Virtual Reality Using Stereoscopic Vision for Teaching/Learning of Descriptive Geometry

Karla Bastos Guedes
Geometry Department
University Federal Fluminense
Niterói, Brazil
karlaguedes@vm.uff.br

Marcelle de Sá Guimarães
Engineering Department, PURO
University Federal Fluminense
Rio das Ostras, Brazil
marcelle@ic.uff.br

José Geraldo Méxas
Applied Mathematics Department
University Federal Fluminense
Niterói, Brazil
jose.mexas@gmail.com

Abstract — **This paper addresses one of the main difficulties observed in some theoretical courses of spatial geometry, which refers to the requirement of abstract spatial visualization skills. The study also shows the demand for computer graphic resources to support teaching and learning of these disciplines. Finally, it is submitted to a virtual system, animated, by using stereoscopic anaglyph vision, covering the basic contents of Descriptive Geometry. This system has already been developed and implemented.**

Keywords-computer graphics; descriptive geometry; virtual reality; spatial stereoscopic visualization

I. INTRODUCTION

The major developments in computing and electronics bring the opportunity to apply new technological resources for teaching/learning courses in graphics. Therefore, we can find in the related literature some studies that have been developed in search for computational solutions within the teaching subjects such as Descriptive Geometry (DG), Technical Drawing, etc..

Valente and Santos [1] proposed an intelligent computing environment, accessed via Internet, which operates according to the profile of each student. The system presents a database of exercises that must be registered by teachers. The virtual environment has not been tested yet.

In [2], Harris presents a proposal to restructure the Drawing Technique discipline. It involves the use of graphical applications on-line in support of teaching. The first results reveal a greater motivation among students that uses the new system.

Also, we found studies that indicate the potential for stereoscopic computer graphic systems for the development of spatial visualization skills [3] and virtual reality techniques have to be employed. It is suggested to use a stereoscopic display system using polarized projections, where students would attend classes using passive polarized glasses. However, the system was not implemented.

Another work of the area has a graphical tutorial system, available on the Internet for teaching Descriptive Geometry. The system consists of written content, accompanied by illustrative animations. The system, however, is not intended for use in classroom, and does not explore stereoscopic capabilities or real-time interactivity [4]. In a more recent study, the author has been making use of augmented reality techniques for visualizing and learning of conical surfaces [5].

The Descriptive Geometry software [6], developed at the University of Lisboa, can be freely downloaded from the website. The program is interactive and has offices in both epure and space representation. The system interface is somewhat overwhelmed by too much information windows and not very suitable for beginning students.

Since the program AEIOU Geometria Descritiva [7] has many graphics and a clear and friendly interface, it is a commercial software.

We observed that the most articles published in technical and scientific events in the area are still at the level of academic research and is not therefore available for use. On the other hand, we find some commercial products available, though expensive and not always perfectly suited to our educational needs.

Therefore, this paper seeks to fill this gap by developing a system using virtual reality techniques, able to support teachers and pupils learning Descriptive Geometry.

Section II presents Descriptive Geometry basic concepts and the problem of spatial visualization disability; Section III proposes the use of virtual reality with stereoscope vision applied for teaching/learning of Descriptive Geometry; Section IV shows the VirtualGD system, which has been developed and implemented in an undergraduate educational institution in Brazil; Section V presents an assessment of the VirtualGD system and Section VI the conclusion and proposes to future work.

II. DESCRIPTIVE GEOMETRY

It is the branch of geometry that intends to represent spatial figures in a plane, so that, in this plane all problems relating to these figures can be solved.

It was created in the late eighteenth century by the french mathematician Gaspard Monge [8].

A. Basic Concepts

Descriptive Geometry is an early discipline, especially for engineering and architecture courses. It addresses to the representation and solution of problems involving spatial mathematical entities such as points, lines, planes, polyhedrons, etc., through its cylindrical orthogonal projections in two planes, perpendicular to each other, in which one is rotated over the other, with the aid of plane

geometry properties, as shown in Figure 1. The figure obtained after this revolution is called Epure.
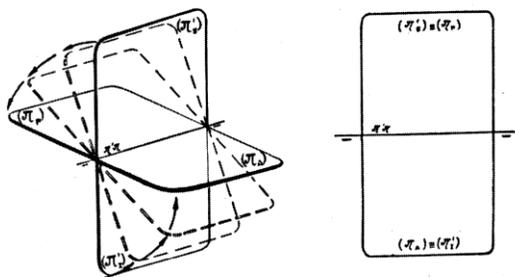

Figure 1. Revolution of the vertical plane on the horizontal plane – Epure.

