A NEW SUPPORT FOR TEACHING AND RESEARCH IN PHOTOGRAMMETRY: THE STEREOSCOPIC CLASSROOM

S. Dequal, A. Lingua
Politecnico di Torino – Corso Duca degli Abruzzi, 24 – 10129 Torino – Italy
DITAG - Land, Environment and Geo Engineering Department
Email: sergio.dequal@polito.it; andrea.lingua@polito.it

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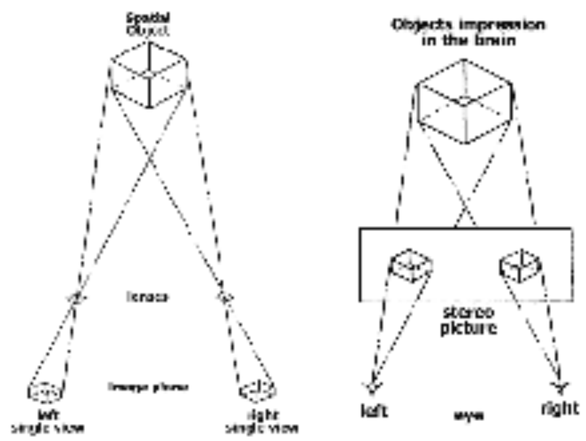
ABSTRACT

Stereoscopic imaging requires a minimum of two pictures, which simulate the perception of two eyes. This effect can be accomplished by using photographic images (stereo photography) or lasers (holography).
Recently, a stereoscopic classroom has been equipped in the DITAG (Land, Environment and Geo Engineering Department), Politecnico di Torino, to support research and teaching activities in photogrammetry. The system is composed of a silver screen and 2 high brightness projectors that use polarizing filters. The users (up to 15-20 people) can observe 3D models using specific (very cheap) glasses with polarized lenses.
In this paper, the authors describe the recent activities using the stereoscopic classroom performed during the photogrammetric lectures in the degree courses and some research applications.

1. INTRODUCTION

1.1 What is "Stereo" or "3D"?

The word "stereo" originates from the Greek and means "solid". Originally the term was associated with stereoscopic pictures, which were either drawn or photographed. In order to avoid confusion with stereophonic sound, one often talks about 3D pictures and especially 3D films, where 3D, of course, stands for three-dimensional.
A person lives in a three-dimensional, spatial, environment. Without a feeling of space, we cannot move within it. Our perception of space is created almost exclusively by our eyes. There are many ways to orient oneself in space, e.g., by perspective, gradation of colour, contrast or movement.
The lenses of the eyes in a healthy person project two slightly different pictures onto the retinas, which are then transformed, by the brain, into a spatial representation. The actual stereoscopic spatial observation is a result of this perception through both eyes.
A number of people, however, have eye-defects, that make stereoscopic viewing impossible. They safely orient themselves in their environment by employing one of the previously mentioned methods. Even a person with only one eye learns how to move around safely, using non stereoscopic cues.



(a) (b)

Figure 1 – Stereophotos and their impression on the brain

A normal picture on paper or film is photographed with only one lens and cannot, therefore, convey a true spatial perception. It is only a flat picture. By taking two lenses and imitating the eyes, it is possible to create a space image (Figure 1a). When a stereo picture is created in such a manner as to be examined with or without instruments, a similar perception of space is formed in our mind (Figure 1b).

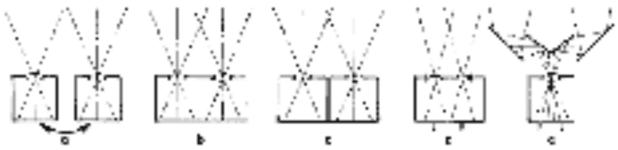


Figure 2 – Stereo photo acquisitions

Two necessary, somewhat different, single views can be generated by different methods. They can be produced in the same way as old stereo artists did, first drawing one then the other single view. The exposures can also be taken one after the other with a normal single lens camera (Figure 2a). It is evident that the subject must not move during this procedure, otherwise the two pictures would not be related to the same scene. A better approach is to imitate the head, and mount both lenses onto a single chassis. In this way a true stereo camera is obtained (Figure 2b). This is basically only the joining and synchronizing of two mono-cameras. It is also possible to take stereo pictures with two coupled cameras (Figure 2c). The two lenses can also be combined as interchangeable optics in a single camera (Figure 2d).
It is also possible to take two exposures with only one lens by placing a beamsplitter attachment in front of the lens. The splitter is constructed with mirrors or prisms or a combination of both. This divides the optical path so that two separate pictures are formed on a single film frame (Figure 2e).

