SV3DVISION: DIDACTICAL PHOTOGRAMMETRIC SOFTWARE
FOR SINGLE IMAGE-BASED MODELING

Diego González Aguilera [a] , Javier Gómez Lahoz [a]

[a] Dept. of Land and Cartography Engineering, High Polytechnic School of Avila University Salamanca, 50, Hornos Caleros Street, 05003 Avila, (Spain) - daguilera@usal.es, fotod@usal.es

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ABSTRACT:

The modern World is constantly changing and education is one of the last things that do not get obsolete. However, its techniques must be adapted to newer resources and environments. Particularly, Photogrammetry is a science that has suffered from so many abrupt changes in the last fifteen years. We have passed from an enclosed and convergent dynamic characterized by Stereoscopic Aerial Photogrammetry, as well as the specialization in instruments and methods, to a divergent dynamic marked by flexibility in instruments, methodologies and relation with affine disciplines. Nevertheless, Photogrammetry continues relying on a strong hardware and software dependence. In fact, some companies have invested heavily on digital implementations for photogrammetric principles, and lead the market in order to obtain massive cartographic data production. Consequently, prices remained high and the access to photogrammetric equipment continues being limited only to those who can afford it.

The ISPRS Symposium organized by the Commission VI on "Education and Outreach" has a very interesting motto: "E-LEARNING AND THE NEXT STEPS FOR EDUCATION". Our Photogrammetry Research Group at Salamanca University aims to contribute in this line through the development of an educational software known as sv3DVision. The basic idea is to develop photogrammetric tools that can be used as didactical elements as Computer-assisted teaching and training on Internet, Classes, Summer Courses and Seminars, in order to ease the students' assimilation of main photogrammetric concepts. Furthermore, a new way of learning Photogrammetry supported by the Bologna Process, which stresses the importance of developing professional photogrammetric skills is put in practise.

The paper presents the following structure: the first section gives an overview about the European Higher Education Space (EES); the second section puts across our photogrammetric learning approach based on Bologna Process; the third section analyses the sv3DVision educational software: from its main features to its own didactical structure; a final section is devoted to remark the main conclusions and future perspectives.

1. INTRODUCTION: TOWARDS THE EUROPEAN HIGHER EDUCATION SPACE (EES)

The University passes through an important change patronized by the European Cultural Frame, whose principal aim is to preserving social and ethical values, as well as to adapt socioeconomic and technological changes progressively. In this sense, the University, through its own research and educational duality, have to 'fight' in order to represent a principal role in the new European Higher Education Space (EES). This EES will allow more comparability and compatibility among Educational Systems, so a confluence of quality in the academic awards together with an optimal integration in the labor market will be a reality.

In this process towards the EES, the Bologna Declaration in 1999 supposes an important reference, not only because constitutes a coordination and integration tool, but also because performs as principal starting point, as well as precursor of guidelines at the University by 2010.

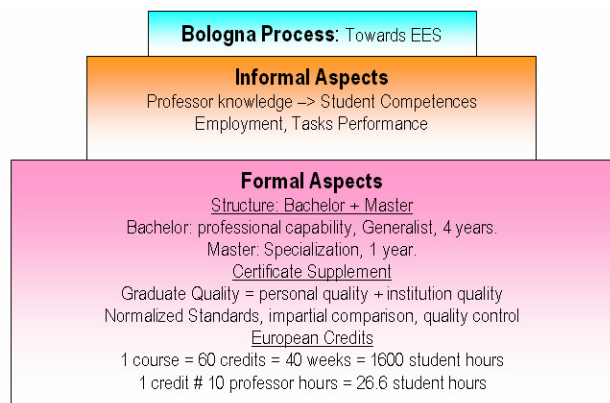The formal and informal aspects associated to Bologna Declaration could be portrayed through Figure 1.

Figure 1. Formal and informal aspects of Bologna Declaration.

Next sections give an overview about a new way of learning Photogrammetry. Particularly, a partial e-learning approach based on the development of an educational software, *sv3DVision*, and the design of a pilot course, *Close-Range Photogrammetry and Computer Vision*, is proposed.

2. BOLOGNA PROCESS ADAPTED TO PHOTOGRAMMETRY TEACHING

The central concept around this new model is that the student instead of acquiring knowledge, develops skills that allow him/her to perform his/her future profession efficiently, considering his/her learning capability and thus his/her capability to self-evaluation. The most important innovation of this new paradigm is that we have passed from a teacher centered approach with students mastering academic contents to a student centered approach with students exercising professional skills. In this sense, the pilot course is structured, developed and evaluated according to students work and not in relation with the traditional contents mastered by the professor. The general aim is not that the student dominates a closed whole of photogrammetric and computer machine concepts and performs specific practices, if not that the student develops his/her capability for solving theoretic and practical tasks or projects related with Photogrammetry and Computer Vision. A tutorial function in its different modalities (individual, collective or electronic) supports this stage.