The distance from one point to the horizontal plane is called quota. The quota coordinate is conventionally represented in Epure by the distance from the vertical point projection to the intersection planes line.

The distance from one point to the vertical plane is called afastament. This coordinate is represented in Epure by the distance from the horizontal point projection to the intersection planes line, according to Figure 2.
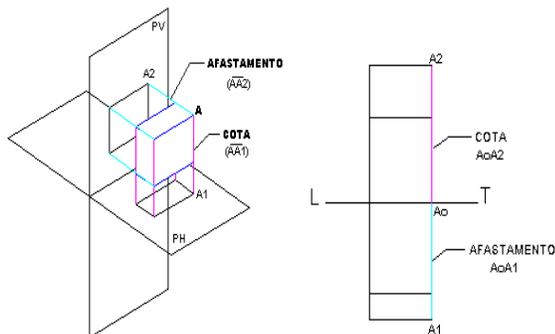

Figure 2. Afastament and cota's point located in first dihedral. Spatial representation and Epure.

The Geometry studies the projections of objects that can be located in any of the four dihedral. In terms of technical design, the Brazilian Association of Technical Standards (ABNT) admits representations in both first and third, being the first dihedral representation the most used one.

B. The spatial visualization problem

Disciplines involving planar representations (views, perspectives and projections) are an essential part of courses like engineering, architecture, industrial design, etc. Much of the work of these professionals involves the design of objects, from small parts to large buildings, which need to be represented and analyzed in the paper or computer screen. The need for representation of such projects in two dimensional media is what makes these essential disciplines, arising also the importance of Descriptive Geometry, as a suitable tool manipulation of these representations.

The Descriptive Geometry is given in general by lecture, using the blackboard, where the teacher makes the designs that are copied by students with the help of specific traditional materials (ruler, set squares, compass, real models, etc.). However, with this practice, it has been observed that a large number of students have serious difficulties in relation to spatial visualization ability, and this is one of the main factors for failure in learning this discipline.

References [9], [10] points to the reduced workload, the lack of a prior contact with the basic concepts of the discipline and the use of traditional teaching techniques are some of the factors that contribute to worsen this situation. The non-development of spatial reasoning during the school results in students, newcomers to undergraduate courses with recognized difficulties to understand the concepts treated in disciplines like Descriptive Geometry and Technical Drawing. Allied to this factor, there is a lack of alternative learning resources that can minimize these difficulties and support the mental abstraction processes necessary for the development of spatial visualization skills. The real models are most often used to facilitate three dimensional understanding.

Thus, we see the need to seek the use of modern techniques that can minimize this problem. In recent years, the use of visualization techniques related to computer graphics is becoming more frequent, so that we can find such applications being developed in several knowledge areas.

Within this context, this project proposes the creation of a virtual environment involving computational techniques such as computer graphics, virtual reality, multimedia, animations, etc., which can be used in Descriptive Geometry courses, aiming to improve the students spatial visualization ability and give teachers a new approach to teach the discipline. The system can be used both by the teacher, as a tool to support classroom, and by the students individually, as a way to strengthen the contents studied. The proposed virtual environment will be seen by students through stereoscopic vision glasses, aiming the better assimilation of the graphical space involved.

III. VIRTUAL REALITY

Virtual reality comes to computer use to bring a new paradigm for interfacing with the man. In this paradigm, human beings will no longer be in front of the monitor, but rather feel it in the interface. In this sense, we can define virtual reality, in a simplified manner, as the most advanced human-computer interface yet available [11].

A. A virtual environment applied to teaching/learning of Descriptive Geometry

A virtual environment is a three-dimensional, multisensory, computer generated, which reacts in real time to user activities. User interaction with the virtual environment of the devices is done through multi-sensory input and output. Input devices are responsible for capturing the user actions and feed the system with this information. The output devices will return the user with sensations in the environment, due to their actions, updated in real time [12].

The modeling of virtual environments can be made using languages such as VRML (Virtual Reality Modeling Language) [13] and its successor X3D [14], and other languages, as well as through authoring tools such as Blender [15], or 3DSMax [16], among others, which offer greater details abstraction of development.