1.2. A brief history

The belief that the ancient Greeks already knew of stereoscopic interaction has been proved a figment of the imagination. The same is true of the story that Leonardo da Vinci drew stereo pictures. These incorrect assertions stem almost exclusively from the English physicist David Brewster, who frequently wrote on stereoscopic matters.
The true discoverer of stereoscopy was, in fact, another English physicist, Sir Charles Wheatstone (Figure 3), who also designed the Wheatstone Bridge. On June 21, 1833, he lectured to the Royal Society in London on his discoveries concerning stereoscopic phenomena. This lecture was also printed and his

work widely became known. He supported his accidental discovery, which resulted from acoustic experiments, with drawings, and developed the first *mirror stereoscope*.

Figure 3 – Sir Charles Wheatstone

On August 19, 1839, the Frenchman Louis Jacques Mandé Daguerre explained his method of generating permanent photographic pictures (*daguerréotypies*). These were taken using a camera obscura, which was invented by the Frenchman Nicéphore Niepce in 1822. It thus became possible not only to draw stereograms, but to photograph them as well.

(a)

(b)

Figure 4 - Sir David Brewster (a) and his stereo camera (b)

Many early photographers flooded this new field with their work. But since only a few had a full grasp of the basics, much nonsense was written. It was, for example, noted in Liesegang's "Photographisches Archiv" back in 1869 that incorrectly photographed stereograms cause headaches.
The above mentioned Sir David Brewster improved the stereoscope and in 1849 the first true stereo camera with two lenses (Figure 4) was built. In 1855 the Frenchman Barnard invented the first frontal stereo attachment constructed with mirrors for single lens cameras.
Later, the Englishman Brown improved on his design. The stereo viewer (stereoscope) was further developed by the Germans Hermann von Helmholtz and Karl Pulfrich.
The stereo craze of that time had already diminished by 1900 and was only later stimulated by the so-called Kaiser-Panorama of August Fuhrmann (Figure 5) from Berlin, for a short period of time. This consisted of a set of several stereo viewers situated side by side in a circle. The stereo slides rotated step-wise on a drum at a certain speed from one viewer to the next.

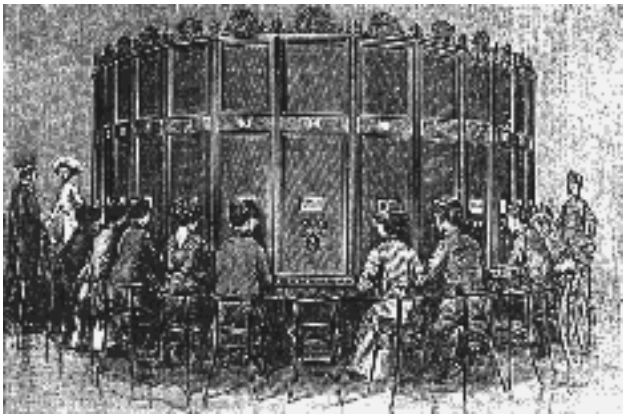


Figure 5 – The Kaiser-Panorama of Fuhrmann

In the year 1936, three techniques were invented for the cheap and industrial production of polarization filters (Bernauer, Kaesemann, Land & Mahler). Picture separation thus became possible even for colour photographs. With the help of these techniques, the amateur could project his stereo slides onto a projection screen. This, of course, generated a great deal of interest, and led to the construction of true stereo projectors with two lenses.

2. VIEWING STEREO PAIRS

In order to create a spatial image in the brain it is necessary for both of the single views to be presented separately to each eye.
Different methods are available to obtain this objective: subtractive or additive procedure.
The subtractive procedure can be further subdivided into:

a) geometric beam selection in the viewer;
b) physical beam selection through anaglyph or polarizing techniques;
c) temporal beam selection through successive transmission.