As a result, the following goals related with this pilot course could be remarked:

➢ The student should change his/her learning capability: from knowing Photogrammetry and Computer Vision to doing Photogrammetry and Computer Vision.

➢ The student should be immersed in the International Photogrammetry and Computer Vision Community.

➢ The student should build his/her own learning methodology, moving forward the self-learning.

➢ A self-evaluation should be applied in the whole process in order to obtain a permanent feedback

On the other hand, this pilot course is under the global scheme of Quality Assurance, which can be divided in three different principles:

➢ Transparency: those elements which constitute the course are public documents, thus everybody can access them.

➢ Coherence: each content of the course should have its own hierarchical structure, at the same time that establishes relation with others courses.

➢ Feedback: course should provide critical evaluations about its own elements. Furthermore, a feedback is given to students at the end of each theme through open tasks performance.

Next paragraphs describe the methodology applied to this pilot course. *Close-Range Photogrammetry and Computer Vision* course presents a workload of 160 hours (student work) divided in the following manner (Figure 2):
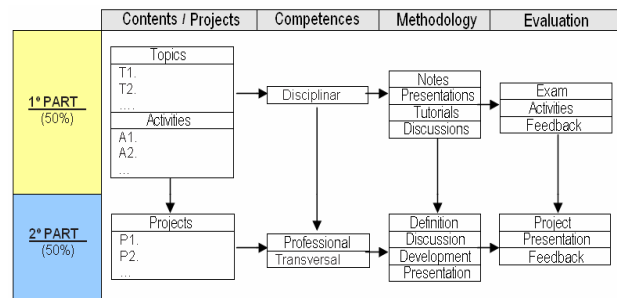

Figure 2. Pilot course planning.

1st part: BASICS PART. (80 hours)

Goal: Guarantee an active and meaning learning about Photogrammetry and Computer Vision. This part of the course is focused towards developing basics competences, which perform as support in the second part of the course.

➢ The contents are distributed through CD-ROM.

➢ Each theme is explained, commented and interpreted by the professor.

➢ Open questions and tasks are proposed by the professor in order to stimulate active and meaning learning.

➢ Contents are studied and analysed by students, taking into account their own criterion and study style, as well as the professor assistance.

➢ Contents are discussed by professor and students through individual or collective tutorials.

➢ Tasks related to open questions are put in common and evaluated by the professor.

➢ Evaluation of theoretical contents is carried out through partial exams. Only, those students who have solved open question correctly could access to these exams.

➢ Exams and open questions are corrected, commented and reviewed in order to provide feedback.

2nd part: PROJECT PART. (80 hours)

Goal: Develop tasks and specific projects related to Photogrammetry and Computer Vision, in order to develop professional (skills) and transversal competences. In this sense, the student can chose between the following proposals:

➢ Resolution of specific tasks.

➢ Algorithms development.

➢ Lecture, review or presentation about a specific or general topic.

➢ Documentation on Internet about the activities of International Community in Photogrammetry and Computer Vision.

➢ Design, develop and perform a photogrammetric and computer machine pilot project.

For these proposals, the methodology would be the following:

➢ Inform and study the proposals.

➢ Select one or several proposals to develop.

➢ Discussion with the professor about the proposal chosen.

➢ Design, develop and perform the proposal by the student.

➢ Public presentation about the proposal developed.

In the pilot course the discussion board and e-mail are used extensively, particularly for course announcements and the dissemination of additional reference material by way of attachments to messages. Such tools function well and are easy to use.

3. SV3DVISION: AN EDUCATIONAL PHOTOGRAMMETRIC SOFTWARE

3.1 Overview

In principle, the educational software sv3DVision consists of two parts: Knowledge and Tasks. In the 'Knowledge' part, sv3DVision describes the synergies between disciplines such as Close-Range Photogrammetry, Computer Vision and Computer Graphics, as well as the methodology developed for single image-based modeling. These contents are interlaced with hyperlinks to a glossary of technical terms and definitions, as well as supported with graphic illustrations. In the 'Tasks' part, sv3DVision allows to work under three different interfaces (Figure 3) in order to carry out exercises and simulations. This triple structure allow to work in different levels, from students who use the program only with learning purposes to PhD students who develop new tools and even professionals who are interested in applying the software to an specific context.
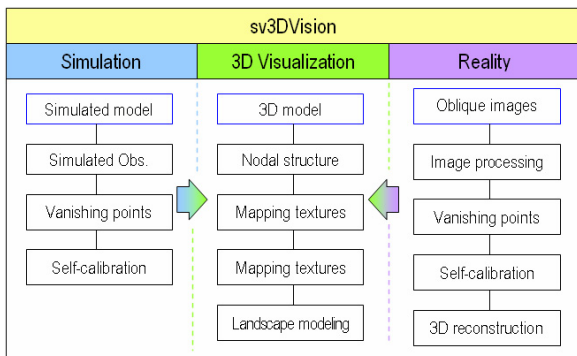

Figure 3. Triple structure in *sv3DVision*.