In recent years, the use of modern virtual reality technologies has been very promisingly disseminated in the technical and scientific field. We can find applications successfully developed in several areas like education, training, entertainment and medical sciences, among others. Also in the field of teaching graphic disciplines and engineering activities, virtual reality is gradually gaining more space, especially with regard to the potential of this tool for the development of spatial visualization skills and the implementation of virtual labs to support engineering activities [17]-[20], which motivated us to evaluate the possibility of using this technology as a tool to support the teaching/learning of Descriptive Geometry.

Some computational techniques such as multimedia, animation and hypertext have been studied and/or implemented [5], [9] and [21] as a way to support the learning of this discipline. The authors have been investigating the use of virtual reality, and only the non-immersive techniques with flat-screen were explored. However, virtual reality using stereoscopic viewing seems to be the most suitable for improving the spatial visualization ability of Descriptive Geometry students.

B. Stereoscope vision using anaglyphic glasses

The design of stereoscopic vision or an object depth occurs when we draw the projections corresponding to the two eyes, left (L) and right (R) as shown in Figure 3.
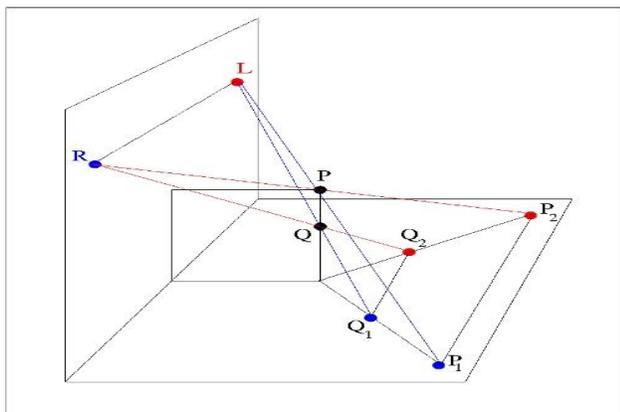

Figure 3. Horizontal plane projections of the P and Q points, according the positions of the left eye (L) and right eye (R).

On P point we have the P1 and P2 projections corresponding to the left and right eye respectively. Notice that the distance between the projections on the horizontal plane is proportional to the height of the point. Thus, P being at a greater height than Q is farthest from its projections which Q projections. So, the perpendicular line projection in a horizontal plane results in two intersecting lines as shown in Figure 4.
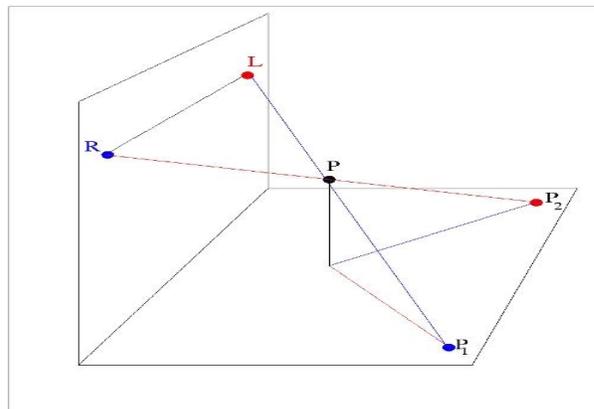

Figure 4. Line projections in a horizontal plane according to positions of the left eye (L) and right eye (R).

To view in stereo the P point, we must separate the left eye (L) projection of the right eye (R) projection. To achieve this, we use glasses called anaglyphic, performing a color filtering, in which the left lens filters out red light leaving only blue light and the right lens filters blue light leaving only red light. So we use the left eye image in blue and right eye image in red. Taking the glasses with the left lens red and blue lens right, we must first calibrate the color of paint so that the left eye does not see the red color (R) and the right eye does not see the blue color (B).

