OPTIMIZING THE PRESENT DAY PHOTOGRAMMETRIC OPERATION

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ABSTRACT

The history of topographical map production by stereophotogrammetry is not very old, only about half a century. According to problem solving approaches, photogrammetry can be classified as analog, analytical, and digital. Vertical photographs are best known and mostly used at the present time, although much of the early development of the basic theory of photogrammetry evolved from horizontal and oblique photographs. Today, photogrammetry has been vastly broadened to include the use of data from sensors utilizing other portions of the electromagnetic spectrum, in additional to the conventional photography (visible portion of electromagnetic radiation) for many applications.

Digital photogrammetry (softcopy photogrammetry) is about ten years old now, however, it has matured and superseded the analytical photogrammetry in terms of accuracy, production, efficiency, and multiple usage. This paper will discuss in detail the current status of analytical and digital photogrammetry, compare them in terms of accuracy, efficiency, and cost.

A benefit/cost analysis will be made based on the technique: minimize cost, and maximize the accuracy, and product usage. The following factors: equipment cost, operation cost, maintenance cost, time consumption, and malfunctioning will be considered in comparing the cost of these two systems. For the benefit analysis the following factors: accuracy standards, flexibility of system, authentic, multi-users, data storage, multiple usage, et cetera will be considered to compare the benefits of the two systems. Finally a benefit/cost ratio will be computed using some weighting schema for different factors to compute the benefit/cost ratio.

A discussion on the multiple usage of digital photogrammetry will be made especially for the large-scale engineering mapping. Examples from several large-scale orthophoto and digital mapping projects will be drawn to discuss the validity of this topic. If fast computers are used with abundant storage (the price of storage, speed, and memory are falling everyday) the digital photogrammetry can revolutionize the digital mapping process, i.e., there would not be a need for collecting planimetric data for large scale engineering mapping (since the orthophoto is so detailed that one does not need planimetric data). Also, if orthophotos are used as planimetric data the engineering design can easily become transparent in terms of interpretation of design by planners, politicians, accountants and administrators (vaguely called laymen).

1 INTRODUCTION

The present-day photogrammetric practice has been the combination of analytical and digital photogrammetry. Many mapping firms still use analytical photogrammetry in their day to day mapping projects. Since there is an ample demand for digital orthophotos, these firms or organizations collect elevation and planimetric data using analytical photogrammetry and use an ortho rectification software package to produce digital orthophotos in case a client demands such a product.

The digital photogrammetry is only about a decade old technology, and it has reached fairly high level of sophistication in terms of accuracy and cost effectiveness. If used properly, it could surpass the accuracy in both elevation and planimetry compared to any analytical photogrammetry system. Digital photogrammetry supercedes analytical photogrammetry in terms of the benefits from digital photogrammetric products.

From our earlier research we found that the scanning resolution is very critical for achieving the accuracy from the digital photogrammetry system. Also, in the past digital photogrammetry was limited in terms of handling the file size and disk space if the images were scanned at high resolution (software JPEG was not available). However, with the software JPEG compression and inexpensive disk space available today, the digital photogrammetry has reached its full capacity in terms of production efficiency and accuracy of the product.

2 APPLICATIONS OF PRESENTDAY PHOTOGRAMMETRY

Applications of present-day photogrammetric products can be in the following fields:

- Civil Engineering
- Geology/Geotechnical
- Wetland Mapping
- Hazardous Waste Management
- GIS Base Mapping
- Resources Mapping
- Research
- Soil Mapping
- Land Use/Land Cover
- Environmental Studies
- Utility Mapping
- Topographical Mapping
- Land Surveying
- Planning

This study is focused on the applications of present-day photogrammetry of large scale engineering type projects; therefore only specific example application will be discussed to cover the scope of this study.

Applications of the present-day photogrammetry have been unlimited due to the fact that digital products can be used simultaneously for different projects and applications, e.g., if high resolution orthophotos (Class I) are produced for a specific project the same orthophotos can be used again and again and by multiple agencies for different applications (planning, design, and computation of volume, etc.). Also, for some applications these orthophotos can be resampled to manage the file size. Some applications of the present-day photogrammetry are given below:

2.1 Utility Corridor Mapping

The utility corridor mapping for natural gas pipe line, electricity supply, telecommunication, etc. include: route survey, design, right of way acquisition, GIS (data base), and post project emergency management system. Digital photogrammetry can be utilized to create digital elevation models and orthophotos which are used as base maps (data) to perform design, calculation of right of way acreage, and GIS data base design.

