From analogue to digital techniques - consequences for the education and training in photogrammetry

by Joachim Höhle, Aalborg

Abstract

The current big changes in photogrammetry concern first of all the technology; but also the practice and the educational institutions have altered. From a survey of all of these changes the consequences for a future-oriented education and training in photogrammetry are outlined; they concern the contents, the form and the quality control. Various examples are given and suggestions are made.

1. Introduction

Currently, great changes are taking place in photogrammetry. This concerns first of all the technology. The advances in computers and software have rendered possible big improvements of performance, new methods and new fields of applications. These changes must be reflected in the education and training. What is the new contents, which subjects shall be dropped? Universities themselves and the students have also changed. Therefore, the form of education and the teaching aids shall be adapted to the changes. It must be the first goal of the education to satisfy the requirements of the photogrammetric practice. All the candidates shall find an interesting job in the fields they have studied. How is the feedback from the practical photogrammetry to the educational institutions ensured? And who is teaching the teacher? Education and training must have a quality control, and how is that done in the best possible way?

2. The technical development

The technical development in photogrammetry is very much technology-driven. The power of today's computer systems allows to handle huge quantities of data with high speed. Then, instead of handling a photograph as a whole, small picture elements (with their colour coded by intensity values) can be processed and stored. The digitizing of analogue photographs can be done by a scanner, or the 'picture taking' can be digital from the beginning. Special sensors allow also to record invisible radiation or return signals. The transmission of the recorded data can occur from a remote place nearly without delay. All this results in many new possibilities and applications (compare tab. 1).
This digital photogrammetry can make the standard applications more accurate and more efficient. The digital processing of images also takes place in other fields, for example in robotics, the graphical industry, medicine, etc. Digital photogrammetry benefits from these developments. But also the needs of the society and other industries push the field forward, for example the need to handle large amounts of photographs in earth or sea floor observation programs requires automation of the inspection. Therefore the technology in photogrammetry has changed and will change. The starting points of analytical photogrammetry is regarded to be 1970 and of digital photogrammetry 1990. /Leberl 1992/ There is, however, a substantial overlap of the three technologies and also quite some delay between research and practical application. The change is notable in instrumentation and methods. The instrumentation for evaluation of photographs (images) has changed drastically, software becomes just as important as hardware (compare tab. 2).

analogue	analytical	digital
topographic mapping (manuscript mapping) photointerpretation (by operator) photo mapping non-topographic applications (architecture, police, medicine)	cadaster acquisition and editing of topographic data bases topographic mapping (direct plotting of final maps) utility mapping map revision with superimposition multimedia problems terrain modelling deformation measurements photo geodesy	remote sensing for resource management monitoring of environment multi-media GIS machine-vision inspections and quality control robotics radargrammetry landscape visualisation

Tab. 1 New application fields of photogrammetry as a result of the changing technology

analogue	analytical	digital
HW precision camera stereoplotter mechanical plotting table point marking and transfer instrument	amateur camera stereocomparator monocomparator analytical plotter analytical orthoprojector digital plotting table graphical screen	digital camera scanner spectral radiometer automatic comparator stereo workstation raster plotter
SW	block triangulation height modelling camera and instrument calibration	orthoimage production automatic height measurement image processing image analysis

Tab. 2 Instrumentation (HW) and software packages (SW) with changing technology

The instrument making companies of the analogue period got tough competition from software and computer companies. The methods of analytical photogrammetry (compare tab. 3) are still necessary, but the instrumentation may become obsolete. But the efficiency of the new instruments and the availability of large and continuous tasks will determine the speed of change. There are, however, many tasks which the digital technology cannot solve in the next future. For example to replace the operator when mapping and coding topographic objects. These efforts seem to be too complex to do this task completely and with an acceptable level of errors.
Digital photogrammetry is also part of the big field of remote sensing and remote sensing is part of mapping. And all these fields contribute to the rapidly growing field of Geographic Information Systems (compare fig. 1). Photogrammetry takes part in shaping these three other fields.
The integration of these fields is named as Iconic informatics. /Li 1991/. Other names suggested are Iconometry, Geomatics, Geoinformatics or Geoiconics. Whatever the new name will be, a lot of tasks and activities in photogrammetry can be expected in the future. This will give photogrammetry a new status and new selfconfidence. /Ackermann 1992/ The transition from analogue to digital photogrammetry has to have consequences in the education and training. It is the purpose of this paper to investigate these consequences.