Thus, we can first draw the figure corresponding to the right eye, red (R) and performing a shearing operation, determine the second figure in blue (B), corresponding to the left eye. In the case of drawing stereoscopic projections of a (P) point on the horizontal and vertical planes, the result is shown in Figure 5. Red (R) is shown the right eye image and blue (B) the left eye image.
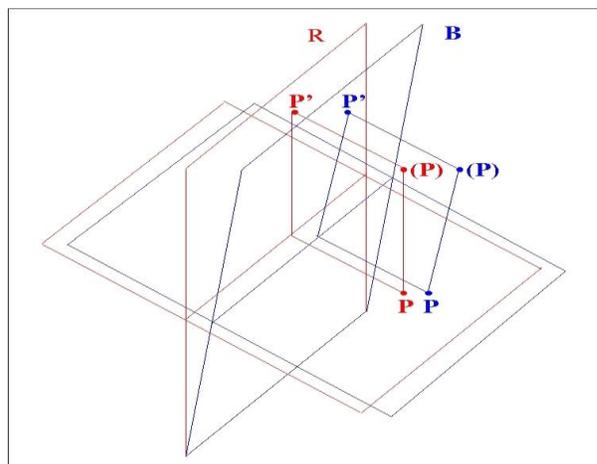

Figure 5. Stereoscopic drawing of (P) point projections on the horizontal and vertical planes.
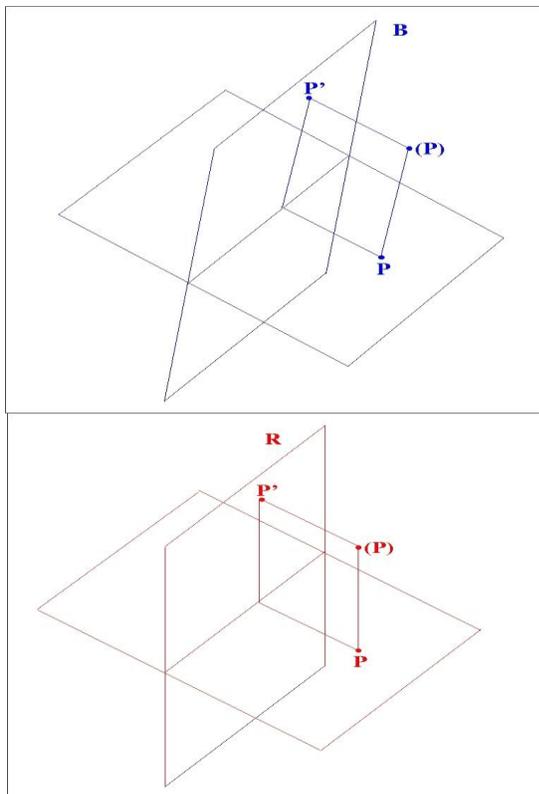
Figure 6. Images of the (P) point projections on the horizontal and vertical planes seen through the left lens (B) and right lens (R) of anaglyphic glasses.

The stereoscopic vision is a natural characteristic of the human visual system, which allows us to see in three dimensions and to perceive the depth of the scenes.

C. Technologies for stereoscope vision

In order to obtain a stereo computed image, we must generate two images of the same object from a little different view points, and present them separately to each eye, as described above. There are several ways to achieve this effect, with different interfaces [22]:

- **Anaglyphic glasses** (passive glasses) – Anaglyphic stereoscopy is the oldest technique of images separation. The viewing, in this research, initially, will be done with the use of anaglyphic glasses for being less costly and easier to implement. The disciplines of Descriptive Geometry are been offered, usually, for groups with large audience, which would not make the use of stereoscopic projection system expensive and complex.
- **Shutter glasses** (active glasses) – Use electronic shutters made of liquid crystal. The computer quickly and alternately generates two images on the monitor, one for each eye. The glasses, in syncronism with the monitor, plug alternately light that reaches each eye, so that, each eye sees only its image.

Figure 7. Shutter glasses.

- **Polarized glasses** (passive glasses) - The technique is widely used in three dimensional movies. The glasses are formed by two polarized lens, so that, the images from each eye are sent through polarized light emitted by two different projectors, one for each lens.
- **Helmet** (active glasses) - To generate two separate images for each eye, two small monitors, each with their images, are attached to the helmet. In this type of underwater equipment, the user does not need to look at the computer screen because the monitor is on the helmet.

Figure 8. Virtual reality helmet

- **Lenticular display** (without glasses) - The figure is covered with small curved lenses and the lenticular effect allows the viewing of images slightly different, depending on the angle of observation.

IV. THE VIRTUALGD SYSTEM

The system which is being developed and implemented entitled VirtualGD [20], [21] consists of modules (files) that are independent, each one covering a specific issue. It intends to cover all the course content. Each lesson, the teacher would have the modules that suits it. The modules are all interactive, responding to user requests in real time. The concepts are illustrated graphically and animated through three-dimensional representations. The subjects can be manipulated, providing their better view from different angles.