In the viewer or stereoscope, a partition is sufficient for image differentiation. Figure 6 (a, b) shows two schemes of stereo-scopes which can be used with stereo photos (obtained as described in 1.1).
With the interchanged single view positioning, which is produced by exposure with twin lenses, the correct positioning must be recreated for the eyes with an appropriate arrangement of mirrors.
It should, at this point, be mentioned that an attachment for projection of both types can be used during projection. The position of the polarizing filters (PF in Figure 6c) must, however, be correctly chosen. The mirrors in the projection attachment must be adjustable. The aperture between the two light beams, with which edge distortion can be screened out, is also important.

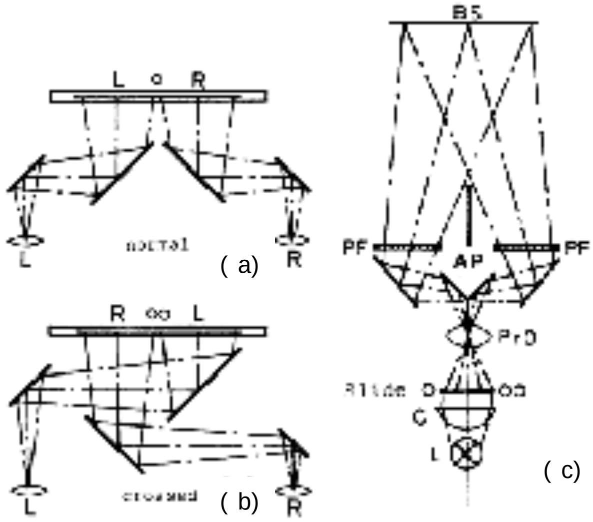


Figure 6 – Some schemas of stereoscopes and viewers

So called mirror-stereoscopes are available for the viewing of larger picture formats (Figure 7). The viewing path is diverted by two mirrors. With formats over 25 x 25 cm^2 it is also possible to do without viewing optics. These large formats are frequent in aerial photos.

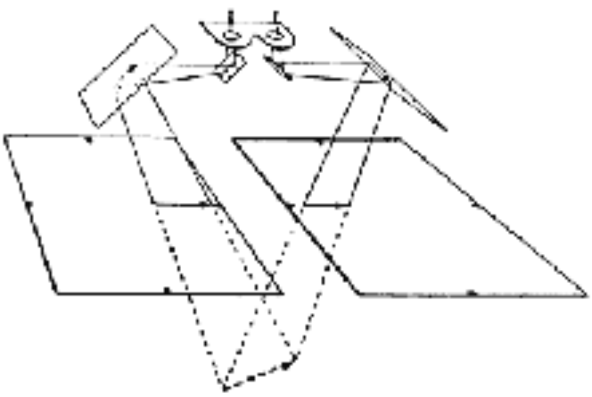


Figure 7 – Scheme of a mirror stereoscope

Another way of viewing larger 3D formats, even coloured ones, is to place them one above the other. Prism spectacles divert the eyes' axes by 13 in a vertical direction. The correct viewing distance depends on the format of the picture, or rather from the separation of the centres of the pictures or the angle between the diverted eyes axes. So one must adjust one's position till one sees only a single spatial image. This is used mainly for 3D illustrations in books or magazines. The most well known brand is the German KMQ system (Figure 8). The system is called "over/under" and it enables a 3D image to be viewed on a TV screen without polarizing filters. There are also glasses that can be adjusted in a range of 0-16°. Viewing is thus possible from different distances.
In order to save space, such pictures are also printed one over the other. For this purpose, complementary colours, usually red and cyan (light blue-green) are used. These complementary colours lie exactly opposite each other in Oswald's circle of colour and appear black when viewed subtractively. If one holds two filters of these colours back to back against the light, they together appear black.
This method is known as *anaglyphic procedure*. It was described in 1853 by Wilhelm Rollmann. The word "anaglyph" stems from the Greek and means "carved in low relief". This procedure can only be used correctly on black and white pictures.
The right single view is printed or drawn in red and the left view in cyan. During viewing through anaglyph spectacles with a red filter on the left and a cyan filter on the right, the left single view appears dark upon a cyan field and the right one appears dark upon a red field. Both blend together into a black and white spatial image upon a light field. The order of the anaglyph glasses can be easily remembered: it is the same as the location of the signal lamps on ships: right = starboard = green and left = port = red.

