Transdisciplinary Lifecycle Analysis of Systems
R. Curran et al. (Eds.)

doi:10.3233/978-1-61499-544-9-647

Improving the Ability of Future Engineers by Using Advanced Interactive 3D Techniques in Education

Wojciech SKARKA[1], Marek WYLEŻOŁ, Marcin JANUSZKA, Sebastian RZYDZIK, and Miroslaw TARGOSZ
Institute of Fundamentals of Machinery Design at Silesian University of Technology, Gliwice, POLAND

Abstract. For technical field a lot of issues which are necessary to understand the subject is adjustable in the sphere of abstraction. For people, who do not have adequate knowledge, imagining even a simple element/assembly based on its orthogonal projections is not a significant problem. Such problems are well known and are the main goal of our research. The objectives of the project InterEdu was mainly to increase the quality of education. The ability to apply the techniques of passive and active 3D is assumed by default for the future engineer applying concurrent engineering methods. Aiding the teaching process with the use of a system which allows presentations of knowledge and data in a 3D virtual reality environment should result in a more efficient way to browse, evaluate, interpret and hence better understand the presented contents. The application of these techniques in a variety of courses not only makes it easy to explore the content of these courses but also allows students to become familiar with the use of sophisticated data visualization and to cooperate in various fields. The aim of the validation studies was to evaluate the operation and usefulness of the system in the context of its use in order to facilitate learning. The evaluation has been subjected to issues how the visualization of knowledge influences the effectiveness of the process of teaching. The students, taking part in the evaluation process, indicated the usefulness of this system in the teaching process. The InterEdu system improves the process of education and effectively aids the students who have difficulties in the content interpretation, especially at the earlier years of study.

Keywords. computer-aided design, concurrent engineering education, interactive presentation, virtual reality

Introduction

Virtual Reality (VR) and three-dimensional visualization is an object of interest of many scientific and research centers around the world [1]. A number of projects aimed at studying the usefulness of the stereographic visualization [2,3] were implemented [14,17]. The authors studied the influence of the use of the HMD and anaglyphic glasses [5,6,7,8,10] among students of technical studies. In this very interesting work [14] the authors test usability of VR in Mechanical Design Course using different VR technologies [11]. In medicine teaching stereographic display is often used [15]. The authors of [18] compare and evaluate ways of display images “Pseudo 3D” from the

[1] Corresponding Author, E-Mail: Wojciech.Skarka@polsl.pl.

"traditional 3D image" that is, created using the passive glasses red/green and the method of displaying images with using active glasses.

During technical studies, especially at faculties of mechanical engineering, "Pseudo 3D" display is often used while working with CAD, CAE programs [25]. In the case of programs for modelling and drawing, stereographic image display is the next step after the computer programs for 2D drawing (e.g. AutoCAD) and 3D programs (e.g. CATIA, Inventor, NX). Some programs such as CATIA V5 allow to generate stereographic images. Nevertheless, special monitor and a suitable graphics card are necessary. Physics of images generation in this mode entails creating more of image frames, which is an additional load for the computers. For this reason, this operating mode is not often used in the daily work.

Problems of visual interpretation [24] apply to courses realized at engineering studies. Therefore, at the Faculty of Mechanical Engineering of the Silesian University of Technology in 2010-2012 "Interactive engineer education" (InterEdu) project was realized [9]. The project included the development of interactive learning materials to the content of education in the following fields: Automation and Robotics, Mechanics and Machine Technology, Mechatronics Management and Production Engineering, Applied Automation with Computer Materials Science, Nanotechnology and Material Processes Technologies [9]. The project consisted in the development of new, interactive didactic aids to the content of education in the scope of lecture topics at these fields of studies. The objectives of the project was to increase the attractiveness of the educational offer, students' interest in technical studies and the quality of education [9]. The developed teaching aids in the form of lectures of interactive, 3-dimensional presentations, were implemented up to 21 courses, grouped into 4 areas: Mechanics, Technology and manufacturing, Design and operating of machinery, Material science.

One of the tasks was to prepare a series of lectures for the course "Computer-aided design and manufacturing". The main problem was the use of new techniques in the field of the key subject having an impact on the development of 3D perception possibilities [25], but also a key subject in the design record of concurrent engineering activities. This task was prepared at the Institute of Machinery Design, which from many years has been dealing with machinery design, methods of acquiring knowledge and computer aided design.

