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Digital Photogrammetry and Its Role in GIS

조규전* · 조우석**
Cho, Kyu-Jon Cho, Woo-sug

ABSTRACT

The idea of digital photogrammetry was first introduced into the photogrammetric community in early 1960s'. At that time, it was impossible to implement the idea due to inferior computer and digital image processing technology. With the recent advancements in computer hardware/software and image processing techniques, digital photogrammetry has made its entry into the field of photogrammetry. The advent of digital photogrammetry also resulted from the increasing amount of digital data acquired through satellites, CCD cameras and digital scanning of photographs. Obviously, the major distinction between conventional photogrammetry and digital photogrammetry lies in the nature of primary input data (analogue versus digital), which could lead to a fully automated digital photogrammetric workstation. However, since digital photogrammetry is in its infant stage, virtually every task is an unsolved problem due to lack of understanding of theories and techniques.

Upon considering the increasing demand of efficient digital mapping method and economical GIS database generation, the union of GIS and digital photogrammetry becomes ever clear. In this paper, the author addresses the current status of digital photogrammetry such as digital imagery and digital photogrammetric workstation as well as the role of digital photogrammetry in GIS.

要 旨

수치사진측량은 1960년대 처음으로 도입되었지만 당시 컴퓨터 및 수치영상처리 기술의 한계로 발달할 수 없었다. 그러나 최근에는 컴퓨터기술과 영상처리 기술의 발달에 힘입어 사진측량분야에서 그 영역을 구축하기 시작했다. 또한 인공위성과 CCD카메라, 사진의 수치정사(스캐닝) 등에 의해 대량의 수치데이타를 얻을 수 있게 됨으로써 수치사진측량에 관한 많은 연구가 이루어지고 있다. 전통적인 사진측량과 수치사진측량은 초기의 입력데이타(아날로그/수치)에 따라 확연히 구분된다. 즉 수치사진측량은 컴퓨터를 이용하여 수치영상처리의 완전자동화가 가능하다. 그러나 수치사진측량은 아직 걸음마 단계이고 실제로 이론과 기술에 대한 이해부족으로 해결해야 할 문제가 많다.

효율적인 수치지도제작과 경제적인 GIS 데이타베이스구축에 대한 수요가 점차 증가하고 있는 현실을 감안할 때, GIS와 수치사진측량기법의 연계는 필연적이다. 이 논문에서는 수치영상과 수치사진측량 워크스테이션 등 수치사진측량의 현재수준과 GIS에서 수치사진측량의 역할에 대해서 논의 하였다.

1. INTRODUCTION

Photogrammetry is the art and science of determining the position and shape of objects from photographs [Schenk, 1992]. Without touching the objects, it reconstructs objects and determines some of their features. Ever since the invention of photographs (1839), photogrammetry has been developed with growing power of computer technology. At the stage of analog photogrammetry, photographs and optical-mechanical instruments was utilized. Analog photogrammetry continued to advance to analytical photogrammetry which similarly uses photographs but computerized instruments.

During the last decades, digital photogrammetry rapidly emerged as a new branch in the field of photogrammetry. Digital imagery from various

*경기대학교 토목공학과 교수
**국토개발연구원 국토정보실 책임연구원

sources with different geometric properties has been adopted in digital photogrammetry, which opens a variety of innovative and challenging photogrammetric research areas [Cho, 1995]. The fact that digital photogrammetry deals with digital images leads the transition from the operator controlled measuring procedure to the possibility of full automation in photogrammetric processes such as orientation, aerial triangulation, and surface reconstruction. In this context, digital photogrammetry is closely related with cognitive science, artificial intelligence and computer vision whose computerized techniques simulate human vision and recognition processes.

In operational and theoretical aspects, digital photogrammetry is different from conventional photogrammetry. In the following chapters, a detailed description of digital photogrammetry is presented.

2. DIGITAL PHOTOGRAMMETRY

It is mentioned that digital photogrammetry utilizes digital images rather than analog photographs. Provided that analog photographs are replaced with digital images on the computer monitors and same analytical photogrammetric techniques are applied to, is it digital photogrammetry or not?