The general idea above the educational software sv3DVision can be portrayed by the following features:

➢ It constitutes a considerable change with respect to the classical photogrammetric software based on stereoscopic vision.

➢ It supposes a contribution in a multidisciplinary context, destined to the synergic integration of methodologies and tools of others disciplines such as: Photogrammetry, Computer Vision and Computer Graphics, providing an ideal learning and research frame and contributing with different approaches: from camera self-calibration and 3D reconstruction, to the interactive and dynamic 3D visualization on Internet.

➢ It establishes an own methodology for the 3D reconstruction from a single view combining several scientific approaches.

➢ It represents a multidisciplinary tool for the popularization and dissemination of the Architectural Cultural Heritage, as well as its utilization in research and education.

3.2 Simulation interface

Through the Simulation interface (Figure 4), the user can control whatever type of geometric or statistical parameter in the generation of a simulated model. The graphic and dynamic simulation of the perspective model is achieved based on the modification of camera parameters (internal and external) and the colinearity condition. In this way, the Simulator developed performs as a checkup platform, where the different input parameters such as: vanishing lines, accidental errors, gross errors and even the own radial lens distortion, can be setup in order to analyze the accuracy and reliability of the algorithms before being extrapolated to real situations (images).
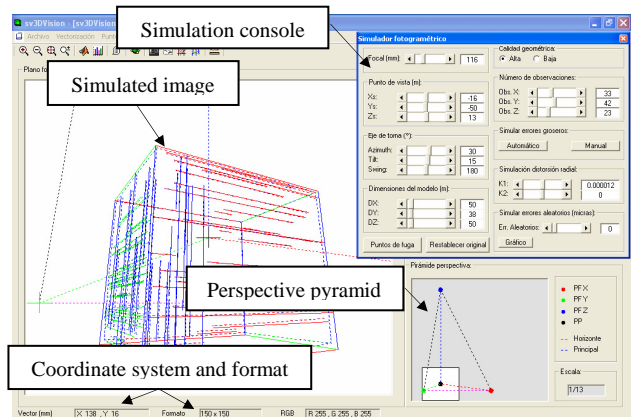

Figure 4. Simulation interface in sv3DVision

The simulation console (Figure 5) enables to control the following parameters:

- Camera geometrical parameters, corresponding to the internal and external parameters.

- Object simulated parameters, corresponding to the three orthogonal dimension (length, depth and height), as well as the datum definition.

- Quality geometrical parameters, corresponding to the maximum and minimum size of observations, segments inclination, as well as gross and an accidental errors ratio.

- Radial lens distortion parameters, corresponding to the value of the coefficients K_1 and K_2.
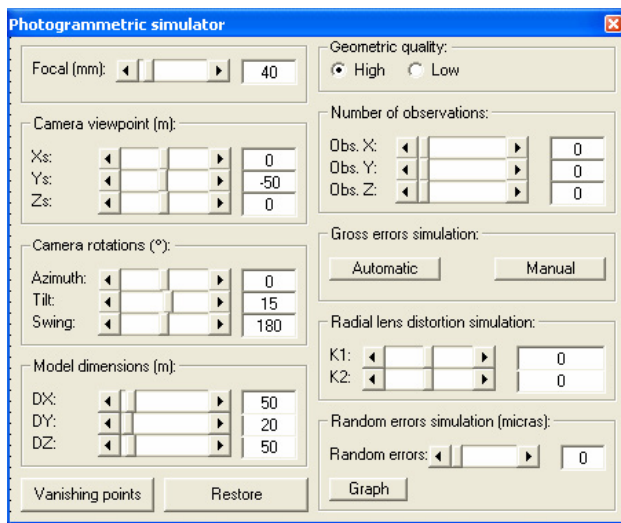

Figure 5. Simulation console in sv3DVision

A complete description of this simulation interface and its performance is given in (Aguilera et. al., 2004).

3.3 Reality interface

Through the Reality interface the user can work with real oblique images belong to architectural buildings, in order to obtain a 3D reconstruction from a single view.

Next, it will be described the most relevant features of sv3DVision corresponding to the Reality interface.