The authors' many years of experience in conducting this type of courses, it can be concluded that most of the students have serious problems with the interpretation of many of the concepts discussed in the framework of the subject "Computer Aided Design". CAD course is carried out through a series of lectures in the number of 15h and 30h of projects classes, where students use specialized software CAx – CATIA v5 and Autodesk Inventor.

Based on the authors' many years of experience in conducting this type of courses, it can be concluded that most of the students have serious problems with the interpretation of many of the concepts discussed in the framework of the subject "Computer Aided Design". CAD course is carried out through a series of lectures in the number of 15 and 30 hours of projects classes, where students use specialized software CAx – CATIA v5 and Autodesk Inventor.

Components modelling using solids and surfaces do not cause many problems for students, neither does assembly modelling. Difficulties arise during creation and verification of a flat technical documentation. Experienced CAD users very often use e.g. cross-sections at 2D documentation to verify the correctness of modelled element.

During the course, this procedure is very rarely used among students. It may be presumed that the reason of this is the lack of understanding of 2D documentation. Although 3D CAD programs have existed for many years, preparing flat documentation is one of the most commonly used tools, and teaching these modules cannot be ignored and skipped as archaic (not used) techniques.

The article presents the results of the research carried out on a large group of students from two fields of study: Automation and Robotics and Mechanics and Machine Technology. One group of research participants were MA students who already held the above courses and often implemented theses, using many different programs of CAx class. In contrast, the second group of research were students of engineering studies at the third year for which CAD course is implemented after such course as Design Representation and Fundamentals of Machinery Design.

1. Description of traditional methodology of teaching CAD

At the Faculty of Mechanical Engineering of the Silesian University of Technology there are approximately 2500 students. Teaching covers 7 courses, and the courses with the greatest number of students are Mechanics and Machine Technology, Automation and Robotics and Mechatronics. At the main course i.e. Mechanics and Machine Technology teaching and using methods of Computer Aided Design (CAD) play a key role of education. There are a few hundred students studying at this course and the subjects related to the use of the methods and techniques of CAD are one of the core domains.

Teaching content related to Computer Aided Design is given during the entire two-cycle studies both at the first cycle of engineering studies and the second cycle of Master degree. First of all, the issues are presented in a series of CAD subjects of Fundamentals of Machinery Design. During the classes of the first subject of this block i.e. Engineering Graphics the students get to know not only the basic issues of today's CAD systems, namely Monge projection, but also the basics of Computer Graphics. Within the scope of Design Representation subject, in addition to the traditionally performed drawings, students perform tasks and projects using 3D CAD – Autodesk Inventor. So the students prepared in this way with the skills of using CAD class 3D and the knowledge of design representation both in the form of technical drawings and in the form of 2D and 3D design representation, proceed to the main subject of this block i.e. Fundamentals of Machinery Design. The syllabus of this subject covers the areas of the methods and basis of design. Students after completing this subject continue with Computer Aided Design (CAD), which improves design methods using the advanced class system CAx – CATIA. During this subject students acquire both theoretical knowledge of the issues of CAD, and also practical skills at computer classes and projects using this system [15]. At the end of the first cycle of studies, students who want to specialize in the design take an opportunity of making an individual project in order to gain additional skills of using advanced CAx system. It also happens that undergraduate students choose very ambitious tasks, working in many students' associations, which can be individual or team tasks and take part in many national and international competitions [4,16,20].

At the second cycle of studies specific issues related to Computer Aided Manufacturing, concurrent engineering using CAE methods are introduced. All these issues require intensive and fluent use of CAx systems skills. As a part of scientific associations, students continue to develop their skills in specialized areas e.g. KBE systems [19,22]. Students also often get involved in the research implemented by the faculty units, taking part in research projects [4,16,20]. A unique opportunity to improve team design methods of concurrent engineering and advanced CAD systems are all kinds of competitions, including global ones [23]. It is quite often that the technical and scientific level which is imposed by global competition pays off in the research [4,16,20].

2. Description of CAD task of Interedu project

The task of preparing teaching materials in subjects related to computer aided design has one outstanding feature compared to other subjects: it is extremely time consuming. This is due to a significant amount of content at which the spatial characteristics is used. For some subjects 3D does not play a significant role. In the case of the subject where the essence is the modelling of spatial objects and the issues directly associated with it, the whole subject uses intensively spatial ability of human vision. However, due to the innovative nature of the project, the scope has been limited to the development of materials for the chosen content, so that they can be used in many different subjects which use computer-aided design techniques. The prepared materials included the following areas of the broad range of Computer Aided Design: Creating geometrical models, edition of point clouds and modelling of sectional curves, evaluation of curves and surfaces, complex surfaces modelling, assemblies used in machinery construction, antropotechnical engineering systems (Fig. 1), virtual prototyping.