analogue	analytical	digital
relative and absolute orientation plotting of contours and situation lines point marking	joint orientation orientation with lines resetting of models multi-model evaluation superimposition object-oriented data collection block triangulation with models and bundles automatic blunder detection self-calibration off-line differential rectification sensor integration	rectification matching orientation with areas real-time evaluation low-cost superimposition automatic triangulation automatic classification feature extraction

Tab. 3 New methods with changing technology

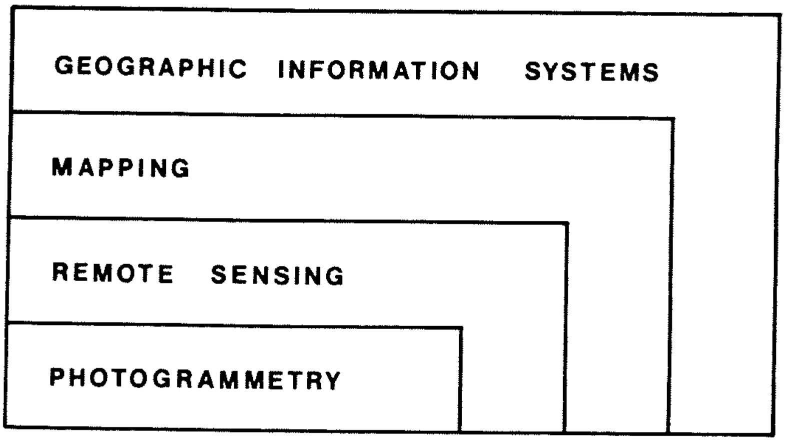

Fig. 1 Photogrammetry contributes to the fields of Remote Sensing, Mapping and Geographic Information Systems

3. The photogrammetric practice

The change in technology has rendered possible many new applications. In tab. 1 some of the new applications are presented as they came up with the analogue, analytical and digital technology. This has given the photogrammetric practice new tasks and a diversification. Furthermore, the previous applications become more efficient and more accurate. For the candidates it meant that they had to acquire still more knowledge. The continuous learning after the studies, the lifelong education is mandatory today. A broad knowledge combined with the capabilities to dig into new subjects, systematically and fast, are requirements for successful candidates. The dominance of software tasks requires knowledge of one or more computer languages, operating systems, exchange formats, etc. Another lesson from the practice is that you cannot do everything by yourself or within your own organisation. Therefore, you have to cooperate with other technical groups (within or outside your own organisation), in order to get the required knowledge at the lowest cost. This means that working in organisations needs good abilities in communication. The work for multinational firms furthermore demands knowledge of several major languages and sensibility and tolerance for differences in cultures. The skill to measure, to plot or to know all the different knobs of a machine is not of sole importance anymore. What counts today is the skill to analyze the constantly changing circumstances and to specify the tasks to be done.
To select, introduce, use and especially to amortize the (expensive) new tools (compare tab. 2) are great challenges for the candidates. He or she must understand a lot of economy and marketing. The professionalism to obtain contracts in various photogrammetric applications, to solve the tasks to the clients' satisfaction (over many years) and to earn money for new investments demands broad skills.

4. The educational institutions

Many changes have occurred at universities, too. In the late sixties a democratisation took place. At universities like Aalborg University the students got influence to shape their education. The students have great freedom, e.g. in selecting the topic of their projects, their teachers and goals for excursions, etc., and they are not pressed by examinations all the time. The professors lost some of their power and responsibility, but are relatively free from administrative work. Education is very much oriented towards practice and is thus 'job-driven'.
The *education of the Danish surveyor* at Aalborg University, for example, covers among other subjects photogrammetry, mapping, remote sensing and GIS. Photogrammetry is taught from the 3rd term up to the 9th term and a final project takes place in the 10th term (see figures 2 and 3). The teachers of the surveying programme belong to the Department for Development and Planning. Image processing and image analysis are also taught at the Electronics Department; their applications are mainly in robotics and medicine.