The decisive factor between analytical photogrammetry and digital photogrammetry is the kind of input material, however simply displaying digital imagery instead of using photographs does not imply digital photogrammetry. The fundamental concept, and mathematical and physical basis of traditional photogrammetry should be changed and further developed in digital photogrammetry.

2.1 Why and What Digital Photogrammetry?

Digital photogrammetry is information technology to drive geometric, radiometric and semantic information of objects in the 3D world from 2D digital images of these objects. In other words, digital photogrammetry deals with different levels of data abstraction running from non-intelligent pixel data to topologically and semantically structured vector data in semi-automatic or automatic fashion.

In general, a new technology gains its attention and comes to successfully implemented in practice only if it offers the leading-edge science and clear advantages over existing ones. Digital photogrammetry is not an exception. In many aspects, emerged are potential advantages in digital photogrammetry which is distinguished by a number of points from conventional photogrammetry. The characteristics and distinguished aspects of digital photogrammetry are the followings:

- Enormous amount of digital data
- Powerful computer hardware and software
- No high precision optical-mechanical parts
- On-line and real-time capability
- Possibly cheaper and faster
- Consistent output and less labor-force
- Potential of full automation

The basic photogrammetric processes implemented in traditional photogrammetry could be used in digital photogrammetry. Beyond this, digital photogrammetry conveys some new aspects. High precision optical-mechanical configuration in conventional photogrammetry is no more big concern and is replaced with digital image processing and computer hardware/software in digital photogrammetry. Powerful computer technology, large memory capacity and huge mass storage continue to enhance and support digital photogrammetry to progress dynamically. It could be anticipated in recent future that on-line/real-time capability will be realized in digital photogrammetry [Wrobel 1991].

From the fact that high precision optical-mechanical parts in conventional photogrammetry is not necessary and recent advancements in computer

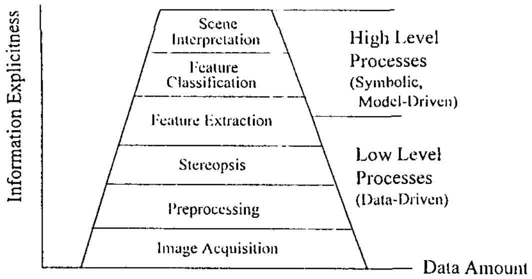

Figure. 1. An overview of digital photogrammetry paradigm

technology are surprisingly fast, the cost of many photogrammetric tasks will be reduced in the field of digital photogrammetry. It must be noted that the requirements of human operator emerge as a cost driver these days. The potential of effective automation that in digital photogrammetry is currently faced with drives the cost down, consistent and robust output and labor-force involvements in many conventional photogrammetric steps less. The success of achieving automation is heavily dependent on algorithmic sophistication resided as difficult problems at current stage of techniques in digital image processing and computer-related technology.

To derive meaningful descriptions of objects from images, digital photogrammetry deals with different levels of data abstraction. An overview of digital photogrammetry paradigm is depicted in Figure 1.

As shown in Figure 1, digital photogrammetry paradigm consists mainly of two parts: low level and high level processes. It is explicitly represented in the paradigm that the amount of data to be processed is getting less and less from low level to high level process.

Imagery is acquired through image formation process where the real world (X) is portrayed to images (Y) through an optical operator (A), expressed by conceptual relation : $Y=A \cdot X$. Evidently the low level process in digital photogrammetry paradigm is the inverse process of image formation. Reconstructing real world from image is determined by $X=A^{-1} \cdot Y$. Like many inverse problems, the low level process that determines A^{-1} is an ill-posed problem because it does not have unique and robust solution. In order to solve ill-posed problem of low level process, certain assumptions and constraints are required. Typical assumptions in digital photogrammetry include the existence of smooth and non-transparent surfaces.

Whereas low level process is concerned with reconstructing the surface, high level process is primarily associated with interpreting this information. High level process depends on domain as well as world knowledge. As for domain knowledge, it conveys domain-dependent information such as 3D structure, appearance (geometric, radiometric properties, shape and so on), and its relationship with other objects. Included are occlusion, perspective projection, and physical support in world knowledge.