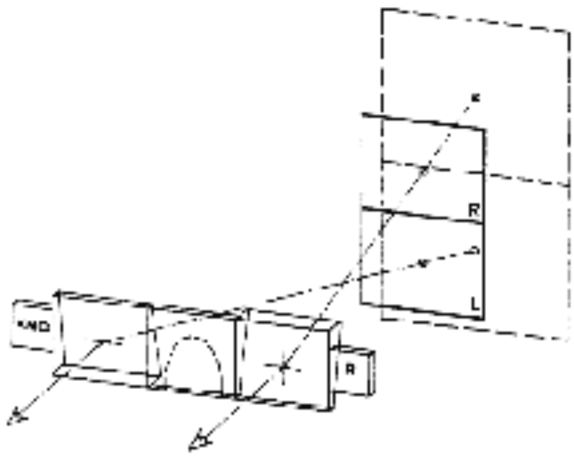


Figure 8 – Schema of the German KMQ system

This standard is not always followed. For example, one must view the frontispiece of a recent book: *La télévision en relief* (3D television) by Marc Chauvierre with one's glasses "reversed" to obtain the correct spatial image.
For the projection of black and white stereo slides, it is not necessary to colour them accordingly but it is sufficient to place the respective colour filters onto the appropriate projection lenses.
The English LEE FILTERS Co., Andover, Hampshire, manufactures such filters. The labelling on the filters is "primary red" No. 106 and "primary green" No. 139.
A different process is required for colour slides: one that employs neutral *polarizing grey filters*. Natural light oscillates in all directions (azimuths). If one sends the light through a filter, which one can imagine as a narrow grating made from very thin, parallel strings, only that part of light oscillating in the direction of the strings will pass through. The light is polarized. Therefore these filters are called polarizing filters (Figure 9).
If a second polarizing filter is then introduced into the light path, only a part of the polarized light which depends on the positioning of the second filter is allowed to pass. This part becomes null, i.e., it becomes dark, when the angle of the polarizing filters to one another becomes 90°. The amount of attainable darkness is a measure of the quality of the polarizing filters. Even when the polarizing filters are parallel to one another, only a part of the light passes through since these also act as grey filters.
The desired image differentiation is achieved by associating the two eyes, and their corresponding paths of beam, with two polarizing filters. These pairs must be parallel to one another and crossed towards each other. One filter is placed on a projector lens and the other in front of one eye as a spectacle. Because of this, each eye sees the light, i.e. the picture from the corresponding projector lens.

Polarized light is also found in nature where it is usually oscillating either vertically or horizontally. In order to avoid distortions from such light, the oscillating direction for polarizing filters used in stereo viewing must be located below 45°. The two oscillating directions should form a "V" whose legs are perpendicular.