Digital processor. One of the most critical steps in 3D reconstruction from a single view resides in detecting with high accuracy and reliability the structural elements belonging to an oblique image. This is not an easy task, taking into account that usually images contains noise due to the own acquisition process as well as the radial lens distortion. So, although a huge proliferation of image processing algorithms exist currently, hierarchical and hybrid approaches are required in order to guarantee quality. Unfortunately, it does not exist an universal method for automatic vectorization, so the own requirements of each case define and adapt the algorithm. In this way, (Heuvel, 1998) applies a line-growing algorithm so-called Burns detector (Burns et al., 1986) for vanishing lines extraction; (Tuytelaars

et. al., 1998) create a parameter space based on Hough transform (Hough 1962) to detect vanishing lines automatically; more recently (Liebowitz et. al, 1999), (Almansa. et. al 2003) and (Remondino, 2003) apply Canny filter (Canny 1984) for the same purpose.

With relation to the methods remarked above, sv3DVision incorporates an original approach for processing oblique images. An automatic vectorization algorithm has been developed which presents a hierarchical structure that starts with the basic task of filtering and ends with the detection of basic primitives through segmentation and clustering approaches. Particularly, in a first level, a preliminary extraction of edges supported by Canny filter is performed. In a second level, basic primitives are obtained through a labelling process supported by colinearity condition. This step provides also an estimation of the radial lens distortion parameters. Finally, in a third level, the lines are clustered with respect to the three main vanishing points direction supported by a RANSAC (Fischler&Bolles, 1981) algorithm.

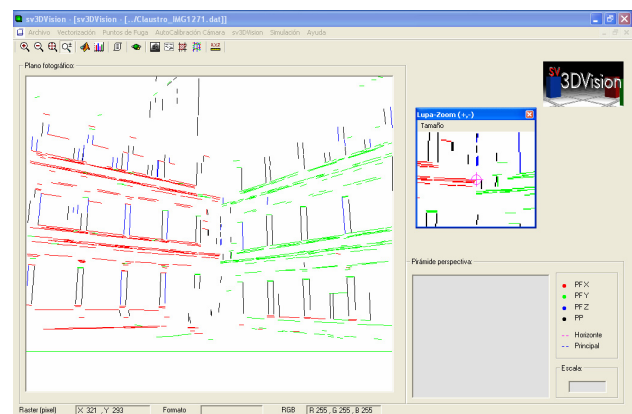Figure 6 illustrates the result of clustering process for three vanishing points.

Figure 6. Clustering lines in sv3DVision

Vanishing points calculator. sv3DVision allows to combine several proven methods for vanishing points detection together with robust and statistical techniques (Figure 7).
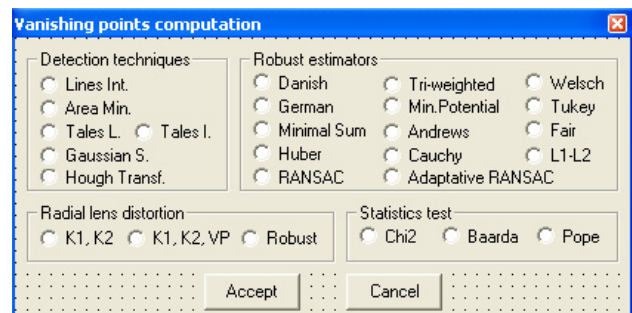

Figure 7. Methods and estimators for vanishing points detection in sv3DVision

A large selection of methods have been developed: from the easiest approaches such as: intersection of lines and triangle area minimization methods, to the most successful methods supported by Hough transform and Gaussian sphere. In regard to statistical tests, every one is based on a hypothesis contrast supported by several statistical parameters. Particularly, Chi-Squared Test allows to obtain a global balance about the model adequacy, while Baarda (Baarda, 1968) and Pope (Pope, 1976) Test allow to detect automatically possible outliers corresponding with wrong vanishing lines through an iterative technique that analyzes the standardized residual with respect to a established threshold. This threshold well-known as 'statistical cutoff or critical value' is determined based on a specific statistical distribution: Gaussian and T-Student distributions are applied for Baarda and Pope Tests respectively. Finally, with relation to robust estimators, a double classification can be considered: M-estimators which apply a specific weight function in an iterative re-weighted least square process (Domingo, 2000), and RANSAC robust estimators which combine the traditional (Fischler&Bolles, 1981) and adaptative (Harley&Zisserman, 2000) approaches, incorporating a specific adaptation to each vanishing point technique.