Based on the statistics during the period of 1992-1993, approximately 60 percent of ongoing photogrammetric research is in digital photogrammetry. Around 90 percent of them are in low level process in digital photogrammetry. The target of recent research in digital photogrammetry is toward:

- increasing degree of automating photogrammetric tasks
- increasing flexibility, comfort, and performance
- broaden user base of photogrammetry
- new applications

Using current techniques, some photogrammetric tasks are tackled. to be automated in recent activities in digital photogrammetry community:

- orientations
- point determination (target recognition)
- feature extraction
- aerotriangulation

- DEM
- digital orthophoto

Among them, orientation and digital orthophoto are completely automated in batch process. Automated are aerotriangulation and DEM generation followed by interactive verification/correction. Coupled with human interaction, point determination and feature extraction are automated.

The ultimate goal of digital photogrammetry will be reached through evolution. The evolution will happen step-by-step, needing to overcome a set of obstacles at each step.

2.2 Digital Image

A digital image consists of a two dimensional matrix with elements which are called pixels. As the information carriers, the value of a pixel depends on the type of recording instrument and on the computer in use. The most widely used range of pixel values ranges from zero to 255, which can be represented by a byte (8 bits). The types of digital images used at present are satellite imagery, aerial imagery, and close range imagery. The images can be acquired either by direct capturing or by scanning of hard copies. The scanning devices can be grouped into three categories, depending on the design principles of arrangements of the detectors:

1. Single sensor - scans in lines (usually by rotation)
   CROSSFIELD, HELL, OPTRONICS, SCITEX.
2. Sensor row - scans in strips
   PhotoScan PS1
3. Square sensor matrix - digitizes a piece at a time
   RS1, VX-Scanner

The volume of digital data captured in scanning a regular-format aerial photograph is very large. In Table 1, the amount of data is listed for a 23 cm × 23 cm aerial photograph with the pixel sizes of 7.5 μm, 15 μm, 30 μm and 256 gray level, respectively.

Table 1. Amount of digital data per aerial image

	Pixel Size (μm)	Image Size (MB)
Gray Image (Monochrome)	30	56.1
	15	224.3
	7.5	896.9

As for direct digital acquisition, three types of scanners are widely used;

1. Pixel by Pixel - Landsat
2. Line by Line - SPOT, MOMS
3. Frame by Frame - CCD (Charge Coupled Devices) Camera

In practice, when high accuracy is required in photogrammetric tasks, indirect acquisition of digital data is preferable over the current stage of digital camera. It was reported that the positional accuracy of scanner comes to be 1 μm. If real time between capturing the image and making the end-product is the primary need, digital (CCD) camera will be the choice. At present, CCD cameras are popularly used in digital photogrammetry due to its size and relative stability. However, because of limitation of today's CCD technology, the pixel size smaller than 7.5 μm cannot be achieved. It should be kept in mind that even the pixel size of 7.5 μm reaches to about 900Mbytes while scanning an aerial photograph as shown in Table 1.

2.3 Digital Photogrammetric Workstation

In principal, the basic role of digital photogrammetric workstation is to extract spatial information from a variety of digital images beginning from scanned data to close range, aerial and satellite imagery. Moreover it is absolutely necessary to import and superimpose existing vector data for the purpose of quality checking, verification process and plotting process. Any computer can install software for the solution of photogrammetric tasks, however, a relatively wide range of peripheral devices is necessary. A digital photogrammetric workstation must meet the following specifications [Gruen 1985]:

- Data-capture unit for input from digitized photographs to CCD camera
- Three dimensional evaluation of digital imagery
- Handling and processing of large images in reasonable time
- Stereoscopic image display
- Graphic data interface
- Plotter or film writer

To incorporate 3D observation in digital photogrammetric workstation, four different techniques are developed and in use at present:

- Split-Screen with Mirror Stereoscope
- Anaglyphic Process with Complementary Color Spectacles
- Alternation with Passing and Blocking (Liquid-Crystal Shutter)
- Alternation with Polarization and Synchronization

While split-screen and anaglyphic techniques are implemented in powerful PC environment digital photogrammetric workstation, most UNIX environment digital workstation adopts the last two techniques. Some of digital workstation even does not incorporate 3D viewing components.