The VirtualGD was developed in the X3D standard, maintained by WEB3D Consortium (2009). The system is

displayed in the Browser, with the FluxPlayer plug-in that comes with Fluxstudio, with the operating system Windows.

The system will be manipulated by the teacher, projected onto a white screen and seen by students by using stereoscopic vision glasses, in classroom or manipulated by the student, on the screen of any computer, such as support classes. A stereoscopic system will contribute to obtain more realistic representations, providing greater clarity about the scene depth and position of objects in space. Thus, we are encouraging the power of visualization and spatial reasoning of the student, and facilitating the assimilation of relations between the mathematical entities involved.

The following is a small illustration of the module "profile lines" of VirtualGD system. The initial scenario of this module presents the horizontal and vertical planes of projection, and a menu designed with the kinds of the lines. If the user selects, for example, "intersecting lines", it appears in the space and the "project" button is provided in accordance with Figure 9.
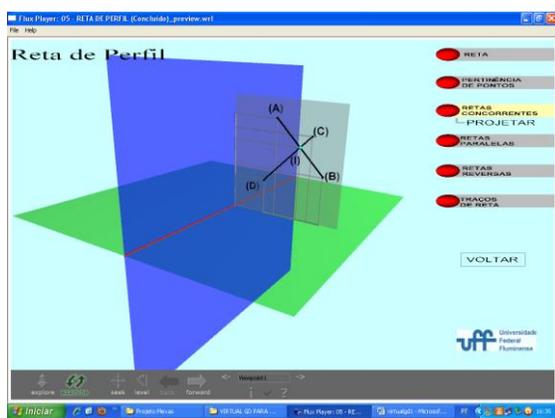

Figure 9.   VirtualGD: Spatial representation of the intersecting profile lines.

The user can freely manipulate these projection planes to better understand the position of these lines in space, as shown in Figure10.
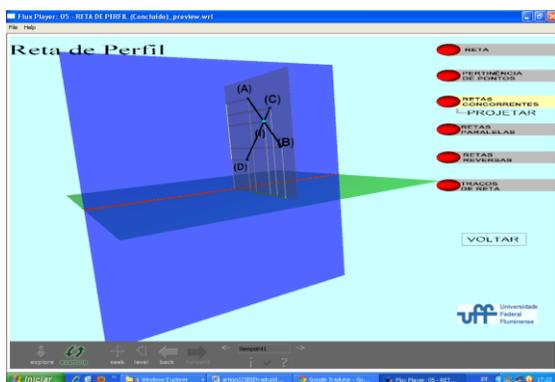

Figure 10. VirtualGD: Study object manipulated by the user.

Selecting the "project" button, the horizontal and vertical projections of the lines are presented in accordance with Figure 11 and the system provides the "Revolution" button.
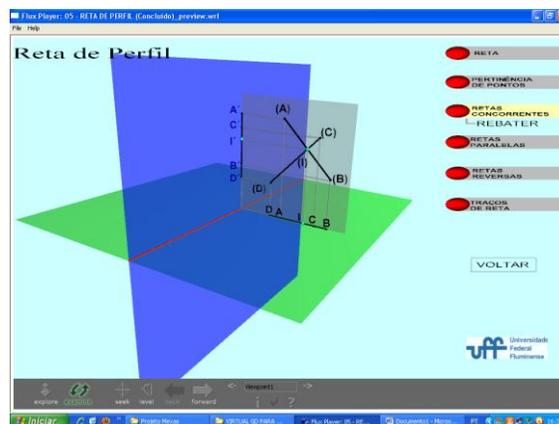

Figure 11. VirtualGD: Horizontal and vertical projections of the lines (A)(B) and (C)(D).

By choosing "Revolution", the system start an animation that illustrates the revolution of the profile plane in the vertical plane, as shown in Figure 12, and provide the "Epura" button.
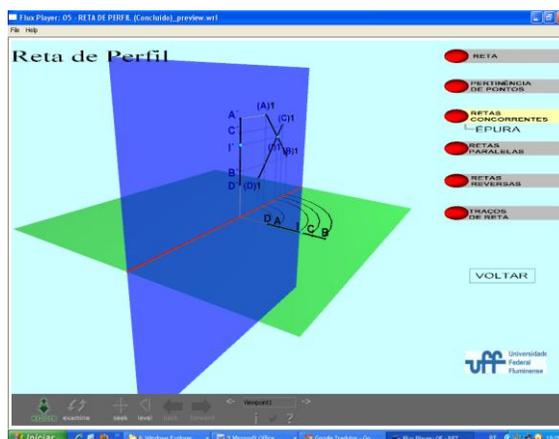

Figure 12. Revolution of the profile plane on the vertical plane.