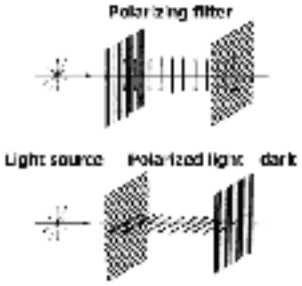


Figure 9 – The polarizing technique

This requirement is already fulfilled in some commercial polarizing glasses. The POLAROID Company, USA, which manufactures glasses of different qualities and price ranges, also offers polarizing filters for projectors of different models. It is necessary to compromise between the quality of the polarization and the amount of light the filter allow to pass.
Only one material must be used for the projection surface, i.e., that does not change the polarization of the light. So called "silver screens" are, therefore, used. These are usually sprayed with an aluminium paint. However, the application of a protective coating often inhibits the desired effect. Not all silver screens are therefore suitable for stereo projection.
Temporal image differentiation using the successive transmission procedure was first used in the projection of 3D movies and in modern Digital Photogrammetric System. It did not become popular, primarily, because of technical problems.
The single right and left views are successively, one after the other, projected onto the screen. The corresponding eye must be uncovered and the other one covered. This is not a problem during projection. With a stereo pair, for example, each picture is either uncovered or covered by a moving aperture. In a film, the single views are alternately positioned on the same strip of film (single-strip procedure).
The difficulty lies in the opening and closing of the eye covering. This covering must not only be temporally synchronized, but it must also be synchronized with regards to the position. In addition, all this causes quite a strain on the eyes.
So called "LCD glasses" are used for this purpose. An advantage of this procedure is that no light-losing anaglyph or polarizing filters are used and no silver screen is required. An invention by the English physicist Dr. Robinson, is the latest of a series of special glasses. These can be lightened or darkened by electrical fields. The electronic switching in the glasses can be controlled by infrared rays emitted by an especially equipped PC monitor, which also alternately display the right or left single views.
The *additive procedure* can be performed by image differentiation through a raster process. With the raster procedure, also called "lenticular", several pictures are used in the creation of a spatial image. In this case it is possible to talk about partial views, which are nestled onto each other as rasters, rather than of left and right single views. Both mechanical and optical rasters exist. All of the methods have one thing in common: the finished pictures cannot be constructed by amateurs. The images can be viewed by the naked eye and are generally well known from the spatial looking postcards that are now available in many shops.
Several examples of lenticular images can be found on the Web (see References in 6.1).

3. THE PROJECTION OF 3D MODELS

A good 3D model visualisation is the high point of any viewing. A prerequisite for this is an equally good mounting job, since even the best projection system cannot correct large mistakes made during mounting.
Each stereo projector must in addition to the focusing dial have controls for horizontal and vertical alignment. These controls should not only be adjusted, but also operated. These possibilities must be considered even for two coupled separate projectors.
As seen in section 2, the two single views are projected, on top of each other, onto the screen. In this way, the lenses or the entire projectors are aligned so that the inner edges of the slides lie exactly on top of each other. The top and bottom edges of the mount must also lie on top of the other. It is best to use one or two empty frames for the first adjustment.
The accessories required for image differentiation, such as anaglyph or polarizing filters, can be mounted anywhere between the light source and the screen. Because of the heat, one should, however, select a position between the slide and the lens. Polarizing filters can only be directly fastened to the lenses if these are not rotated during focusing, otherwise their relationship with the polarizing glasses is lost. During projection, it is unimportant which projector shows the right or left single view. It is sufficient that the correct ordering of the image differentiation accessories is retained. The projectors can be located side by side or one on top of the other. The latter results in less image distortion. Sometimes it is necessary that some form of heat insulation be placed under the top projector so that it is not needlessly heated by the one below. For warranty reasons, required setting controls are usually attached to the base on which the projector rests rather than to the projector itself.
As noted earlier, the polarizing filters in commercial glasses are already set in a correct V-position. They can be purchased as single sheets in either square or round formats. With the square format, the direction of the oscillation is already under 45°, i.e., diagonal to the outside edges. Because of this, they are easy to adjust and may only require a rotation of 90°. One half of the glasses is covered for calibration. The open eye should therefore only see the light from the corresponding projector. One lens should be covered at a time for control purposes.
The method is identical for round filters. The opposite filter is rotated until the picture darkens. For example, the projector showing the right single view is controlled by the left eye. An adjustment to darkness is more sensitive than one to brightness. The final setting should be marked on the filter and on the holder so that no re-adjustment is necessary when the filter is removed for cleaning. It is a good idea to cover the filtering sheets with glass plates such as those from old photo plates.
Projection of 3D models basically involves (Figure 10):

a) Use of a dual-lens projector, or two single-lens projectors;
b) Polarized filters over each projection lens aligned at right angles;
c) Use of an aluminium (silver) or lenticular screen, not a white one. A white screen will de-polarize the projected light, destroying the stereo effect. A silver, or lenticular silver screens, preserve the polarization of the projected light. However, not all silver screens are suitable for stereo projection;

d) Polarized glasses, which match the alignment of the projector lens polarizing filters, being worn. In most projectors and glasses, the orientations of the polarization is in a "V" shape. A notable exception is the FED projector and glasses, which have the polarization in the vertical and horizontal directions;