Camera self-calibrator. Single image calibration is a fundamental task starting in the Photogrammetry Community and more recently in Computer Vision. In fact, both share several approaches with different purposes: while Photogrammetry tries to guarantee accuracy and reliability, Computer Vision is more concerned about the automatization and rapidity in camera calibration. In this way, approaches exploiting the presence of vanishing points have been reported in Photogrammetry (Bräuer&Voss, 2001), (Heuvel, 2001) and (Grammatikopoulos et. al. 2003), as well as in Computer Vision (Caprile&Torre, 1990), (Liebowitz et. al., 1999), (Cipolla et. al., 1999) and (Sturm, 1999). In the context of Photogrammetry the general approach established is based on the use of three orthogonal vanishing points and some constraints among lines. Alternatively, in the context of Computer Vision, several approaches are supported by the computation and decomposition of the absolute conic from three vanishing points or the rotation matrix.

The self-calibration method performs by sv3DVision presents a hybrid character that combines approaches related to Photogrammetry and Computer Vision. On the one hand, applying tools belonging to the image processing and geometric constraints of the object in order to estimate the radial lens distortion parameters, and on the other hand exploiting the geometry of structural elements, mainly vanishing points based on the orthocentre method (Williamson, 2004), in order to compute the geometric camera parameters.

Therefore, sv3DVision allows to calibrate unknown or semi-unknown cameras taking into account the following assumptions: (*i*) the single image contains three vanishing points; (*ii*) the length (in 3D space) of one line segment in the image is known; (*iii*) the own geometry of the object provides the necessary constraints not being necessary to use calibration targets. In this sense, sv3DVision performs the camera self-

calibration following a triple process: Firstly, internal camera parameters (principal point, focal length and radial lens distortion) are estimated automatically. Secondly, camera orientation is computed directly based on the correspondence between the vanishing points and the three main object directions. Then, camera pose is estimated based on some priori object information together with a geometric constraint.

More details about this calibration method are given in (Aguilera, 2005).

Oblique image rectifier. sv3DVision allows to rectify oblique images without using control points, once the vanishing points and internal camera parameters have been computed. In this sense, given an oblique image corresponding to a 3D object, the goal is to obtain a metric rectification of each plane that composes the object. This is equivalent to obtaining an image of a specific plane of the object where the camera's image plane and the object plane are parallel. Nevertheless, the own complexity of the scene which presents several planes with different depths carries that a partial rectification corresponding with each fundamental plane has to be performed. In this way, the user will have to define manually each one of the structural planes of the object and assign the corresponding geometrical constraint (Figure 8).
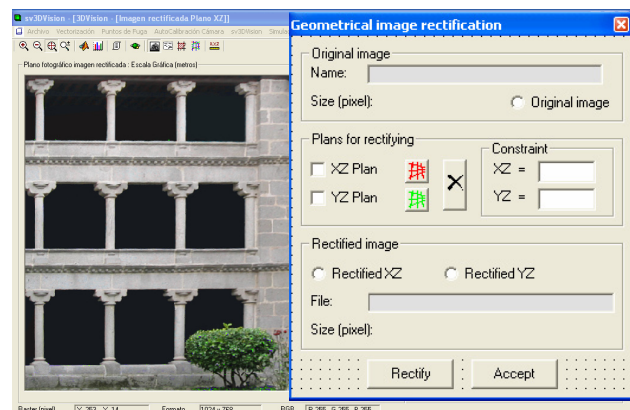

Figure 8. Rectification in sv3DVision

Particularly, the approach developed in sv3DVision is based on the projective transformation and in its decomposition using the Singular Value Decomposition (SVD) method (Golub&Reisch, 1971). As is well known, the map between an object plane and its corresponding image plane is a projective transformation. Habitually, this map can be determined from the correspondence of four (or more) points with known position. However, it is not necessary to determine the entire projective transformation in order to obtain a metric rectification (Liebowitz et. al. 1999); the plane rotation, translation and uniform scaling which are part of the projective transformation map, and account for four degrees of freedom, are irrelevant to the rectification. Thus, the idea is to determine only four of the eight parameters of the projective transform, exploiting geometric relation on the object plane such as parallelism and orthogonality. These geometric relations maintain correspondences in the image plane with the vanishing points

and infinite vanishing line. Concretely, the infinite vanishing line determined by the union of two or more vanishing points, represents the image of the line at infinity of the object plane and allow passing from projective to affine geometry and the opposite. Thus, this line has two degrees of freedom which encode all the pure distortion of the plane. This interchange between transformations based on a decomposition of the projective transformation is carried out applying a SVD approach supported by several Gives rotations (Golub&Reisch, 1971), which allow to introduce zeros in the projection matrix selectively.