By choosing "Epura", the system becomes an animation that illustrates the revolution of the horizontal plane or the process of obtaining Epure, as shown in Figure 13.
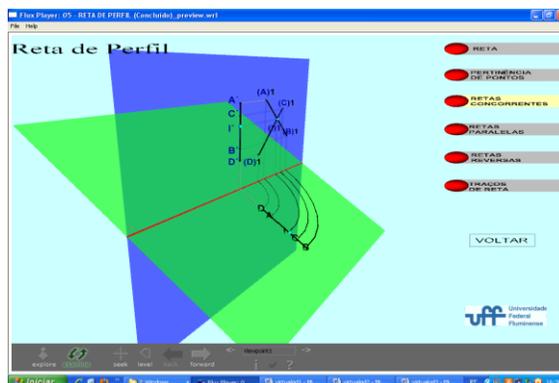

Figure 13. Revolution of the horizontal plane on the vertical plane to obtain the "Epure".

The system is in its developmental stage and has implemented the modules "projections and the point study", "special positions lines", "lines and planes intersections", "special positions planes and lines contained in these planes", "profile lines", "rotation", "revolution" and "change of plane".

V. ASSESSMENT

The VirtualGD was experienced in a Geometry Descriptive class composed of 40 students of Production Engineering at our university. All contents were presented by the teacher in the classroom, with the support of VirtualGD system, which was designed in flat screen, inside the classroom. The VirtualGD was also made available for students to use it outside the classroom. The evaluation criterion was based on scores in the first test performed by the students, since the VirtualGD in its current version only covers this stage to the course content. These scores were compared with the students' first test of the previous year which did not work with VirtualGD, and was called "control group".

A. Results

Of the 40 students in the class that used VirtualGD, 33 performed the first test. Of the 40 enrolled in the class above, the control group, only 19 performed the first test. That high level of abstention observed already seems to reflect the greater difficult presented by this group, which did not used the VirtualGD, and the consequent fear of failure in the evaluation.

Table 1 shows the scores, in ascending order, of the students' first test in each class, in addition to the arithmetic averages of the classes.

TABLE I – STUDENTS FIRST TEST SCORES AND CLASS ARITHMETIC AVERAGE.

Students	Classes	
	VirtualGD	*Control*
1	0.5	0
2	0.5	0
3	0.5	0
4	1	0
5	1	0
6	1.5	0
7	1.5	0.7
8	2.5	0.7
9	4	0.8
10	4	0.9
11	4	2.5
12	4	2.5
13	4.5	2.8
14	5	3.2
15	5	5.7
16	5.5	6
17	6	6.8
18	6	7
19	6	8.5
20	6	-
21	6.2	-
22	6.3	-
23	6.5	-
24	7	-
25	7	-
26	7.2	-
27	7.2	-
28	7.5	-
29	7.5	-
30	7.5	-
31	8	-
32	9	-
33	9.5	-
Average	5.01	2.53

In Table 1, it is observed that the average of the control group was significantly lower (approximately 50%) to the average obtained by the class that used the VirtualGD.

The frequency distribution graph is shown in Figure 14. It shows the percentual of students in each class who took scores at intervals ranging from zero to two, two to four, four to six, six to eight and eight to ten.
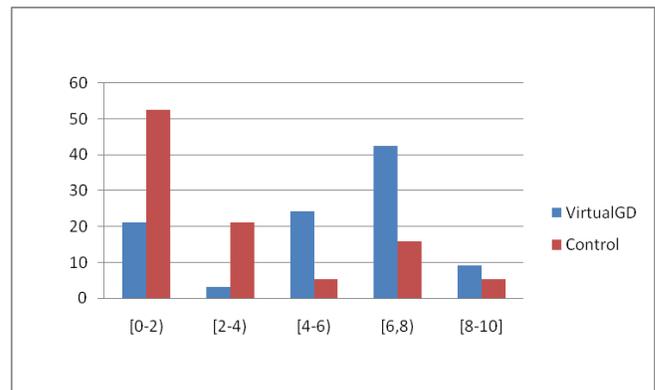

Figure 14. Frequency distribution of students by scores intervals.