Figure 1. Ergonomic analysis application.

For each of the tasks the following scope of materials has been elaborated: scenario, interactive models integrated into mutual application, user manuals in Polish and English.

Regardless of the contents, all the applications reflect the same teaching methodology with the use of 3D visualization techniques. The methodology includes a repetitive scenario for creating the same applications and using them in teaching. The details of the methodology are the basis for the whole project InterEdu. This methodology will be described below for the task of teaching certain aspects of Computer Aided Design.

The new teaching materials include interactive educational presentations made and used only with stereoscopic visualization techniques. They represent qualitatively different, than previously used, didactic material. The two most important features of the new materials are: interactivity and three-dimensional visualization.

A new kind of presentation is characterized by, among others, the fact that all the elements are displayed using three-dimensional visualization techniques. This aspect is very important. By using these techniques, the image viewed by a student is independent of his point of observation. Viewed three-dimensional objects are visible regardless of the angle of observation. This increases the comfort of the observation of the scene (the scene is here equivalent to the slide). In addition, each scene can be viewed from any perspective and at different magnification. This allows you to focus students' attention to any detail of the scene, and for the students without the spatial imagination this way of scene watching is easier and moreover, makes the assimilation of a portion of the learning material easier. In addition, the selection of an appropriate surface rendering scene objects and their lighting facilitates better perception of information and knowledge acquisition.

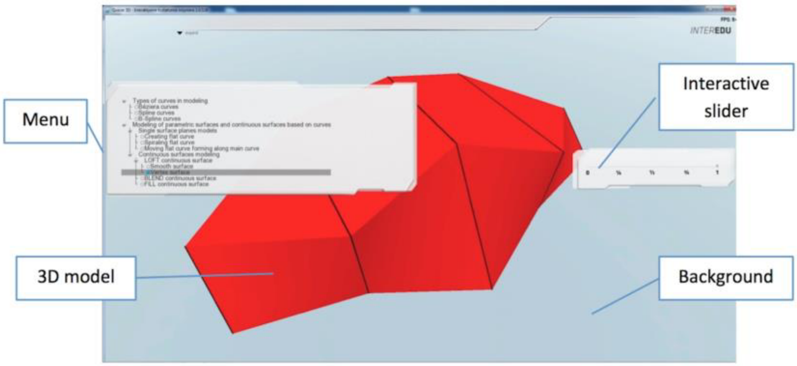

Figure 2. Main elements of exemplary scene.

The new interactive and three-dimensional presentations are composed by scenes. These scenes can be static or dynamic. The composition of the scene are: static and dynamic 3D models, two-dimensional descriptions, charts, active buttons and multi-level menu (Fig. 2). Implementation of interactive three-dimensional presentations, but also the way they are used requires the development of scenarios, made like screenplays (Fig. 3). Scenarios contain detailed descriptions of individual scenes, the order and the legitimacy of their display and their use in the teaching activities (Fig. 4). That does not mean, that the use of any scene is always described clearly; part of a teacher's activities is always possible to change, but only in a planned range (e.g. way to show the model can be different each time due to its three-dimensionality).

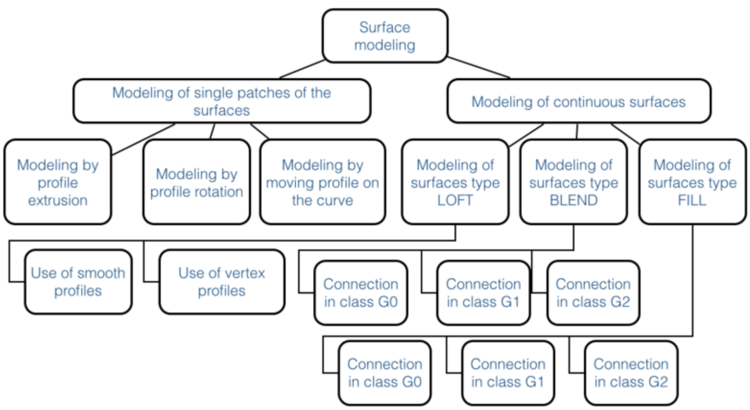

Figure 3. An example of scenario schemata.