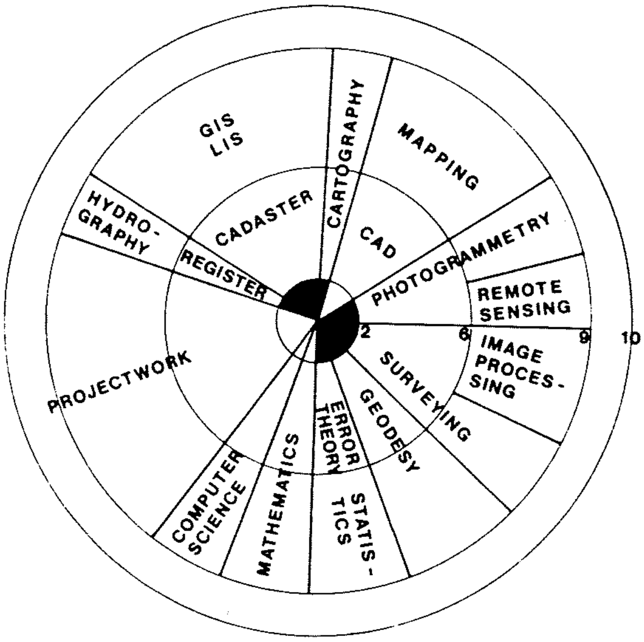

Fig. 2
Subjects of education for surveyors with relation to photogrammetry (the AUC model).
The three circles mean a change within the study, the numbers at the three circles represent the number of terms. Within the completion of the
2nd term: End of general education and start of professional education
6th term: Bachelor degree, start of specialisation
10th term: Master degree, end of study

At the Technical University of Copenhagen Photogrammetry, Remote Sensing and GIS are part of the Civil Engineering studies. There exist general courses in image processing which is taught for a variety of other fields. GIS is taught at various other universities in Denmark, and the teachers have established a cooperation and founded a group which holds regular meetings. /Kaae 1992/ The universities in the Scandinavian countries are holding regular meetings to exchange information on their research activities in GIS. Aalborg University takes part in an informal network of universities in Europe which deals with LIS/GIS subjects and provides education for yong teachers from East European countries within the TEMPUS programme of the EC /Stubkjær 1993/.
Digital photogrammetry and image processing are not a monopoly of the surveying education. Cooperation between different departments on a regional, national and international level contributes to promote the new technologies and to share human and equipment resources. Other changes at the university concern a harmonisation of the education within the European Community. For example, the structuring into Bachelor, Master and PhD degree studies will allow more flexibility, from the point of view of the student, in changing the subjects, the university or the country. Then students and candidates can accomodate their wishes and adapt themselves to the requirements of the job market.
Nowadays students have many possibilities and much freedom. And perhaps they are also more wealthy, combined with the fact that personal computers (PCs) be-

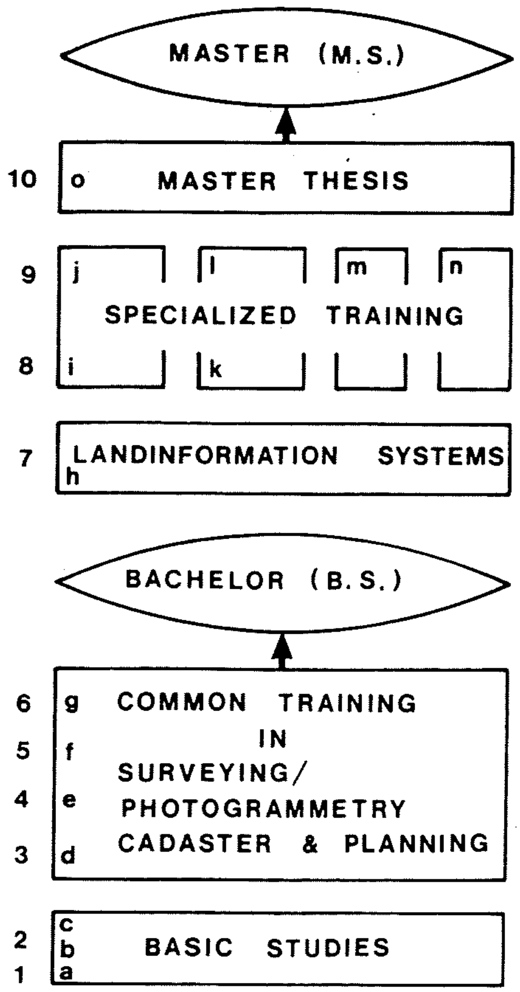

Fig. 3
The curriculum for the education of chartered surveyors at Aalborg University.
The numbers in the figure mean terms, the letters project units. At the project units the following themes are covered:

a,b,c	general themes of technical/natural or social science
d	regional and local planning
e	town surveying
f	cadastral management
g	land surveying
h	land information systems
i	technical surveying
j	mapping
k	public management
l	land management
m	urban and regional planning
n	international technology planning
o	one of the themes h-n

come affordable. This implies that the students possess their own PC and are used to do word processing and have knowledge of and access to many useful programs. Many students are familiar with computer programming. This applies already to students at the high school. These changes at high schools and universities have to be considered when discussing new contents, form and quality control in photogrammetry.