According to Figure 14 more than half of the control group (52.63%) received score equal to or less than two in the first test. As for the class that used the VirtualGD system, the more frequently result (42.4%) was observed at the score interval between six and eight.

Figure 15 shows the cumulative frequency distribution for the two classes, considering the same scores intervals.
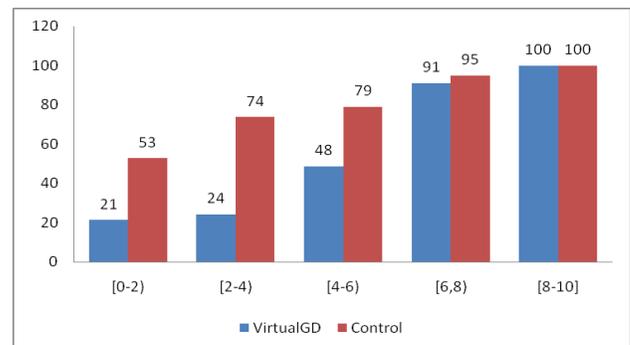

Figure 15. Cumulative frequency distribution of students by scores intervals.

According to Figure 15, 74% of the control group was scored below 4.0 compared with 24% for the class that used the VirtualGD. Considering that at the university the student has to take a final average equal to or greater than 6.0 (six point zero) to be approved in the course, Figure 15 shows that 52% of the class that used VirtualGD managed to stay above this level compared with 21% for the control group.

VI. CONCLUSION AND FUTURE WORK

This paper presented the VirtualGD, a virtual reality system designed to support the teaching and the learning of Descriptive Geometry. The product includes various contents of this discipline, all dealt with three dimensional graphics, interactive, equipped with animations and using stereoscopic anaglyphics vision to support the mental abstraction process of students spatial visualization.

Initially, the finished modules have been tested by students and teachers in regular classes of Descriptive Geometry of an undergraduate educational institution in Brazil. Preliminary results were quite satisfactory, as the students were able to understand the concepts presented in the system, assimilated the best spatial positioning of entities involved, and were able to answer questions by filling gaps left by the theoretical explanation in the classroom, since they could watch the modules at home. The tutors and teachers, in turn, felt comfortable with the use of modules, which were considered friendly and intuitive. The results suggest that VirtualGD was able to contribute to students' performance because their test scores increased significantly with the use of the system.

The next steps involve the complementation of this work with the development of new modules (covering all course contend), the implementation of the proposed system with stereoscopic vision in all modules and increment the statistic study about the best results in teaching/learning of Descriptive Geometry using this new approach.

The future propose is to extend this stereoscopic vision system to other disciplines which involves spatial visualization like Geometries in general and Molecular Chemistry.

The VirtualGD will be available via Internet. The already implemented modules can be seen on YouTube [23]. Thus, the program can be used not only by teachers but also by students and tutors in extracurricular schedules for further review of the contents seen in classroom.

REFERENCES

[1] Valente, V. C. P. N. and Santos, E. T. (2004) "Ambiente Computacional para Apoio ao Aprendizado de Geometria Descritiva", Congresso Nacional de Hipermídia para Aprendizagem, Florianópolis.

[2] Harris, A. L. N. C. (2006) "Aplicações e Resultados Iniciais de uma nova Didática de Ensino para a Disciplina de Desenho Técnico no Curso de Engenharia Civil da FEC – UNICAMP", 5º Encontro Regional de Expressão Gráfica", Salvador.

[3] Seabra, R. D. and Santos, E. T. (2005) "Análise de Requisitos de uma ferramenta 3D para desenvolvimento da Cognição Espacial", 17º. Simpósio Nacional de Geometria e Desenho Técnico, Recife.

[4] Lima, A. J. R.; Haguenauer, C. J.; Lima, L. G. R.; Cunha, G. G.; (2007) "Espaço GD – Uma Experiência Semipresencial de Ensino de Geometria Descritiva", GRAPHICA, Curitiba.