2.2 Highway Design

Highway design projects need topographic (elevation) data, planimetric data, and orthophotos to perform design, calculate volume, and right of way delineation. Also, the database can be imported to a GIS to perform modeling for transportation studies: planning, emergency management, future automated transportation system design, et cetera. If high-resolution orthophotos are produced and used along with the DTM data, then there would be no need for the planimetric vector data (which is expensive and cumbersome).

2.3 Subdivision Design

Subdivision design for residential or commercial housing requires elevation and planimetric data for the design, computation of volume, to study environmental impact, and utility and roadway work for the subdivision. Therefore, it requires similar type of data as discussed in utility corridor and highway design projects.

2.4 Environmental Studies

The present-day photogrammetry digital B/W, Color, or CIR orthophotos can be used to study environmental problems with existing or new projects related with utility, housing, or transportation projects. For environmental studies color infrared imageries would be appropriate since these imageries can easily discriminate changes in plants, water quality, soil type, et cetera.

2.5 Country/ State/ County Wide Project

The present-day photogrammetry can be efficiently used to map an entire county, state, or country. The mapping project (digital orthophotos) can be used for planning and preliminary design of development, maintenance, or management of any projects.

3 OPTIMIZATION OF PRESENT-DAY PHOTOGRAMMETRIC OPERATION

Having discussed the multiple application of the present-day photogrammetry, we will discuss how to optimize the present-day photogrammetric operation. The following strategy can be suggested:

Minimize the Cost: This can be done by analyzing a benefit/cost ratio. Since the output from the photogrammetric mapping is indirect, the analysis of benefit/cost is not easy. The cost and benefit factors have been analyzed for two different systems of photogrammetric operation to derive an optimal operational strategy.

Maximize the Accuracy: In the past, the concept of choosing an optimal technique was to increase precision, accuracy, and reliability, which are interrelated, without putting any emphasis on the other factors. Given a specific cost, few alternatives were available because of limited and expensive technology. However, the situation has now changed. The cost of analytical and digital photogrammetry system is very competitive. Although, the digital photogrammetry systems are still evolving, they have already superceded the level of accuracy of analytical photogrammetry system. The digital photogrammetry outweighs the analytical photogrammetry in terms of operational cost and multiple applications of the digital products as given in Tables 1 through 3.

Maximize Product Usage: Basically, the photogrammetric operation is to create planimetric and DTM data. In analytical photogrammetry, the original data sets (the photographs) play a role in the intermediate stage only, but with the digital photogrammetry the final product would be DTM, planimetry, and images (orthophoto) which can be used by several users and for many other applications. The orthophoto mosaic can be used as a backdrop for all engineering design work and for checking the accuracy of ground points. It can be used as a planimetric map itself, and as a tool to display projects in public hearings, etc. Digital photogrammetry can greatly reduce the need for a photo lab. The data storage has already been inexpensive and with the availability of less expensive read-write CD/DVD, different size magnetic media tapes (4, 8 mm) and CD mastering equipment, digital photogrammetry can easily replace a photo lab.

4 BENEFIT/COST EVALUATION

Based on the criteria outlined above, a cost-benefit analysis was done by evaluating cost factors and benefit factors of both digital and the analytical photogrammetry systems.

5 COST EVALUATION FACTORS

The following factors have been considered to compare analytical and digital photogrammetry systems:

Equipment Cost: This is a major cost factor to any photogrammetric shop. Analytical photogrammetry is comprised of analytical plotters along with dodging and point transfer equipment et cetera; similarly, the digital photogrammetry is comprised of workstations, scanners, et cetera. The airplane and aerial camera are common equipment for both systems.

Operational Cost: The operation cost is another important factor in optimizing a photogrammetric operation.

Equipment Maintenance: The cost of maintaining equipment (hardware) and software (software support) is an important factor while evaluating the cost factors.

Supporting Equipment Cost: Analytical photogrammetry needs supporting equipment such as point transfer device, dodging equipment, computer hardware and software; in case of digital photogrammetry a precision scanner (to digitize photos), and appropriate computer hardware/ software are required.

Training: Both analytical and digital photogrammetry need some sort of training of personnel; the latter being a computer technique, may be versatile and easy to train personnel than the former one.

Equipment Malfunctioning: This is another factor that has to be considered in both the systems. With the digital photogrammetry computer software malfunctioning or creating problem would be more common. A technique for cost evaluation has been developed based on the above discussion and is given in Table 1.