5. Contents of the education in photogrammetry

In order to form the contents of a modern education in photogrammetry photogrammetry should be put in the centre of the considerations and the contributing disciplines should be placed around it. This is justified because photogrammetry is also an established profession with many applications and organisations. However, at many universities photogrammetry is just a part of either surveying engineering or geoinformatics or geography. The large thematic expansion of photogrammetry can only be handled in a limited way, depending on the weight which photogrammetry gets at the specific university. Old techniques, methods and instrumentation must be dropped in order to find room for new subjects. There should be a shift from skill-based learning to a problem-based learning. The geometric thinking should be supplemented by image understanding and computer vision. Furthermore the education should follow pedagogical principles. For example, the basic knowledge is followed by a systematic building up to more sophisticated knowledge. Exercises and projects should put the student in a very active role (compare also next chapter).

The following is based on the experiences of the author at Aalborg University which is in many ways a very special university. Great emphasis is laid on education, and the education is very experimental and innovative.
Fig. 2 shows subjects within the education for surveyors. These subjects have a strong connection to photogrammetry or contribute to the knowledge in photogrammetry. These are quite a lot of subjects, some stretch over the total length of the study (e.g. mathematics and computer science). The subjects are taught by lectures (accompanied by solving smaller tasks), exercises and project work (see next chapter). Tab. 4 and 5 show for the main subjects (photogrammetry, remote sensing and mapping) more detailed contents of the courses and the attached exercises.

Photogrammetry terrestrial photogrammetry advanced analytical photogrammetry camera calibration precision photogrammetry and photogrammetric surveying of technical objects digital images and their characteristics digital camera and frame grabber correlation applications	8th term
scanning of photographs digital ortho image production stereo digitizing from digital images automated mapping (incl. matching, perceptual organisation with examples)	9th term
Remote sensing incl. image processing electromagnetic radiation and spectrum image characteristics sensors and platforms image representation principles in image processing image improvements classification application of remote sensing data systems for handling of remote sensing data	7th term
rectification of remote sensing data mapping with SPOT, RADAR and LIDAR data feature extraction coastal & ocean mapping	9th term
Mapping coding of data storing of data in data bases map updating data exchange interactive graphics systems (IGS) raster techniques height models combination raster/vector topological mapping data modelling map editing generalisation	9th term

Tab. 4 Courses[1] at the technical specialisation (7-9th term) at AUC (status 1992)

These examples from the MSc programme (status 1992) of Aalborg University demonstrate that analogue photogrammetry is not completely out but education in photogrammetry is becoming very much digital. Aerial photography for mapping purposes will still be made by analogue cameras for quite some time to come,

1 Lecture and solving of smaller tasks.

mainly for economic reasons. The analogue photographs will be digitized by means of scanners. Tasks with demands for high precision (e.g. deformation measurements in industry) require also analogue photography. Small format CCD cameras have their potential in real-time applications, but the achievable accuracy with them is limited. This is one of the experiences which the students will gain, when they apply both techniques. Therefore, analogue photography is still a subject of our training.

Photogrammetry

Point determination with high precision
Mission planning, picture taking, control point measurements, developing of photo plates, measurements in the analytical plotter, error analysis
(by means of precision camera and analytical plotter)

Computation of object points by different methods
Programming of procedures, assembling of different programs, computation of object points by different methods
(by means of personal computers)

Taking of digital images and their processing
Picture taking, storing, input to different image processing systems, rectification, correlation and screeen plotting
(by means of CCD camera, image processing software 'CHIPS' (University of Copenhagen) and 'IMAGER' ('Intergraph')

Remote sensing/image processing

Classification of SPOT imagery
Data input, manipulation, screen plotting, collection of statistical data and classification
(by means of the image processing software 'CHIPS')

Mapping

Object-oriented mapping with topology
Object definition, designing of object hierarchy, screen digitizing on top of large-scale orthoimage, object-oriented mapping and editing, selecting and measurement of attributes, study of topology, analyzing of data
(by means of the GIS software 'TIGRIS' (Intergraph)

Height modelling
Input of data, interpolation and conversion between TIN and GRID structure, analysis, presentation by means of contours, profiles, isometry
(by means of software package 'MODELER' (Intergraph)