[5] Lima, A. J. R. and Haguenauer, C. J. (2007) "Visualização das seções cônicas da Geometria Descritivas através de Realidade Aumentada", Exhibit and Products Demo no IX Symposium on Virtual and Augmented Reality, Petrópolis.

[6] Teodoro, V. and Clérigo F.; Software "GD"-Descriptive Geometry, developed in Nova Lisboa University. http://www.edumatec.mat.ufrgs.br/softwares/soft_geometria.php, view in Dec/2011.

[7] Morgado, F.; Unuversidade Agostinho Neto, Portugal Software "AEIOU Geometria Descritiva" – Ensino de Geometria Descritiva Assistido por Computador http://www.estv.ipv.pt/paginaspessoais/fmorgado/aeiougd/default.htm , view in Sep/2011.

[8] Pinheiro, V.A. "Noções de Geometria Descritiva" vol. 1, 2 e 3, Editora LTC.

[9] Jacques, J. J.; Azevedo, G. Z.; Aymone, J. L. F.; Teixeira, F. G. (2001) "Nova Abordagem para o Ensino de Geometria Descritiva Básica", COBENGE.

[10] Brus, C.; Zhao L.; Jessop J. (2004) "Visual-Spatial Ability in First-Year Engineering Students: A Useful Retention Variable?" Proceedings of the American Society for Engineering Education Annual Conference and Exposition, Portland, Oregon,.

[11] Burdea, G. C.; Coiffet, P., (2003) *Virtual Reality Technology,* J. Wiley & Sons Inc.

[12] Alcaniz, M.; Lozano, J. A.; Rey, B., (2004) "Technological Background About VR", Cybertherapy - Internet and Virtual Reality as Assessment and Rehabilitation Tools for Clinical Psychology and Neuroscience, Riva Ed.: Amsterdam..

[13] [VRML97,2008] "The Virtual Reality Modeling Language", http://www.web3d.org/x3d/specifications/vrml/ISO-IEC-14772-VRML97/, view in Dec/2011.

[14] [Web3d,2008]WEB3D CONSORTIUM, "X3D Documentation", http://www.web3d.org/x3d/, view in Dec/2011.

[15] Brito, A., (2006) Blender 3D: Guia do Usuário, Ed. Novatec, São Paulo.

[16] 3DSMax, (2008) AUTODESK, www.autodesk.com/3dsmax,view in Dec/2011.

[17] Hamza-Lup, F. G.; Goeser, P. T.; Johnson, W.; Thompson, T.; Railean, E. ; Popovici, D. M.; (2009) "Interactive 3D Web-Based Environments for On-line Learning, Case Studies, Technologies and Challengs", International Conference on Mobile, Hybrid and On-Line Learning, pp. 13-18, Cancun, Feb 1-7.

[18] Goeser, P. T.; Johnson, W. M.; Hamza-Lup, F. G.; Schaefer, D. (2011) "VIEW; a Virtual Interactive Web-based Learning Environment for Engineering", IEEE Advances in Engineering Education Journal, Special Issue on Research on e-Learning in Engineering Education, vol. 2(3).

[19] Karwet, M. A.; "A Virtual Engineering Laboratory Course"; http://www.jhu.edu/virtlab/virtlab.html, view in Nov/2011.

[20] Guimarães, M. S.; Guedes, K. B.; Silva, I.O.; Seixas, S. M.; Silva, H. G. A., (2008) "Realidade Virtual no Apoio ao Ensino de Geometria Descritiva", X Symposium on Virtual and Augmented Reality, pp. 296-299, João Pessoa.

[21] Guimarães, M. S.; Guedes, K. B.; Silva, I.O.; Stutz, B.; Seixas, S. M., (2009) "Realidade Virtual no Ensino de Engenharia: O Sistema VirtualGD", XXX Congresso Íbero-Latino-Americano de Métodos Computacionais em Engenharia, Armação de Búzios.

[22] Siscoutto, R.A. et al.; (2004) "Estereoscopia - Realidade Virtual: Conceitos e Tendências" – Livro do Pré-Simpósio SVR 2004, pp. 179-201, Ed. Mania de Livro, São Paulo.

[23] http://youtu.be/RHr70Q-0MFk; http://youtu.be/qXIP8flWz00; http://youtu.be/OJ1qRUxc9pg; http://youtu.be/Cjj78I0Y1Hs ; http://youtu.be/eER4nfY8FPA, view in Dec/2011.