The authors of the scenarios are teachers (in this case – academics). The content of the scenarios refers to the description of all the elements making them, multi-level menu commands, the way of interface elements use (keyboard, mouse), the deployment and the use of active keys (public – represented in the form of 2D graphics and implicit, representing fragments of 3D models of scenes).

Scenarios are necessary for programmers and graphic designers who make interactive presentations with graphics systems and programming languages. They need detailed guidance reported in the order 'from general to particular' respecting how to prepare the scene with an accuracy of each element constituting the scene, and the scope of interactivity.

All scenarios are performed using conventional text editors, usually every scene is saving in the form of an ordered table, where each cell contains all the necessary information about the scene.

Scenarios should also contain the necessary information about the shapes of all the 2D and 3D models. This information can be presented in the form of screenshots containing views of relevant models, handmade sketches or self made models. If the author of the scenario performed alone the 2D or 3D model, then usually he has to accept the fact that his model will have to be transformed to the form required by graphic designers (specifically the use of their systems). Making or verbal description of 3D models must contain all the necessary information about the geometric form of models, also with their surface details (usually imitating any material) and sometimes also their dynamic characteristics (the way of deform or way of moving).

Graphic designers and programmers also need information about the way of verification. It is the authors of the scenarios who are the first users and critics of the interactive presentations. Their comments are very important for all performers, because only the authors of the scenarios can evaluate the quality of the presentation made. Of course, the target audience of the new presentations are students, whose comments are very important not only for the performers of the presentation, but also for the authors of scenarios.

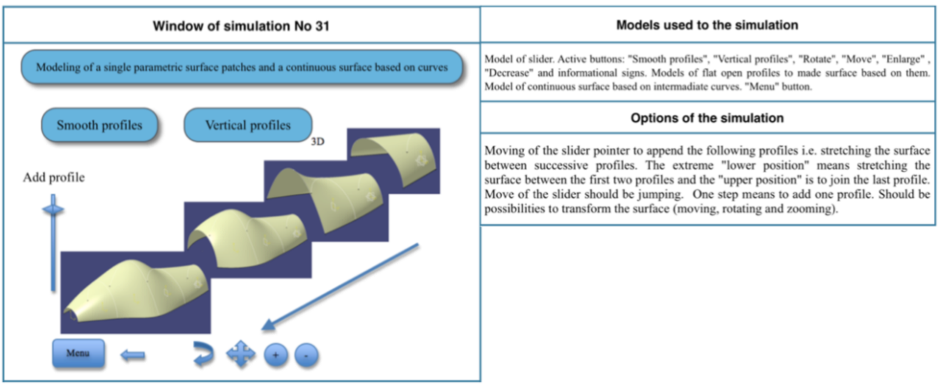

Figure 4. An example of one scene of the scenario.

Teaching with new presentations are the final part of their verification. The resulting assessment of their quality is the reason to make the necessary changes in the content of the scenarios, as well as in the construction of the scenes.

3. Validation of the InterEdu system for interactive engineer education

The aim of the validation studies in relation to the developed system was to evaluate the operation and usefulness of the system in the context of its use to facilitate learning during the two courses i.e. Computer-Aided Design and Design Methodology. The evaluation has been subjected to issues how the visualization of knowledge (and thus the virtual reality system InterEdu) influences the effectiveness of the process of teaching for the two groups of students: early years of study (first cycle BSc studies) and subsequent years of study (second cycle MSc studies).

To evaluate the quality of the system quantitative and qualitative measures were selected (related to e.g. ease of use and technical quality of the visualization, the simplicity in the interpretation of knowledge, usability of knowledge, possibilities of interaction). Aiding the teaching process with the use of a system which allows presentations of knowledge and data in a three-dimensional virtual reality environment should result in a more efficient way to browse, evaluate, interpret and hence better understand the presented contents.

3.1. Participants of experimental studies

Experimental studies have been carried out with the participation of a group of students consisting of 66 people. The students were divided into two groups: students of the first cycle of studies (group II), and subsequent years students – second cycle (group I). The students were studying in the Mechanical Engineering field of study. A subset of first-level students consists of 51 people, and the second level of 15 people.