Exchange of map data
Creating of a small map in an Interactive Graphics System, conversion of the map data via the National Exchange Format to the DXF (AUTOCAD) format. The same data set is also directly converted to AUTOCAD
(by means of the IGS software 'GeoCAD' (Aalborg University))

Tab. 5 Exercises[1] at the technical specialisation (7-9th terms) at AUC (status 1992)

Also the digital mapping in 3D by means of analytical plotters is still a part of the undergraduate training. The coding of objects, the precise and economic measurements will be carried out best by an operator, under stereo observation and with analogue photography. This will not change in the near future. Nevertheless, the Laboratory for Photogrammetry has recently acquired two low-cost digital instruments which replace the optical-mechanical stereoplotters. These digital instruments shall be used for training in orientation and map updating. These instru-

1 Exercises of 4 hrs. each.

ments have a built-in superimposition and 'instruction oculars'. These features cost a 'fortune' at the analogue and analytical instruments. Digital stereoplotters are therefore ideal for training and education. They also have all the prerequisites of automation, for example the automatic height setting during the planimetric mapping. It is obvious that available digital instruments do not use the full poten-

8th term	- Photogrammetric surveying of a reconstructed vikingship - Terrestrial photogrammetry by means of simple instrumentation - an accuracy evaluation - Correlator & measurements of water depths
9th term	- Texture analysis in digital images described by means of co-occurence matrices (together with TU Helsinki) - Quality test of orthophoto 475 - Least squares matching (together with KTH Stockholm) - Neural network - applied to classification of black & white orthophotos - Monoplotting - The Danish road data base D/200 VDB and its use for route optimizing
10th term	- Automatic derivation of a digital height model from scanned contour lines - Digital photogrammetry - an alternative today? - Automatic measurement of crossroads in digital images - Automatic/interactive line extraction in satellite images in view of updating topographic maps 1:100000 - Design of a photogrammetric editing station - Photogrammetric mapping in Tanzania - Application of digital orthoimages - Design and application of perspective images - Production of digital colour orthoimages - using a height model derived from a digital map - SPOT images for the supervision of nature

Tab. 6 Examples of projects at AUC.

tial of digital photogrammetry. But the education and training at universities must look ahead. Topics like correlation, edge enhancement and object extraction are important for future applications. Therefore digital photogrammetry has great importance already today.

6. Form of education

Also the form in university education should be adapted to the requirements of the future. This means a preparation of the students for professional work which will continuously change and which will require communication, cooperation and competition with other fields and at an international level. With these goals in mind the following *changes in the form of the education* should take place:

1. The student is considered as a partner in the educational process who contributes to the education by his own contacts to the practice, with his own studies on his personal computer and teaching software and by literature study in new fields. The student has to have an active role. The traditional lectures ('monologues') of the teachers have to be reduced or at least complimented by solving tasks, by exercises and especially by project work.

2. The education should *not* be considered as a by-product of the research at the particular university. The student himself has to get in touch with very different practice and research within the studies. There exists a plenty of tasks and problems in the society to the solving of which the students can contribute. A small group of students (2-5) should define and analyze the problems and solve them during a whole term. The problem solving shall be done by means of literature study, experiments and field work. The teachers give the introduction

and overview on the subjects, lead the project relevant study circles and guide the groups during problem solving. Besides the university employed teachers also guest lecturers from practice should give information and ideas to the project group. Fig. 4 shows the components of the problem-oriented project work. (Some of the recent projects at AUC are presented in tab. 6).

3. The studies should provide a great deal of flexibility in selecting projects, various specializations or a temporal stay outside the unversity, e.g. a one-year stay at a foreign university.

4. The education should include the use of the English language. For example report writing, oral and poster presentations and excursions to foreign institutions will improve the students' ability in technical and scientific communication.

5. The use of personal computers is recommended in the lectures by the teachers, and in the exercises by the student. Furthermore, special learning software should be used by the student in self-study. (This computer-assisted learning is explained in more detail in (Höhle 1992). CAL for photogrammetry is being used at AUC since 1988).

The outlined changes in the form of the studies will require a high flexibility and broad experience of the teachers. He or she has to be educated continuously as well. By participating actively in the projects, solving problems all the time, updating the courses, preparing new courses and study circles and own research activities the teacher's education will continue.