There are literally dozens of different digital photogrammetric workstations developed to meet the needs of core photogrammetric tasks. Table 2 shows current commercial offering of digital photogrammetric workstations grouped into three categories depending on stereoscopic-viewing methods.

Table 2. Current commercial offering of digital photogrammetric workstations

Vendor	Product	Platform
3-D systems		
Intergraph	ImageStation	Platform
Helava Ass.	HAI-500	PC/UNIX
Leica	HAI-750	SUN/UNIX
Autometric	Pegasus	SGI/UNIX
Matra	Traster-T10	SUN/UNIX
Leica	DSP-1	DEC/VMS
Split-screen		
DVP	DVP	PC/DOS
VTA	VMAP	PC/DOS
Non-stereo		
Galileo	Orthomap	PC/UNIX
I²S	Prism	SUN/UNIX
MDA	Geomate	SUN/UNIX
ISM	SYSImage	PC/DOS

In addition, the DPW (Digital Photogrammetric Workstation) has to include photogrammetric software modules for the following tasks:

- Image Acquisition / Storage / Display / Data Management
- Image Enhancement / Radiometric Correction
- Image Matching
- Automatic Point Identification / Orientation
- Image Transformation
- Feature Extraction
- Verification of Results

2.4 The Role of Digital Photogrammetry in GIS

As mentioned, digital photogrammetry deals with different level of data (abstraction of data) running from non-intelligent pixel data to topologically and semantically structured vector data. From the digital photogrammetry paradigm, we ultimately expects that image data be converted to accurate, intelligent description of object space which may form the basis of Geographic Information System. Whereas information in GIS is represented explicitly, information in photographs is implicit. In this context, digital photogrammetry can be viewed as a way of reducing the amount of data, starting from image data to meaningful feature data. Moreover image data which is basic input to digital photogrammetry can be incorporated as background information in GIS. Thus, the union of GIS and digital photogrammetry is indispensible.

Recent popularity of GIS brings the major changes in mapping community and affects photogrammetry community. The GIS creates a new set of requirements for image-based data:

- Image itself as an information layer in GIS
- Information extracted from imagery to be used in GIS database
- Image data for updating source for GIS database

While photogrammetry is viewed as a science for data collection, GIS is a way of data analysis. This traditional view should be changed and it must be realized that GIS and photogrammtry is in complementary partner. When an existing GIS database is incorporated as an background information, many tasks of digital photogrammtry can be solved and real-time photogrammetry can be foreseeable in the recent future.

The addition of digital image to the GIS as an information layer also have effect on the GIS user who has now an access on latest information, otherwise only relies on old GIS data. Recently users in GIS community need for digital orthophoto as background information layer to update their database. Conclusively, data collection and data analysis come to an integrated system supported by both digital photogrammetry and GIS.

3. CONCLUSION

There has been a tremendous development in the field of digital photogrammetry since early 1980s'. The digital technologies needed to support photogrammetry have progresses dynamically in recent years. Many factors have influenced the developments of digital photogrammetry including the drive for automation due to high labor cost, the need for real-time operations in quality control and robotics, the availability of digital imagery from satellites, the development of accurate and affordable digitizers and CCD cameras, the inherent stability of a purely digital system, and availability of low-cost computer components to provide the required speed, storage, and display facilities.

The final goal of digital photogrammetry is to achieve fully automatic photogrammetric processes without operator's intervention. As results, digital photogrammetry is to automatically produce 3-D coordinates (DEM), transformed digital imagery (digital orthophoto), surface reconstruction, and semantic object space description.

At present, digital photogrammetry is not yet well understood to be modelled efficiently. There is only an insufficient theoretical basis for the mathematical description and modeling of 3-D scene. Further progress in automating photogrammetric processes depends on a precise understanding of how human operators solve vision problems. The concentrated efforts in artificial intelligence, cognitive science, computer vision and some interdisciplinary sciences promises success in digital photogrammetry.

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