All used geometrical tasks are presented in the Illustration 1.

In the evaluation process two factors were taken into consideration: the understanding of the solid's construction and the ability to correctly label visible (with a continuous line) and hidden edges (with a dashed line) of each of them.

With the consent of the participants, the analyses also included the results of the mid-term test and the final exam grades taken in the "Descriptive geometry" course as well as the final grade from the course of "The introduction to the theory of architectural and urban design". In the last course, students were graded for doing individual design projects of the business premises to which the assumption was that the space was built-up by using a few solids. This piece of work was entitled: "the inside, the light and the shade".

2.4. Procedure

The participants attended a lecture on Platonic solids, after which, and based on which (not being allowed to look into the notes), they were asked to solve geometrical problems and fill in the PNS-Geometry scale. After a week, the subjects were asked to do the Personal Need for Structure scale. Since the research was conducted during regular classes, not all of the participants were present in both parts of this research.

2.5. Statistical analyses

The analyses were conducted with the use of statistical analysis software STATISTICA 10. In the analysis of the structure of PNS-Geometry scale, the exploratory factor analysis and the reliability analysis of the obtained factor structure were made. Moreover, the correlation analyses and t-tests were conducted. The level of the statistical significance was assumed as $\alpha = .05$. Considering preliminary character of the research and a rather small group of samples, the results in which the statistical significance level alpha is less than one ($\alpha < .1$) have also been presented.

3. Results

3.1. The analysis of the PNS-Geometry structure

Bartlett's test ($\chi^2(66) = 112.20$; $p < 0.001$) and the KMO = 0.55 factor showed heterogeneity of the factor matrix, which justifies the usage of factor analysis [5]. As the criteria for determining the amount of the factors, the Kaiser's criterion (eigenvalue larger than one) and the Cattell's criterion (based upon the factor scree plot) were used [5]. After taking them into account, the structure with three and four factors was chosen. The Varimax rotation showed, that a three-factor structure is better adjusted to the analysed factors (Table 1).

Table 1

Varimax rotation – loads >.55 are presented

Item	Factor 1	Factor 2	Factor 3
It upsets me when I encounter a geometrical problem unlike any problems I have encountered in the past.			0.59
When solving a geometrical task, I am not bothered when I hit a dead end and have to adopt a new strategy.			–0.68
When approaching geometrical constructions, I enjoy having a clear and structured set of instructions.	0.81		
I feel better about geometry when I am able organize geometrical rules and concepts into simple, overarching structures.	0.82		
I am fascinated by geometrical tasks that can be approached in multiple ways.		0.68	
I find that doing geometrical tasks with a series of clear and simple steps to their solution feels boring.		–0.67	
I don't like working on geometrical tasks when I am uncertain about whether I can get the correct answers.	0.71		
I hate it when I have to change my approach to solving a particular geometrical task.		–0.69	
I hate it when geometry professors are unpredictable.			0.60
I find that having a consistent approach to geometry enables me to enjoy working geometrical tasks more.		0.55	
I enjoy the exhilaration of being presented with geometrical constructions unlike any I've ever seen before.			0.63
eigenvalues	**2.58**	**1.57**	**1.54**

The analysis showed that the full scale reached the average level of reliability (Cronbach's $\alpha = 0.61$), and a similar result was obtained for each factor (factor 1: Cronbach's $\alpha = 0.60$; factor 2: Cronbach's $\alpha = 0.56$; factor 3: Cronbach's $\alpha = 0.55$). Factor no. 1 refers to the desire for structure during the process of solving geometrical problems (e.g.: "When approaching geometrical constructions, I enjoy having a clear and structured set of instructions"). Factor no. 2 is related with the participants' reaction to the lack of structure in solving this type of problems (exemplary item: "It upsets me when I encounter a geometrical problem unlike any problems I have encountered in the past"). Factor no. 3 was described as avoiding unpredictability in geometry (exemplary item: "I don't like working on geometrical tasks when I am uncertain about whether I can get the correct answers"). To determine the relation between PNS-Geometry and the construct of Personal Need for Structure, the analysis of Pearson's correlation was conducted. The relation between the general result of PNS-Geometry and the Avoiding of Unpredictability in Geometry with general score in Personal Need for Structure was found (Table 2).