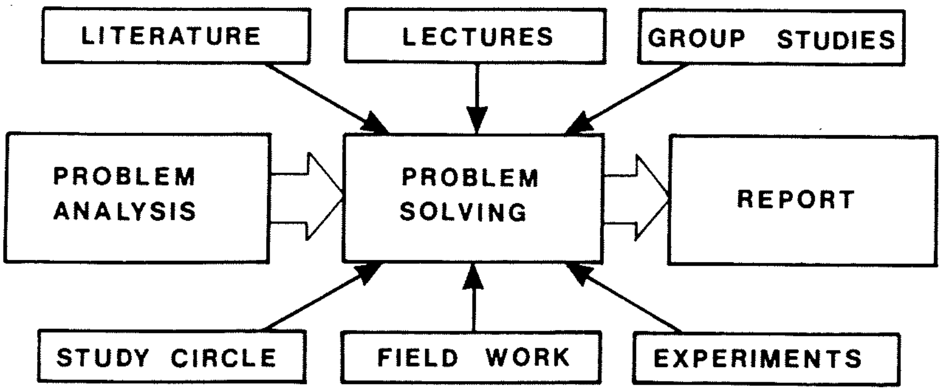

Fig. 4 Principles of problem-oriented education

The use of practitioners as guest lecturers and project consultants as well as the technical excursions will give practical input to the projects. Therefore the teacher's active participation in the student's project work as well as his own research work and contacts to practice are essential for a good and future-oriented education (compare fig. 5).

7. Quality control

In order to achieve and maintain a high quality in the education and training, evaluations should be carried out. According to /Stubkjær 1992/ these evaluations can be done by:
- self-ratings
- ratings by colleagues
- ratings by administrators
- ratings by graduates
- student achievements or

- student ratings.

The valuation concerns not only the education but also the research. Only active research of the teachers ensures the stimulation of the creativity and curiosity of the students who are obliged to adapt to new things. /Enemark et al. 1988/

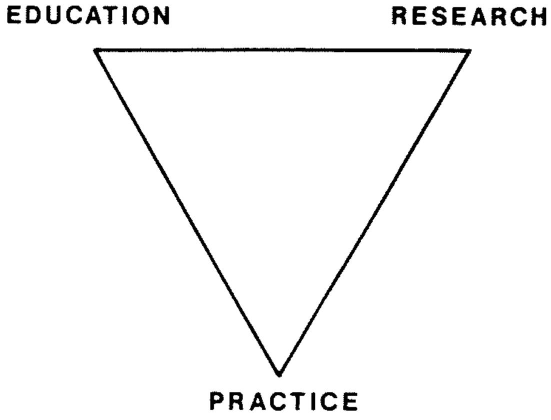

Fig. 5 The triangle of a future-oriented education

At Aalborg University the evaluation of the courses and teachers is done by the students after each term. They are encouraged to write an evaluation report which is then discussed together with the teachers in a joint meeting. The projects of the students are evaluated by internal or external examiners. The external examiners come from practice or other educational institutions, they give the ratings. Tab. 7 shows a list of the terms/project units and the type and number of examiners.

Term	Project unit	Type	Number
1			
2	general themes	external	1
3	regional and local planning		
4	town surveying	internal	1
5	cadastral management	external	1
6	surveying/photogrammetry	external	1
7	land information	internal	1
8	technical surveying	internal	1
9	mapping	internal	1
10	final	external	2

Tab. 7 Project work evaluation by examiners (AUC 1992)

The external examiners supervise the quality in the projects. They also contribute to a continuous feedback from practice to the university. The research work of the research units, in our case 'Mapping and Land Information Systems', is evaluated by a group of internal and external examiners every five years. It is based on a report which is compiled by an internal group using the documented research of the teachers (articles, research reports, etc.). The quality of the education at an university is sometimes measured by the number of students per teacher and the number of academic degrees (PhD, Doctor) within the academic staff. At the surveying education at AUC these numbers are at the momemt 11 : 1 and 30 per cent, respectively.

8. Conclusion

The change in technology - from analogue to digital - has far-reaching consequences for the education and training in photogrammetry. The optical-mechanical instrumentation is obsolete and should be replaced by an instrumentation based on digital images. The methods of photogrammetry have changed, too, and still more processes can be automated. Therefore, computer vision has to be taught, but also how the collected information is stored and analyzed in Geographic Information Systems. Besides these changes in the contents, the form of education should be adapted as well. The student must have a more active role in the studies which are very much computer and software oriented. Group work with problem-oriented projects applying cooperation and communication with other fields should be introduced. A continuous quality control for education and research must take place and should include examiners from the professional practice.

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