Dimensional analyzer. sv3DVision allows to analyze the different dimensions of the object based on coordinates, distances and areas, as well as contrasting the corresponding associated deviations in order to estimate the accuracy of the reconstructed 3D model (Figure 9). Particularly, sv3DVision incorporates procedures supported by colinearity condition and geometric constraints (coplanarity and parallelism) (Heuvel, 1998) that allow to obtain dimensions of whatever part of the object measuring directly onto the oblique image. Obviously, the camera calibration parameters must be known.
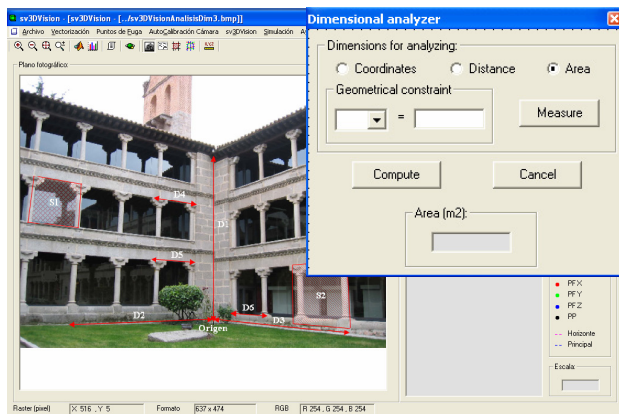

Figure 9. Dimensional analyzer in sv3DVision

An interesting approach to obtain whatever dimension related with the object from single images is developed in the ImageModeler software (ImageModeler, 1999).

3.4 3D Visualization interface

sv3DVision and its 3D Visualization interface (Figure 10) fulfils the following requirements and features:

Requirements

Flexibility: the 3D Visualization interface allows its utilization in an independent and flexible way, so we can work directly with VRML files in order to create, edit and visualize 3D models and scenes.

Extensibility: the 3D Visualization interface provides the possibility to develop new tools in order to improve the program.

Scalability: the 3D Visualization interface allows the combination of different 3D models together with real or artificial landscapes, in order to generate and extend complex scenes.
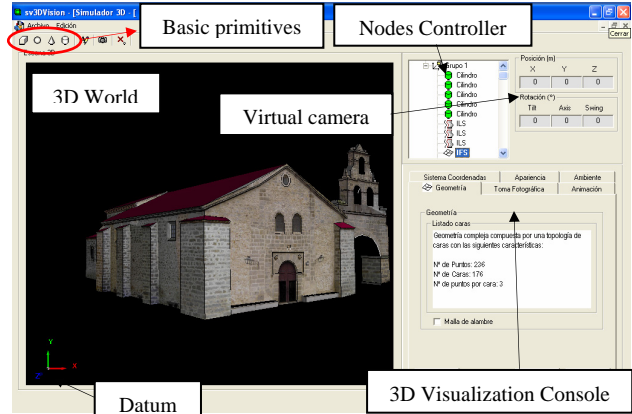

Figure 10. 3D Visualization interface in *sv3DVision*

Features

Obtain a 3D interactive visualization of the reconstructed model. The 3D Visualization interface provides an automatic transformation of the reconstructed 3D model into a topological structure (points, lines and surfaces) sorted hierarchically in a nodes network similar to VRML (Aguilera et. al., 2004).

Nodes Controller and 3D Visualization Console. The Nodes Controller and the 3D Visualization Console allow an integral control over the 3D model and the scene. In this way, whatever operation of creation, editing or deletion over the model or scene, will be performed selecting the element over the Nodes Controller and introducing the corresponding value in the Visualization Console (Figure 11).
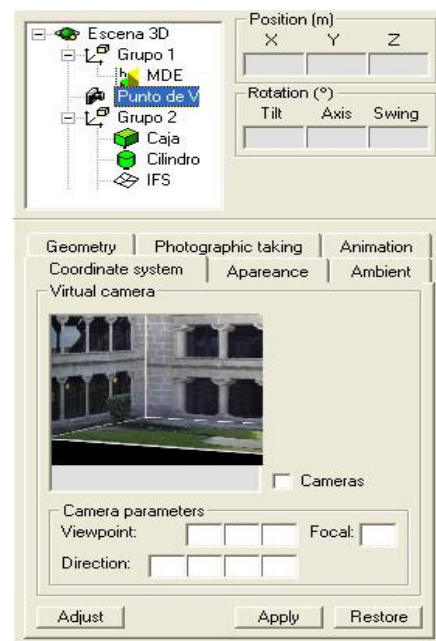

Figure 11. Nodes Controller and 3D Visualization Console

Define global and local coordinate systems. The 3D Visualization interface enables the definition of multiples coordinate systems that allow whatever spatial action: rotation, scale factor and translation over the model (local system) or scene 3D (global system).

Create and edit different types of geometries. The 3D Visualization interface allows to create, edit and visualize different types of geometries: from simple geometries (basic primitives) to complex geometries supported by the topology of points, lines and faces. Furthermore, the 3D Visualization interface allows three different levels of representation: (*i*) Wire-frame representation, which represents the geometry exclusively; (*ii*) Shaded representation, which represents the faces that integrate the object; (*iii*) Textured representation, which represents the faces that integrate the object together with its texture.