Table 2

Correlations between PNS-Geometry with Personal Need for Structure

		PNS-Geometry	**PNS-Geometry *Desire for structure***	**PNS-Geometry *Response to lack of structure***	**PNS-Geometry *Avoiding unpredictability***
PNS	***r***	0.46	0.20	0.31	0.42
	p	0.005	0.260	0.069	0.012

3.2. Comparisons of PNS and PNS-Geometry with abilities to solve geometrical problems and projecting

Due to a low number of participants, the level of significance was not reached, however, the conducted analysis of Spearman's correlation showed that the participants had the tendency to achieve lower scores in geometrical problems solved directly after the lecture, with the higher general need for structure in geometry ($rho_{N=40}$ = –0.34; p = 0.065). The participants also performed better in geometry exams, with hig her scores in the Avoiding of Unpredictability in Geometry scale ($rho_{N=40}$ = 0.29; p = 0.073). This effect was observed not only for a summary result, but also for the ability to allow for the fact that the solids be visible ($rho_{N=40}$ = 0.28; p = 0.080) and the ability to provide a correct solution for construction problem ($rho_{N=40}$ = 0.27; p = 0.096).Furthermore, it was observed that the general personal need for structure ($rho_{N=28}$ = –0.34; p = 0.080) and the difficulty in dealing with the lack of structure ($rho_{N=28}$ = –0.34; p = 0.081) were negatively correlated with participants' ability to correctly solve the constructional part of geometrical tasks.

The more detailed analyses within each constructional problems showed that subjects who provided correct solutions for the tetrahedron task had lower levels of Personal Need for Structure (on the edge of statistical significance, also for both PNS sub-scales), and scored lower on Avoiding of Unpredictability in Geometry scale, than the subjects who did not solve the problem correctly (Table 3).

Interestingly, PNS was not significantly related to any of the abilities measured during the examination and the test from the "Descriptive geometry" course.

Table 3

The differences in level of PNS-Geometry and PNS for correct and incorrect solutions of tetrahedron task

	M_0	M_1	t	df	p	N_0	N_1	SD_0	SD_1
PNS-Geometry	50.83	47.00	1.62	28	0.117	12	18	5.52	6.83
PNS-Geometry *Desire for structure*	15.33	14.72	0.70	28	0.488	12	18	1.97	2.54
PNS-Geometry *Response to lack of structure*	18.25	18.06	0.16	28	0.878	12	18	2.96	3.61
PNS-Geometry *Avoiding of unpredictability*	17.25	14.22	2.38	28	0.024	12	18	3.41	3.41
PNS	47.73	40.71	2.22	26	0.035	11	17	8.13	8.19
PNS *Desire for structure*	17.27	14.47	1.98	26	0.058	11	17	4.34	3.14
PNS *Response to lack of structure*	30.45	26.24	2.00	26	0.056	11	17	4.68	5.90

0 – group with incorrect solution of tetrahedron task.
1 – group with correct solution of tetrahedron task.

3.3. Comparisons between particular abilities developed during the classes on "Descriptive geometry" and "The introduction to the theory of architectonic-urban projecting", and the performance in solving geometrical problems

Relationships between the results of the test, the examination in the "Descriptive geometry", grades in projecting, and the results in geometrical problems solved directly after the lecture were also analysed. The results in solving the geometrical problems were associated exclusively with the test scores. It was observed that, along with the increase in the performance in solving problems in the constructional part, the level of performance in the test also increased (visibility criterion: $rho_{N=40} = 0.45$; $p = 0.012$; construction criterion: $rho_{N=40} = 0.48$; p=0.008; general score of the test: $rho_{N=40} = 0.46$; $p = 0.010$). Moreover, the higher the general result in solving the geometrical problem, the higher was the performance in the constructional part of the task during the test ($rho_{N=40} = 0.37$; $p = 0.042$).

What is more, the results of the examination and the evaluation of architectural projects were not significantly related to the level of solving geometrical problems.

It was also observed that the grades in architectural projects were positively correlated with the results of the test ($rho_{N=40} = 0.36$; $p = 0.022$) and the results of geometry exam ($rho_{N=40} = 0.47$; $p = 0.002$).

4. Discussion

The obtained results show specific relationships between the personal need for structure, the personal need for structure in geometry, and the ability to correctly analyse and integrate information about construction of complex spatial structures. The discovered tendencies seem to show that, with the increase in the need for simple structure and for Avoiding of Unpredictability, the numbers of mistakes in the complex geometrical understanding grow, which in consequence leads to errors in the constructional solutions. This regularity was observed only in the case of formerly unlearnt abilities. However, when subjects were able to learn and prepare themselves in advance – even without understanding how to solve specific constructional problems – the tendency was opposite. This implies that subjects with a stronger need for simple geometrical structure were dealing better in this case, since their ability to avoid unpredictability in geometry could have resulted in paying more attention to mastering the required material. Consequently, the participants with low levels of this trait have relayed more on their general abilities – not skills – which, in a situation as stressful as examination, might have led to making mistakes.