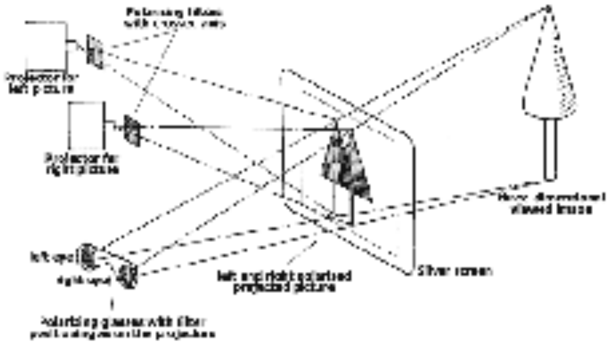


Figure 10 - Principle of a 3D model projection

Modern technology allows these systems to be managed using a 3D stereoready PC . This PC has a 3D video adapter which displays the two stereoscopic images on the same monitor in temporal beam selection (see section 2) using an active polarised screen (such as the well known Z-Screen produced by Stereographics). The user can observe the stereoscopic model using polarizing glasses (Figure 11).

Figure 11 – Stereoscopic visualization using a PC equipped with Z-screen

The output signal port which the PC is equipped with is a VGA port, which generates video signals, and a sync port, that transmits a synchronization active stereo viewing signal (left – right images).
An active to passive stereo 3D converter is therefore needed to split the video signal according to the synchronization signal so that each projector only receives one of the images of the stereo model (Figure 12)
An example of this system is the Viz3D system (Figure 13), which is produced by CYVIZ and distributed, in Italy, by GeaMedia Group S.r.l.. This system has recently been installed in the stereoscopic classroom at the DITAG - Politecnico di Torino.
Figure 13 shows the main components of the system in detail. Each projector produces a brightness of 2500 ANSI lumen for a total of 5000 lumen output which corresponds to about 2400 stereo lumens to the eye with 2500:1 contrast ratio.

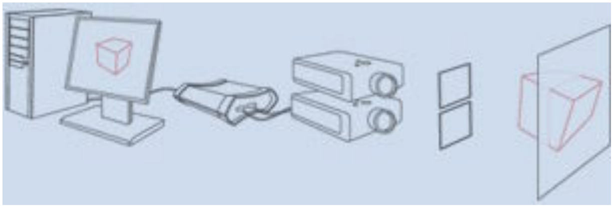


Figure 12 – Schema of stereo 3D projection system

Figure 13 - The Viz3D projection system at the DITAG

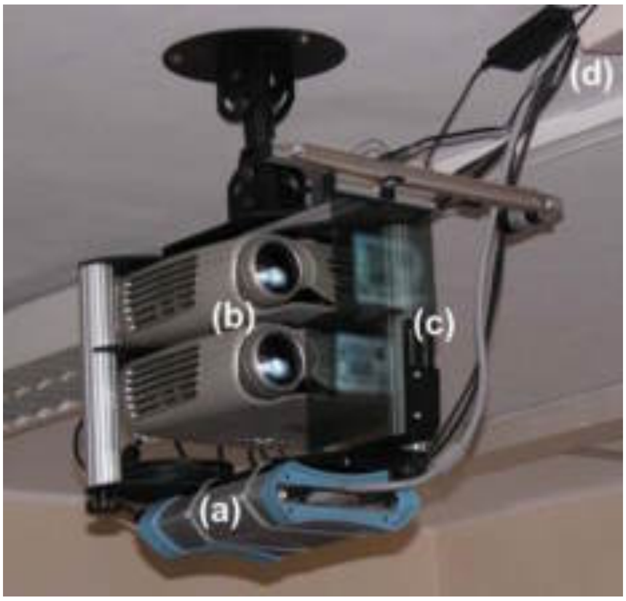


Figure 14 - The projection system: (a) stereo 3D converter, (b) projectors, (c) polarizing filters, (d) wire connection to the PC

The active to passive stereo 3D converter is shown in Figure 15.

5. TRAINING AND RESEARCH

Training in photogrammetric techniques and their applications requires that each student makes personally a significant part of the practical operations of orientation, photo interpretation, restitution of objects and contours, aerial triangulation and editing of digital maps.