Scene modeling. The 3D Visualization interface allows to create and edit different environments: from artificial landscapes based on cylindrical or spherical illuminated panoramas which represent the remainder of the landscapes and far objects, to the automatic generation of real environments through Digital Elevation Models (DEM) with orthorectified textures (Aguilera et. al. 2005). The final integration of the 3D Model with the artificial or real scene will provide an increase in the level of realism (Figure 12).
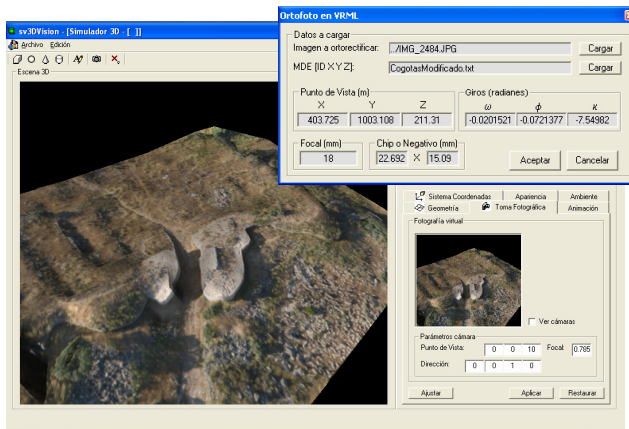

Figure 12. DEM and orthophoto generation in sv3DVision

Furthermore, a Triangular Irregular Network (TIN) generation structured over breaklines together with the incorporation of TIN topology is added in order to deal with vertical walls, event pretty common in archaeological excavations.

Materials and orthorectified texture mapping. Materials defined by their colours and radiometric properties (opaqueness, transparency, diffusion, reflection and emission), are mapped through a uniform and continuous renderization supported internally by VRML. Unfortunately, the photo-texture mapping cannot follow the same approach and a previous correction (rectification) will be required in order to obtain a realistic result. In this sense, an adaptation of 'Anchor Points Method' (Kraus, 1993) to VRML has been developed, allowing a

orthorectified texture mapping between the 3D geometry and the image.

Virtual camera. The 3D Visualization interface allows the introduction of view points into the scene and the manipulation of the different camera parameters in order to visualize the object from whatever imaginable perspective. In this sense, the virtual photograph can be saved and used for different analysis and operations. Furthermore, a simple algorithm supported by a Proximitysensor node enables to obtain the camera pose in real time and thus the possibility to create animated flights.

4. CONCLUSIONS AND FUTURE PERSPECTIVES

Wit relation to the pilot course designed '*Photogrammetry and Computer Vision*', participants fell that the new system adapted to Bologna philosophy represent a very effective means of updating their knowledge and continuing their professional development. They fell the learning experience is a good one provided that feedback is forthcoming from course professor in a timely manner. Nevertheless, the generation of content suitable for the efficient learning of complex concepts is time consuming. Material must, therefore, be re-usable in other courses or educational resources. Tutorials covering complex concepts are possible through the use of communication tools provided they are well prepared and structured.

With relation to educational software development, sv3DVision represents a clear contribution in a multidisciplinary context, destined to the synergic integration of different methodologies and tools, in the 3D reconstruction from a single view. Therefore, teaching and research work can be presented as an interactive learning program. The 'knowledge' is presented by dynamic figures and hypertexts, while 'tasks or experiments' can be carried out with different free educational tools such as sv3DVision. Good learning is achieved by doing and by self-assessment.

Regarding future perspectives, our aim is to go on developing pilot courses together with free educational tools and software in order to incorporate them in a new master study program of Photogrammetry.

5. REFERENCES

References from Journals:
Álvarez, M., Gómez, J., González, D., Mostaza, T. Pérez, C. 2002. "La declaración de Bolonia: ¿obligados a innovar?". Datum XXI. N4, N5, N6.

Andrés Almansa, Agnès Desolneux, and Sébastien Vamech, 2003. *Vanishing points detection without any a priori information.* IEEE Trans. on Pattern Analysis and Machine Intelligence, 25(4):502–507.

Burns, J.B., A.R. Hanson, E.M. Riseman, 1986. *Extracting straight lines.* IEEE transactions on pattern analysis and machine intelligence, Vol. 8 (4), pp. 425-455.

Canny J.F. 1986. *A computational approach to edge detection.* IEEE Trans. Pattern Análisis and Machina Intelligence.

Caprile B. and Torre V. 1990. *Using vanishing points for camera calibration.* IJCV 4 (29).

Gómez Lahoz, J. 2003. "La enseñanza de la cartografía bajo la perspectiva de Bolonia". Encuentro Internacional de enseñanza de la Ingeniería Civil.