Table 1: Cost Analysis of Analytical and Digital Photogrammetry Systems

Number (J)	Evaluation Factor (I)	Weight Factor (W)	Analytical Photogrammetry	Digital Photogrammetry
1	Equipment cost	1.0	0.8	0.5
2	Operation cost	1.0	0.9	0.5
3	Maintenance cost	0.6	0.2	0.2
4	Supporting cost	0.6	0.8	0.4
5	Time consumption	1.0	0.7	0.4
6	Training	0.8	0.5	0.3
7	Malfunctioning	0.6	0.4	0.6
Overall Cost ($\sum C_{IJ} W_J$) →			→ 4.4	→ 2.9

6 BENEFIT EVALUATION FACTORS

It is not an easy task to perform a benefit analysis of photogrammetric operation, because these benefits are indirect, and in-depth knowledge and experience are required to evaluate them. Some indirect benefit evaluation factors follow.

Accuracy Standards: This is one of the prime factors for evaluating the benefit of a photogrammetric system. Although minimum accuracy standards are always required to perform a photogrammetric operation, different techniques produce different accuracies. The assignment of proper values for evaluation factors and weights depends on long term planning, location, and financial condition of mapping organization.

Flexibility: Flexibility of products (i.e., ease of data transfer from one system to the other) can be one of the major evaluation factors.

Authenticity: The products of one technique may be more authentic than the product of other techniques. Authenticity means that a product not only meets a criterion for technical work, but also that it may be used as a legal document.

Multi-user: Most of the products of photogrammetric mapping systems are produced for a specific end user, making the cost of the product very high. If the same product were made to meet other user's requirements, it could be produced at an economical rate. Digital photogrammetry can produce different image products from the same data set that can meet requirements of different users.

Data Storage: The data produced by one method may be flexible and easy to store and reproduce than data that are rigid and not easy to reproduce for multiple application. Storage of digital data is safer/easier and more economic than analog data such as negatives and diapositives.

Multiple Usage: Some techniques of photogrammetry are integrated and it can have multiple usage of the product than the other, e.g., digital photogrammetry can provide data in multiple formats and different users can use the same data.

Based on the benefit evaluation factors discussed above, a technique of benefit evaluation has been developed and is given in Table 2.

Table. 2: Benefit Analysis

Number (J)	Evaluation Factors (I)	Weight Factors (W)	Analytical Photogrammetry	Digital Photogrammetry
1	Accuracy	1.0	0.9	0.9
2	Flexibility	0.8	0.6	1.0
3	Authenticity	0.6	0.8	0.8
4	Multi users	0.8	0.5	0.9
5	Data Storage	0.8	0.5	0.6
6	Multi-applications	0.8	0.5	0.9
7	Integration	0.8	0.6	1.0
Overall Benefit $\Sigma(B_{IJ}W_J)$			→ 4.4	→ 6.1

Table 3: Benefit/Cost Ratio Analysis

Method	Overall Cost	Overall Benefit	Benefit/Cost Ratio
Analytical Photogrammetry	4.4	4.4	1.00
Digital Photogrammetry	2.9	6.1	2.1

7 CONCLUSIONS

In this paper we discussed briefly the present-day photogrammetry: status, application, and how to optimize the system. Based on this research it can be concluded that the image quality, scanning resolution, and the software and hardware used is very critical for achieving centimeter level of accuracy in digital photogrammetric mapping. The major costs associated with the present-day photogrammetry are for DTM and planimetric data collection. The DTM collection is most critical for achieving given accuracy of digital mapping and its most challenging to meet that demand in many cases. It is very difficult as well as expensive to check the accuracy of DTM data for large-scale digital mapping. Aerial triangulation could be an optimal solution for the process of quality control (QC) for elevation or planimetric data. Using the orthophotos directly as planimetric data could substantially save money by not collecting the planimetric data. The automatic DTM collection and or Laser Scanning data combined together can improve quality of DTM data and it could be inexpensive to collect DTM data. Until the precision/resolution of digital camera becomes efficient for the large-scale mapping, the scanning of analog diapositive/negative remains critical; the scanning resolution should be decided based on the GRD of photos and the GSD of the scanned images. It is proven that the higher the resolution of scanning the better the accuracy, except when a camera's GRD is very low. To optimize the present-day photogrammetry operation, resolution plays an important role in achieving higher accuracy in DTM collection; therefore, the highest scanning resolution should be used in this type of mapping. Also, grid spacing in automatic DTM collection plays a vital role in achieving required accuracy. The digital photogrammetry outweighs analytical photogrammetry in every aspects of photogrammetry. The cost-benefit ratio for analytical and digital given in Table 3 shows that the digital photogrammetry is about 110% more efficient and cost effective than analytical photogrammetry.

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