Figure 15 - Active to passive stereo 3D converter

The trouble has always been that the traditional (analogical) stereoplotters and, later on, also the analytical instruments were equipped with binoculars that allowed the observation of the stereoscopic model by only one operator at a time.
Considering the high costs of those instruments and the number of students, often considerable, it was nearly impossible to allow the single student to be directly involved in practical experience on the instrument for a sufficient period of time.
Other clever solutions (still costly, though!), proposed in the sixties and consisting of "double binoculars" which allowed two operators (usually an instructor and a beginner) to observe all the operations done on the stereoscopic model at the same time, did not solve the problem of university teaching in photogrammetry.
The situation improved with the coming of digital photogrammetry and the spread of workstations equipped with polarized screens (for example Z-screen), by which stereoscopic vision is obtained using low cost polarizing glasses. In this case, a small group of 4 or 5 students can sit in front of the screen, able to follow the phases carried out by the operator directly. The additional cost for each additional observer is marginal.
Some limitations still remain, however: the number of participants is still very restricted, because the size of the Z-screen is limited (19" in diagonal) and it cannot be seen either from a distance of more than a couple of meters, or from an angle of more than 30°.
The recent appearance on the market of 3D video projection systems seems to be the ideal answer to the problem. It is now possible to organize a classroom for 25-30 students or more, equipped with a large screen (3 m in diagonal), perfectly visible to everyone, even at a distance of 6-8 m.
Last year DITAG – Politecnico di Torino bought one of these systems, as described in the previous paragraph. It has been interfaced with a photogrammetric workstation based on a PC and can be used without problems for every photogrammetric application available in our laboratory, both for teaching and research needs (Figure 16).
In detail, the following modules are available on the system:

1. General purpose orientation and restitution: Socet Set, LPS, Stereoview, GeoIn
2. Aerial triangulation: ORIMA, MST, SV Triangulation, GeoIn
3. 3D Navigation and Stereophotomap: StereoSpace
4. DTM production and Orthopho Projection: PCI Geomatics, Erdas, GeoIn

During the practical lesson, in the presence of the entire class, the teacher shows how to carry out a phase of the photogrammetric process (ex.: the relative orientation). Then he gives the control PC, in turn, to each student. The other students watch at the same time, learning the sequence of the operations and training their stereoscopic view.
The 3D classroom can also be used, with profit, for research purposes, whenever a problem of land analysis (land use, land slides, earthquakes, environmental disasters, …), requiring multidisciplinary competences, has to be examined.
In those cases the various experts (in geophysics, geology, geotechnics, geomatics, town planning, etc.) can sit in front of the screen, explore the 3D model all together, observe in real time and measure the objects of interest.
Very promising too are some non cartographic applications, for ex. in mechanical 3D modelling, medicine and bio-engineering.

Figure 16 – The stereoscopic classroom during a CIPA meeting

6. CONCLUSIONS

A good 3D model visualisation is the high point of any experience. The stereoscopic classroom, recently equipped at the DITAG in the Politecnico di Torino, allows 3D model visualisation to be shared by several operators, students and users with different degrees of knowledge. The photogrammetric lectures and practical lessons can therefore combine theoretical topics with applicative experiences in such a way as to assure a good, effective and sure teaching result. Moreover, in research applications, the stereoscopic classroom can guarantee operative cooperation between photogrammetrists and other specialists and lead to comprehensive analysis of multi-disciplinary studies.

REFERENCES

Books

Kraus K., "Photogrammetry" – Vol. 1 and 2 – Ferd. Dümmlers Verlag, Bonn

Other Literature

Artimo,K, "Different Aspects to University Education Surveyors", CESCG, April 1998

Artimo, K, "CAL The Educational Tool of the Future", Proceedings of FIG XXI International Congress, pp. 115-123, Brighton, 1998

Önder, M, "National Report of Turkey on Photogrammetry and Remote Sensing". International Archives of Photogrammetry and Remote Sensing, Vol. XXXIII, Part B6. Amsterdam, 2000

Web Sites

http://www.stereoscopy.com
http://www.geamedia.com
http://www.cyviz.com
http://www.orasee.com/one/main.php3
http://clik3d.com/Default.htm
http://stud4.tuwien.ac.at/~e9525021/CESCG98.htm