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## PHOTOGRAMMETRY AND CAD/CAM IN CULTURE AND INDUSTRY - AN EVER CHANGING PARADIGM

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### ABSTRACT

For the past ISPRS period 1996-2000, there has been remarkable changes in terms of photogrammetric research and applications in conjunction with CAD/CAM systems. Due to the dynamic nature of both CAD and GIS software as well as due to the ever demanding needs for new and challenging cultural and industrial applications, research has been driven far beyond the initial expectations.

Innovative technologies for data acquisition, data processing, and information management, new cultural and industrial products, and their visualization have been developed. Additionally, the advances in technology have driven the evolution of new low-cost and user-friendly systems. Existing CAD/CAM systems have further improved their functionality and portability, giving thus a positive pull to development of new methodologies and tools for the integration of photogrammetric systems with CAD/CAM. New object-oriented measurement procedures support the transfer of photogrammetric technology to the industrial design, engineering and manufacturing sector, as well to architecture and archaeology.

As a bottom line, all these changes have remarkably helped the photogrammetric society to pull the attention of many other scientific societies dealing mainly with the visualization of the photogrammetric output. Under the light of these changes, the paradigm has shifted from the pure photogrammetric recording to a holistic approach of recording, processing, archiving, managing, visualizing, and distributing information. This holistic approach builds an added value to the photogrammetric product, much higher than what for many years used to be.

### 1 CHANGING THE PARADIGM

Documentation and conservation of cultural heritage are being increasingly seen as tasks of national – ultimately international – priority. Due to the digital techniques, photogrammetry now appears as more efficient and inexpensive; today's user-oriented software is easier to handle by non-experts, thus widening the potential spectrum of application in architectural and archaeological recording.

The main strength of photogrammetry, that is the reconstruction of an object surface geometry by remotely sensing it, has been recognized also by other disciplines than photogrammetrists. This important merit is currently being enhanced by :

- a trend to move from traditional stereoscopy to multi-photo surface reconstruction
- the low-cost digital image acquisition capabilities of the current technology
- the potential of multi-sensor information collection
- the wide acceptance of Information Systems currently enhanced by digital images as well
- the wide spread of 3D modeling, visualization and web-authoring tools

As a result, Architectural Photogrammetry, as a discipline, has recently undergone profound changes. Even the term "Architectural Photogrammetry", once from the focal points of Commission V, is not adequate any more to describe the wide range of recent developments. During the last ten years, we are witnessing an evolution of the paradigm from what was known as "Architectural Photogrammetry" to "Application of Close-range Vision Techniques and Spatial Information Systems to world cultural heritage".

CAD, on the other hand, can be considered a discipline somewhere between engineering and computer science /computer graphics. Over the last 20 or so years the meaning of CAD changed increasingly from computer aided drafting and the design of three-dimensional objects to a central part of the manufacturing process. CAD systems provide a computer internal representation of the product/object characteristics (geometry data and user dependent information). They are able to guarantee the communication between all the process steps (construction, manufacturing, testing, control, maintenance etc.) performed by some other computer aided techniques such as CAP (Computer Aided Work Planning), CAM (Computer Aided Manufacturing), CAT (Computer Aided Testing), CAQ (Computer Aided Quality Assurance).

That development has been important for the interrelation between CAD and Photogrammetry. CAD systems serve as database for the integration of different types of data acquired by a number of measurement techniques including photogrammetry. 3-D object models can be generated, e.g. for the as-built documentation in areas such as industry and architecture, for 3-D indoor scene modeling and reverse photogrammetry, for object visualization, manipulation, animation etc.. In addition, CAD modeling concepts support the automated or semi-automated photogrammetric measurement using a priori knowledge of the object from a 3-D model. Summarizing, the common photogrammetric recording and reconstruction process has been increasingly replaced by a holistic approach of recording, processing, archiving, managing, visualizing, and distributing information. The integration of photogrammetric tools with existing CAD environments may lead to closer partnering between the measurement and end-user communities.

Before studying the characteristics of the new paradigm it is useful to span through the recent history of the developments, as they have been reported through the symposia, the workshops and the related literature.