Heuvel F.A., 1998. *3D reconstruction from a single image using geometric constraints.* Journal Photogrammetry and Remote Sensing.

Parodi P, Piccioli G., 1996. *3D shape reconstruction by using vanishing points.* Trans Patt Anal Machine Intell 18:211–217.

References from Books:
Aguilera, D. G., 2005. *Reconstrucción 3D a partir de una sola vista.* Tesis doctoral. Dpto. De Ingeniería Cartográfica y del Terreno. Universidad de Salamanca.

Baarda W., 1968. *A testing procedure for use in geodetic networks.* Netherlands Geodetic Commission, Publ. on Geodesy, vol. 2, nº 5, Delf.

Domingo Preciado Ana, 2000. *Investigación sobre los Métodos de Estimación Robusta aplicados a la resolución de los problemas fundamentales de la Fotogrametría.* Tesis Doctoral. Universidad de Cantabria.

G. H. Golub and C. Reisch 1971. *Singular value decomposition and least squares solutions.* In Handbook for Automatic Computation, Vol. 2 (Linear Algebra) (J. H. Wilkinson and C. Reinsch, eds), 134--151. New York: Springer-Verlag.

Hartley R. and Zisserman A., 2000. *Multiple View Geometry in Computer Vision*, Cambridge Univ. Press.

Kraus, K. 1993. *Advanced Methods and Applications. Vol.2. Fundamentals and Standard Processes. Vol.1.* Institute for Photogrammetry Vienna University of Technology. Ferd. Dummler Verlag. Bonn.

Pope AJ., 1976. *The statistics of residuals and the detection of outliers.* NOAA Technical Report NOS 65 NGS 1, U.S. Departament of Commerce, National Geodetic Survey.

Williamson James R., Michael H. Brill, 2004. *Dimensional analysis through perspective.* 123 Photogrammetry, Texas, 77549-1221.

References from other Literature:
Aguilera D. G, M. A. Claro-Irisarri, J. Gomez Lahoz, J. Finat, and M.Gonzalo-Tasis*, 2004. Development of a simulator for reliable and accurate 3D reconstruction from a single view.* Proceedings of ISPRS, Istanbul.

Brauer Richard, Burdchart and Klauss Voss, 2001. *A new method for determination and correction of weak radial lens distortion using single views.* Computer Science and Digital Processing Image Group. Germany.

Cipolla, R., Drummond, T., Robertson, D.P., 1999. *Camera calibration from vanishing points in images of architectural scenes.* Proc. 10th BMVC, pp. 382-391.

Comisión Europea. "White Paper on Education and Training. Teaching and learning. Towards the learning society".

Fischler, M. A., and R. C. Bolles, 1981. *Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography.* Communications of the Association for Computing Machinery.

Grammatikopoulos, L., Karras, G., Petsa, E., 2003. *Camera calibration approaches using single images of man-made objects.* Proc. 19th CIPA Int. Symp., Antalya, pp. 328-332.

Haug, G. 2002. Cooperation towards educational objectives in Europe. El espacio europeo de educación superior: una convergencia necesaria. Cursos de Verano de El Escorial, 2002.

Liebowitz, D., Criminisi, A., Zisserman, A., 1999. *Creating Architectural Models from Images*, EUROGRAPHICS'99, 18(3).

Morgan, P Hodkinson, R. Enemark, S. 2002. "Quality assurance in surveying educa-tion". FIG Publications. http://www.ddl.org/figtree/Pub/flgpub/Publ9/flgpubl9.htm

Remondino, F., Roditakis, A., 2003: *Human Figure Reconstruction and Modeling from Single Images or Monocular Video Sequences.* The 4th International Conference on "3-D Digital Imaging and Modeling" (3DIM), pp. 116-123, Banff, Canada.

P. Sturm and S.J. Maybank. 1999. *A Method for Interactive 3D Reconstruction of Piecewise Planar Objects from Single Images.* BMVC - 10th British Machine Vision Conference, Nottingham, England, pp. 265-274.

Tuytelaars T. Van Gool L. Proesmans M. Moons T., 1998. *The cascaded Hough transform as an aid in aerial image interpretation.* Proceedings of ICCV.

References from websites:
ImageModeler, 1999, http:// www.realviz.com

Tuning. 2002. "Tuning educational structures in Europe" http://www.relint.deusto.es/TUNINGProject/index.htm.

Wagenaar, 2002. Educational structures, Learning Outcomes, Workload and the cal-culation of ECTS credits". http://www.relint.deusto.es/TUNINGProject/line3.asp.

Woods, D.R. 1997. "Problem based learning: helping your students gain the most from PBL" http://chemeng.mcmaster.ca./pbl/pbl.htm