3.2. Test environment

The test environment has been prepared on the basis of the system InterEdu. The validation process of the developed system was implemented in the form of a lecture. The lectures for each of the groups were realized in two rooms. Classes lesson for students of second cycle were realized with the use of a mobile version of the system InterEdu. Classes for students of second cycle took place in a lecture hall with a permanently installed system InterEdu (static version).

3.3. Plan of validation

Effectiveness in the teaching process with the use of InterEdu system and student satisfaction were examined for both groups of students. The validation of the system was assessed with the use of induction method, according to the following plan:

- Training of the participants.
- Presentation of the lecture with the use of InterEdu system.
- Evaluation of the system in order to verify a possibility of aiding a teaching process.

3.4. Evaluation of the system

The evaluation of the system was mainly in qualitative form. The primary tool used to evaluate the system were questionnaires developed for the experimental studies. The questionnaires were filled in by the students after the lecture. Each questionnaire contained 10 statements to which the participants had to respond: 1. the mechanism of interaction with the virtual objects was intuitive and natural, 2. the InterEdu increases spatial impression during the presentation of spatial objects, 3. it is possible to effectively analyse objects from multiple points of view, 4. it is possible to effectively manipulate virtual objects in InterEdu virtual environment, 5. there were delays between actions of operator and the system response to them, 6. the image quality of the display interferes or distracts attention from the presented content, 7. the knowledge displayed by the InterEdu system was useful, 8. the system makes it easy to visualize the results of designer's work (his/her projects), 9. InterEdu system allows better understanding and interpreting design solutions, 10. a lecture aided by InterEdu system is better than the traditional lecture.

The participants responded to statements using a seven-point Likert scale [12]. The scale rating was determined by evaluation from 1 – strongly disagree, through 4 – I do not have opinion, up to 7 – strongly agree. The questionnaire also included several open questions. These questions should allow to evaluate the strengths and weaknesses of the InterEdu system. The choice of the form of the questionnaire was mainly determined by the fact that the assessment should not take a lot of time. The statements to the questionnaires were chosen and constructed to permit simplicity, comprehensiveness and overall usability of developed InterEdu system in aiding the presentation of the content during the lecture.

The statements to which students responded were assigned to the following categories of evaluation: substantive quality (Merit) - (statement 7 and 9), the ability to interact (Inter) - (1 and 4), the effectiveness of visualization (Visual) - (3 and 8), technical quality (Techn) - (2, 5 and 6), overall usability (Sum) - (10).

3.5. The results of usability evaluation

The selected qualitative scale (for the statements in the questionnaires), with the use of which the students evaluated the system has been converted to the new scale from 1 to 7 (Fig.5), where: from 1 to 2.5 failing grade, from 2.5 to 3.5 satisfactory grade, from 3.5 to 4.5 assessment neutral, from 4.5 to 5.5 good grade, from 5.5 to 7 very good grade.

Category *Substantive quality* allows to evaluate the thematic content presented during a lecture using the InterEdu system. The used InterEdu system should allow to present useful knowledge in accordance with its current state-of-the-art level and allow to interpret the presented knowledge. The students evaluated the system in this category as good. The system has been evaluated at 5.1 by the students of secondary cycle and at the level of 5.2 by the students of the first cycle. For the students of second cycle evaluation in this category received the highest score among all the categories of evaluation. The realized analysis of variance showed that the difference between the mean values, for the adopted level of significance $\alpha=0.05$, for both groups is irrelevant.

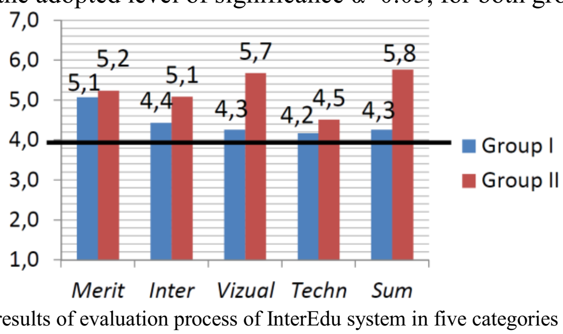

Figure 5. The results of evaluation process of InterEdu system in five categories for the two groups of students (Group I – second cycle students, Group II – first cycle students).