The lack of significant correlations between grades in the projection design and the results from the examination in geometry with the ability to understand complex spatial structures, and the openness to ambiguity and novelties, might signalize that, during the process of architectural education, and for the final evaluation, the abilities connected with reproducing of the already-known structures are more important than innovative designing of space, which is of secondary importance. Or that the tasks involving the creativity are very structured, which significantly facilitates the functioning of individuals with high levels of PNS [12]. Those conclusions are consistent with findings stating that the individuals with the need for structure – understood as the need for any sort of answer in an unclear situation to avoid uncertainty – are less creative than those with lower intensity of this trait [4], but when task is highly structured, they could be as much creative [12]. One should bear in mind that, although the architecture is a conscious process of shaping the space in a way that would correspond with intended function – in specific construction and form [2] – relying only on known and verified schemes leads to architectural monotony and mediocrity. As a consequence, artistry – the perception of architecture as a form of art – will disappear.

The presented research obviously has a preliminary character, and hence, the formulating of final conclusions should be taken with caution. It is necessary to conduct further research in this area, perhaps taking into account other indicators of creativity in a design practice, and certainly conducting research on a larger sample of subjects.

References

[1] Abelson R.P., *The psychological status of the script concept*, American Psychologist, 36/1981, 715-729.

[2] Charytonow E., *Projektowanie architektoniczne*, Państwowe Wydawnictwa Szkolnictwa Zawodowego, Warsaw 1985.

[3] Chirumbolo A., Livi S., Mannetti L., Pierro A., Areni A., Kruglanski A.W., *Motivated closed-mindedness and creativity in small groups*, Small Group Research, 36/2005, 59-82.

[4] Chirumbolo A., Livi S., Mannetti L., Pierro A., Kruglanski A. W., *Effects of need for closure in small group interactions*, European Journal of Personality, 18/2004, 265-278.

[5] Czopek A., *Analiza porównawcza efektywności metod redukcji zmiennych – analiza składowych głównych i analiza czynnikowa*, Zastosowania metod matematycznych w ekonomii i zarządzaniu, 7/2013, 7-23.

[6] George J.M., Zhou J., *When openness to experience and conscientiousness are related to creative behavior: An interactional approach*, Journal of Applied Psychology, 86/2001, 513-524.

[7] Grabowska A., *Percepcja wzrokowa i jej analogie do innych form percepcji*, [In:] *Mózg a zachowanie*, eds. T. Górska, A. Grabowska, J. Zagrodzka, PWN, Warszawa 2000, 147–183.

[8] Fiske S.T., Taylor S.E., *Social cognition: From brains to culture*, Sage, London 2013.

[9] Kahneman L., *Attention and effort*, Prentice-Hall, Englewood Cliffs, New York 1973.

[10] Neuberg L., Newsom J.T., *Personal need for structure: Individual differences in the desire for simpler structure*, Journal of Personality and Social Psychology, 65(1)/1993, 113-131.

[11] Nowakowska Z., *Architektura mieszkaniowa - sztuka szczególnie odpowiedzialna*, [In:] *Wprowadzenie nowej tkanki mieszkaniowej w istniejące struktury zabudowy miejskiej*, eds. Z. Nowakowska, Agencja wydawnicza ZEBRA, Kraków 2000, 6-9.

[12] Rietzschel E.F, Slijkhuis J.M., Van Yperen N.W., *Task structure, need for structure, and creativity*, European Journal of Social Psychology, 44(4)/2014, 386-399.

[13] Sarnataro-Smart S., *Personal Need for Structure: Indiscriminate Classification Systems As Barriers to Processing Mathematical Complexity*, Honors Thesis Collection, Paper 110, 2013.

[14] Thompson M.M., Naccarato M.E., Parker K.C., Moskowitz G.B., *The personal need for structure and personal fear of invalidity measures: Historical perspectives, current applications, and future directions*, [In:] *Cognitive social psychology: The Princeton symposium on the legacy and future of social cognition*, eds. G.B. Moskowitz, Lawrence Erlbaum Associates, Mahwah, New York 2001, 19-39.

[15] Thompson M.M., Naccarato M.E., Parker K.E., *Assessing cognitive need: The development of the personal need for structure and personal fear of invalidity scales*, Annual Meeting of the Canadian Psychological Association, Halifax – Nova Scotia 1989.

[16] Vishwanath D., Van Tonder G.J., Albertazzi L., *Perception Beyond Inference: The Information Content of Visual Processes*, MIT Press, Cambridge – Mass 2010.

[17] Wagemans J., Elder J.H., Kubovy M., Palmer S.E., Peterson M.A., Singh M., von der Heydt R., *A Century of Gestalt Psychology in Visual Perception: I. Perceptual Grouping and Figure-Ground Organization*, Psychological Bulletin, 138(6)/2012, 1172-1217.

CONTENTS

SPIS TREŚCI