## **2 A REVIEW OF THE REPORTED TRENDS**

Since 1996, when the ISPRS Convention in Vienna took place, the trend was clear, and quoting from the symposium conclusions "...*The largest number of papers for any Working Group concerned those in Architectural and Archaeological Representations (Working Group V/4). Over 45 authors had interesting examples to report. These ranged from the reconstruction of old monuments and buildings using conventional silver-halide photographs to the use of CAD modeling, video, surface matching, digital-still cameras and digital orthoimages to methodologies for the maintenance of inventories of historic cultural items... Again the involvement of more than one sensor was a feature of some of the more outstanding papers and the integration of multiple sensors into a system was a recurring theme... The Congress in Vienna portrayed the increased emphasis on still- and moving-video technology in the close range environment. Many papers detailed new applications, which have been discovered for video-photogrammetry. They are very exciting and represent the leading edge of this developing technology...*"

However, approximately 30 papers with a strong CAD/CAM component were presented in Vienna indicating the wide range of interest in CAD/CAM systems. That led Commission V to split the theme to the newly formed WG V/2, which was to deal with integration of CAD/CAM with photogrammetry, besides the old WG on Architectural Photogrammetry. WG V/2 also received the CAD/CAM related parts of the former WG V/3 "Structural and Industrial Measurements with Consideration of CAD/CAM aspects". The two WGs formed the next Terms of Reference :

### ***WG V/2 - INTEGRATION OF PHOTOGRAMMETRIC SYSTEMS WITH CAD/CAM***

- Survey of existing CAD/CAM systems (functionality, data formats etc.)
- Development of methodologies and tools for the integration of photogrammetric systems with CAD/CAM
- Development of CAD/CAM based object-oriented measurement procedures
- The transfer of photogrammetric technology to the industrial design, engineering and manufacturing sector

### ***WG V/5 - WORLD CULTURAL HERITAGE***

- Application of photogrammetry and spatial information system technology to the recording, mapping and visualization of structures and items of the World Cultural Heritage
- Incorporation of innovative technologies for data acquisition, data processing, information management, development of new products, and visualization

- Development of low-cost digital systems for the recording and documentation of the World Cultural Heritage
- Fostering close cooperation with national and international groups
- Active promotion of the use of digital photogrammetric recording methodologies and products

Since the main event in 1998 was the Commission V Inter-Congress Symposium in Hakodate, Japan, the status in progress, needs, trends and developments, regarding the WGs' topics, had the opportunity to show up there. At that symposium a total of 51 papers were presented, covering, as expected, largely diversified topics, such as:

- Imaging with new sensors (e.g. CCD-like scanners, laser scanners, digital cameras, video, etc.)
- Sensor and data fusion (e.g. GPS + INS + image data, use of GPR, thermal sensors, MRI, etc.)
- CAD based object recognition and measurement
- Modeling and reconstruction (e.g. texture, artifacts, etc.)
- Processing (e.g. vanishing lines, super-wide-angle lens distortion, edge detection, texture matching, simple software, emphasis in digital aspects, etc.)
- As-built documentation
- 3-D object reconstruction, visualization and Virtual Environments
- Information Systems and image archives
- Use of Internet and Multimedia for research and education

The trends of the Hakodate Symposium were clear :

- the use of new digital technology
- the need for Information Managing Systems
- the enhancement of communication between ISPRS and other scientific disciplines

Regarding the needs in mapping and documentation of the world cultural heritage, we should note that :

- There is a clear need for using technologically advanced tools, which offer wider flexibility and reduced costs.
- There is a clear need in developing simple but efficient tools.
- There is a clear need to adapt the widely used aerial photogrammetric algorithms and tools to terrestrial applications.
- There is also a need to manage the recorded information. The development of Monument Information Systems (MIS) becomes vital.

In 1999, the two WGs co-organized (in co-operation to 4 CIPA WGs, namely: WG3 (Simple methods in Architectural Photogrammetry), WG4 (Digital Image Processing), WG5 (Archaeology and Photogrammetry) and TG2 (Single Images in Conservation)) an International Workshop on "Photogrammetric Measurement, Object Modeling and Documentation in Architecture and Industry", Thessaloniki, Greece. 110 participants from 12 countries presented a total of 43 papers, covering topics like:

- Mathematical models – Algorithmic aspects
- Measurements and processing in archaeology, architecture and industry
- Integration of photogrammetric systems with CAD/CAM
- Sensor integration and data fusion
- Object modeling and visualization
- Documentation in archaeology and architecture
- Spatial Information Systems in archaeology and architecture

The trends of the Thessaloniki Workshop were . (see also Chapman et al., 1999):