Another category of evaluation: *Ability to interact* allows to evaluate interactivity of the system, namely the possibility of impact on the presentation, i.e. possibility of presenting objects comfortably from any perspective and manipulate them, and indicate different parts from the presentation. Another factor influencing the score for this category was a possibility of non-linear realization of a lecture (e.g. depending on questions arising from students).The students evaluated the system at the value of 5.1, which is a good result, while the students of secondary cycle at 4.4 which means a neutral degree. The conducted analysis of variance showed that the difference is significant from a statistical point of view. Higher evaluation by the students of the first cycle can be due to their fewer needs in relation to the interaction with virtual objects. It may be a result of their smaller amount of knowledge and less awareness of possible interactions. Therefore, for the first-cycle students there was no need of clarification such a frequent view or presentation of the interior of the object. For students of the second cycle the system probably is not fully satisfactory, hence the neutral rating.

The category *Effectiveness of visualization* allows to evaluate the possibility of presenting educational content in the form of 3D objects. A factor affecting the evaluation in this category is a possibility of presenting a 3D object from multiple perspectives in order to analyse and better understand the content. The InterEdu system in this category was evaluated very well by the students of the first cycle – mean rating of 5.7. The students of the second level evaluated the system as neutral (mean rating of 4.3). Worse assessment of second cycle students may result from their greater knowledge. In the case of older students who have knowledge and skills related to the correct reading of technical drawings of various kinds of objects it causes the ability to imagine the exact form of the object on the basis of drawings, without the need of presenting these objects in the form of 3D models. Younger students tend to have more trouble with imagining the form of the element/assembly solely on the basis of two-dimensional drawings, hence the higher average rating in this category.

In the category of *Technical quality* InterEdu system has been rated the worst among all the categories of the evaluation. The system has been rated as neutral (average rating of 4.2 from students of second cycle and 4.5 from students of first cycle). The hardware components of the InterEdu system, especially displays glasses had the most important impact on the evaluation. For people, who do not normally need glasses, this type of display may cause some discomfort and distraction. Moreover, the quality of the 3D effect (spatial effect) was not always satisfactory in the opinion of students (additional comments in questionnaires). This disadvantage is caused by the same visualization technology, however, this technology is still under development .

The last category of the evaluation i.e. *General suitability* allows to evaluate whether, in the opinion of students, lectures aided by using interactive techniques (InterEdu system) are better than the traditional form of teaching. In this category there is also a significant difference in the evaluation results for both students' groups. Students of first cycle evaluated the system very good (grade 5.8). It means that definitely this form of teaching is better for them than traditional one. However, the students of secondary cycle evaluated the system at 4.3, which means a neutral evaluation (hard to tell whether this form of teaching is better for them than traditional).

4. Conclusions

On the basis of evaluation in each category the overall evaluation of the system was specified. The students of the second cycle, taking part in the evaluation process, evaluated the InterEdu system as neutral (average score – 4.4), but they noted a certain usefulness of this system in the teaching process. The students of first cycle evaluated the InterEdu system well. This group clearly indicated the usefulness of this system in the teaching process (the average score – 5.25). In the future it is planned to greater integration tasks from different courses such as CAD course to other tasks such as CAM tasks and taking into account activities such as teleoperation for CNC machines.

References

[1] A. Bamford, *LiFE: Learning in Future Education Evaluation of innovation in learning using emerging technologies*, 2011, http://www.gaia3d.co.uk/wp-content/uploads/2012/11/Evaluation-of-Innovation-in-Learning-using-emerging-technologies-by-Prof-Anne-Bamford-2011.pdf, Accessed, Mai 30th, 2015.

[2] A. Bhatti (ed.), *Current Advancements in Stereo Vision*, InTech, Rijeka, 2012.

[3] B. Block, P. Mcnally, *3D Storytelling: How Stereoscopic 3D Works and How to Use It*, Focal Press, New York, 2013.

[4] A. Cholewa, K. Sternal, W. Skarka, M. Targosz, Electric Vehicle for the Students' Shell Eco-Marathon Competition. Design of the Car and Telemetry System. In: *J. Mikulski (ed.): Telematics in the Transport Environment. Series: Communications in Computer and Information Science, Vol. 329. 12th International Conference on Transport Systems Telematics*, Katowice, Ustroń, Poland, Oct. 10-13, 2012, 26-33.

[5] M. Dunleavy, C. Dede, Augmented reality teaching and learning, In: *J.M. Spector, M.D. Merrill, J. Elen, M.J. Bishop (eds.) The Handbook of Research for Educational Communications and Technology*, 4th ed., Springer, New York, 2014.

[6] EON Reality Pte Ltd.: http://www.eonexperience.com/home.aspx, (accessed on 04-2015).

[7] R.R. Hainich, O. Bimber, Displays: Fundamentals and Applications. CRC Press, Boca Raton, 2011.

[8] I.P. Howard, B.J. Rogers, *Binocular Vision and Stereopsis*, Oxford University Press, 1995.

[9] InterEdu Home Page: http://www.interedu3d.pl, (accessed on 04-2015). (in polish)

[10] M. Januszka, W. Moczulski, Acquisition and Knowledge Representation in the Product Development Process with the Use of Augmented Reality, In: *J. Stjepandić et. al (eds.), Concurrent Engineering Approaches for Sustainable Product Development in a Multi-Disciplinary Environment*, Springer-Verlag, London, 2013, pp. 315-326.

[11] M. Januszka, W. Moczulski, Augmented reality system for aiding engineering design process of machinery systems, *Journal of Systems Science and Systems Engineering*, Vol. 20 (3), 2011, 294-309.

[12] R. Likert, A technique for the measurement of attitudes, *Archives of psychology*, (140):54-55, 1932.

[13] W. Linder, *Digital Photogrammetry: A Practical Course*, Springer-Verlag, Berlin New York, 2009.

[14] M. Mengoni, M. Germani, Mechanical design learning environments based on virtual reality technologies, *International Conference on Engineering and Product Design Education*, Sep. 4-5 2008.

[15] T.R. Nelson, Stereoscopic Evaluation of Fetal Bony Structures, *J. Ultrasound Med.*, 2008; 27:15-24.

[16] M. Otrębska, W. Skarka, P. Zamorski, Designing Safety Systems for an Electric Racing Car. In: *J. Mikulski (eds.): 13th International Conference on Transport Systems Telematics, TST 2013, Communications in Computer and Information Science*, Vol. 395, 2013. Katowice-Ustroń, Poland, Oct. 23–26, 2013, 139-146.

[17] C. Pan, S. Smith, 3D stereo vision system effectiveness for engineering design and graphics education *Computer Applications in Engineering Education*, Vol. 16/4, 2008, 256-267.

[18] M. Rydmark, T. Kling-Petersen, R. Pascher, F. Philip, 3D Visualization and Stereographic Techniques for Medical Research and Education, *Studies in Health Technology and Informatics, vol. 81: Medicine Meets Virtual Reality*, 2001, 434-439.

[19] S. Rzydzik, W. Skarka, Multiagent system for aiding designing process. *In: J. Pokojski, S. Fukuda, J. Salwiński (eds.): New World Situation: New Directions in Concurrent Engineering. Proceedings of the 17th ISPE International Conference on Concurrent Engineering*, Springer, London, 2010, pp. 275-282.

[20] W. Skarka, M. Szumowski, M. Targosz, Velocity Planning of an Electric Vehicle Using an Evolutionary Algorithm. In: *J. Mikulski (eds.): Activities of Transport Telematics. series: Communications in Computer and Information Science, vol. 395, 2013. 13th International Conference on Transport Systems Telematics, TST 2013*, Katowice-Ustroń, Poland, Oct. 23–26, 2013, 171-177.

[21] W. Skarka, Application of MOKA methodology in generative model creation using CATIA. *Engineering Applications of Artificial Intelligence*, Vol. 20/5, Elsevier 2007, 677-690.

[22] W. Skarka, Using Knowledge-based Engineering Methods in Designing with Modular Components of Assembly Systems. In: *D. Marjanovic et al. (eds.): Proceedings of The Design 2010 11th International Design Conference*, Dubrovnik, May 17-20, Vol. 1-3, pp.1837-1846.

[23] Modeling and Design Student Scientific Association: http://www.mkm.polsl.pl, (accessed on 04-2015).

[24] G. Su, Y. Lai, A. Kwasinski, H. Wang, *3D Visual Communications*, John Wiley & Sons, Hoboken, 2012.

[25] C. Zhu, Y. Zhao, L. Yu, M. Tanimoto, *3D-TV System with Depth-Image-Based Rendering: Architectures, Techniques and Challenges*, Springer-Verlag, New York, 2012.

[26] T. Ito, A proposal of body movement-based interaction towards remote collaboration for concurrent engineering, *Int. J. Agile Systems and Management*, Vol. 7 (2014), Nos 3/4, pp. 365-382.