- Development of vision-based techniques and novel systems under new concepts for documentation
- Multi-sensor data acquisition and multi-source information integration
- Developments on simple and efficient digital recording tools
- Integration of CAD with Photogrammetry for model driven object reconstruction
- Automated and semi-automated production of constructive solid geometry models from image networks offering considerable potential for the future
- Automatic production of 3D models appropriate for visualization purposes from image sequences captured by video camera equipment. Whilst yet not geometrically precise, such techniques can be combined with established photogrammetric geometry and calibration principles to promote them among non-photogrammetrists.
- Development of Information Systems, with special attention to the use of digital images, for documentation and information management
- Visualization in virtual environments (e.g. virtual museums, historical sites documentation, image-based 3D texture mappings, etc.) enhancing thus the promotion of the cultural heritage

- Eagerness of the specialists from a variety of scientific communities, like photogrammetrists, architects, archaeologists, computer engineers, geophysicists, information managers, to communicate, interact and exchange knowledge and experience on a common aim : *To map and document our cultural heritage*.

And now in the ISPRS XIX Congress, we are witnessing trends, like (see also van den Heuvel, 2000):

- Development of visualization techniques for geometrically precise and aesthetically mature models of the world's cultural heritage
- Qualitative analysis of digital images for material study and damages assessment
- Assessment of the state-of-the-art in photogrammetric recording for close-range applications in architecture and archaeology
- Modeling and algorithmic aspects and demonstration of new techniques
- Management of large quantities of multi-sensor data for Information Systems applications
- 3D modeling and geo-referenced VR integration pertaining to cultural heritage
- Low-cost systems development and demonstration
- On-line as-built modeling techniques
- Combining aerial and close-range information in Information Systems
- Testing, calibration and efficiency assessment of new data acquisition equipment and their integration to photogrammetric means for cost and time reduction in mapping cultural goods
- Promotion of cultural heritage through VR
- Reverse engineering and CAD automation
- Model-oriented photogrammetric measurement of industrial installations

### 3 LOOKING AT THE FUTURE

If one had to appreciate these changes and uncover their future evolution, some thoughts are worth reporting. It seems that this paradigm shift is characterized by the following trends :

The research area of the two WGs is increasingly diversified. And there are at least three reasons for that. First, the old technology is very mature and the applications based on it are straightforward. Therefore there are many different applications reported, and this has a nice impact on the end-users: It attracts their attention, since it shows that photogrammetry is an accessible, usable and cost-justifiable technology for many industrial, educational and public sectors. Second, new technology is entering the picture in growing rates and this drives innovative research. This fact gives rise to rapidly emerging new concepts and as a spin-off result attracts participation from related disciplines. Third, it becomes increasingly clear that both mature and innovative know-how have a lot to benefit and earn added-value from cooperation with other disciplines.

Knowledge-assisted 3D scene and object reconstruction is a rapidly emerging research area, which on one hand drives further the cooperation between CAD and photogrammetry and promises more automation in reconstruction, and on the other hand broadens the focus of the discipline of photogrammetry to a more interdisciplinary character.

Visualization techniques and VR output attract increasing interest and become more and more rewarding both for the researchers and the end-users. This technology is currently coupled with image-based rendering and image networks and promises in the future more detail, better quality, and a wide array of applications. Both "low-end" and "high-end" visualization needs attention since their application areas are different. This will inevitably lead to what is nowadays perceived as "Virtual Heritage".

There is a strong international growth of interest in the prospect of using Information System for the documentation of historic sites and items of our cultural heritage. This goes beyond the previous status of technology for such systems and further research is needed. Successful demonstrations have been already reported and it is expected that in the future the use of Internet for information retrieval and sharing will be increasing.

Having in focus the new paradigm, the role of ISPRS can be defined as to:

- Continuously monitor and evaluate the state-of-the-art of new technology (camcorders, CCD cameras, smart cameras, laser scanners, other sensors, low-cost software, new techniques, etc.) in terms of improving the quality and reducing the cost for data acquisition, processing and handling for architectural, archaeological and industrial applications.
- Develop methods and techniques to produce geometrically precise and aesthetically mature 3-D models for cultural items.

- Popularize the photogrammetric techniques by developing user-friendly processes and broaden the market pull by introducing innovations and developing a “critical mass” through cooperation with other scientific disciplines.

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