IS PHOTOGRAMMETRY STILL RELEVANT?

by EDWARD M. MIKHAIL

This paper was originally given as the Keynote Address at the ISPRS Commission III Symposium, Columbus, OH, July 6-10, 1998.

INTRODUCTION

This a critical time to address this question. I recently attended several technical meetings in which some well-respected and experienced photogrammetrists unabashedly declared that essentially, photogrammetry is no more! It is now, so they say, part of computer graphics, or it is superceded by image understanding, or by computer vision, or whatever. I have no doubt that these learned individuals know much more than I do, but I believe it would be important to analyze the arguments on both sides of the question.

As a guide to structuring this presentation, I wrote down a set of questions under the rather provocative heading: Is Photogrammetry Dying? (Figure 1), the answers to which form the essence of this analysis. And while I have my own definite ideas, I sent the questions to several of my former students, colleagues, and friends in order to gather many diverse views. The first question that I posed was:

IS PHOTOGRAMMETRY DYING?

(1) IN VIEW OF ITS CURRENT ACTIVITIES, HOW WOULD YOU DEFINE PHOTOGRAMMETRY?

(2) WHAT DO YOU THINK THE MOST SIGNIFICANT ADVANCES IN THE FIELD DURING THE PAST DECADE ARE?

(3) WHAT DO YOU VISUALIZE AS THE SIGNIFICANT ADVANCES DURING THE NEXT DECADE?

(4) DO YOU AGREE WITH THOSE WHO CLAIM THAT PHOTOGRAMMETRY AS A FIELD OF ACTIVITY IS BECOMING OBSOLETE? WHY? OR WHY NOT?

(5) DO YOU THINK THE DIVERSITY OF CURRENT ACTIVITIES WARRANT A CHANGE IN THE NAME (PHOTOGRAMMETRY)? IF SO, WHAT DO YOU PROPOSE?

Figure 1.

IN VIEW OF ITS CURRENT ACTIVITIES, HOW WOULD YOU DEFINE PHOTOGRAMMETRY?

But before I get into specifics, Figure 2 presents the origin of the word and the definition as published in two editions of the Manual of Photogrammetry. While the name could imply restriction to "light," the recent definition extends the activities to a much broader energy source.

PHOTOGRAMMETRY

PHOTOS = LIGHT
GRAMMA = SOMETHING DRAWN OR WRITTEN
METRON = TO MEASURE

EARLY: "THE SCIENCE OR ART OF OBTAINING RELIABLE MEASUREMENTS BY MEANS OF PHOTOGRAPHS".

***1980:* "PHOTOGRAMMETRY IS THE ART, SCIENCE, AND TECHNOLOGY OF OBTAINING RELIABLE INFORMATION ABOUT PHYSICAL OBJECTS AND THE ENVIRONMENT THROUGH PROCESSES OF RECORDING, MEASURING, AND INTERPRETING PHOTOGRAPHIC IMAGES AND PATTERNS OF ELECTROMAGNETIC RADIANT ENERGY AND OTHER PHENOMENA".**

Figure 2.

Most of the nearly three dozen respondents agree with the current definition. Three distinguished photogrammetrists gave short definitions, as shown in Figure 3. The components of photogrammetry, as I have presented in a variety of forums, including many on-site courses, is in Figure 4. You will note that it includes the elements of all definitions. Two distinct components are characteristic of photogrammetry specifically, sensor/platform modeling and accuracy estimation or error propagation.

Others, notably computer scientists, have discovered photogrammetry. They obviously approach it differently and certainly make valuable contributions from which we benefit. We have always taken advantage of developments in other fields that have positive impact on our activities. But just because we exploit other tools does not mean we abandon our strengths. The way sensors are modeled

OTHER DEFINITIONS

PHOTOGRAMMETRY IS THE "SCIENCE AND TECHNOLOGY OF EXTRACTING INFORMATION FROM IMAGERY AND PRESENTING IT TO THE USER IN A MEANINGFUL WAY"

"PHOTOGRAMMETRY IS SENSOR MODELING AND MATHEMATICS"

"PHOTOGRAMMETRY IS MODELING WITH IMAGES"

Figure 3.

FUNDAMENTAL COMPONENTS OF PHOTOGRAMMETRY

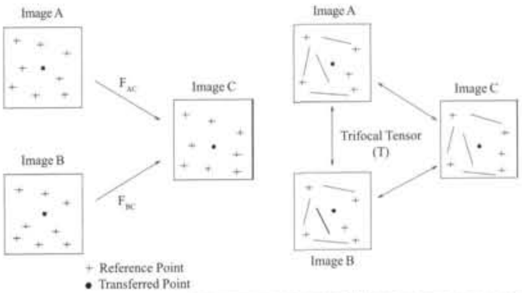
SENSOR/PLATFORM MODELING
EXTRACTION OF DATA FROM IMAGERY
DERIVATION OF INFORMATION
ASCERTAINING QUALITY/ACCURACY ESTIMATES
PRESENTATION OF RESULTS

Figure 4.

in photogrammetry compared to methods developed in other fields is vastly different. Frequently, other disciplines seek fast linear formulations with parameters that often have nothing to do with the physical sensor models. While in photogrammetry we deal with redundant cases and pay great attention to error propagation and robustness, their solutions often deal with unique (or minimally determined) cases. They sometimes reinvent, often badly, many techniques well known to us, but they certainly make us look at old problems in new ways. We therefore acknowledge the benefits, but we have solid and unique approaches that are not duplicated in any of the other disciplines. I strongly believe that we can have a significant influence on several other disciplines if we can convey to them the value and usefulness of our techniques.

As an example, consider image invariance which is a technique that originated in photogrammetry and has been advanced and used in Image Understanding, IU, and Computer Vision, CV. Many IU/CV activities are unique to these disciplines, although one can often derive equivalents in photogrammetry. Figure 5, depicts the task of image transfer as may be accomplished by invariance and photogrammetric techniques. Given three im-

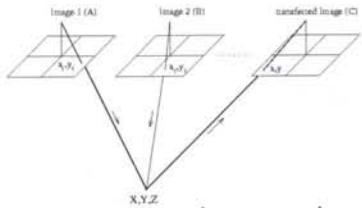
Invariance Techniques
Fundamental matrix or Trilinearity equations



$$a_1^T F a_2 = 0$$

$$a = \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Photogrammetric Equivalent
Extended Relative Orientation



$$\begin{vmatrix} B_X & B_Y & B_Z \\ x_1' & y_1' & z_1' \\ x_2' & y_2' & z_2' \end{vmatrix} = 0$$

Figure 5. Image Transfer

ages, A,B,C, with a sufficient number of corresponding points and/or linear features to establish the relationships between them, any feature that appears in two of them can be transferred to the third. In invariance, the formulation is linear and does not require, nor does it use, interior or exterior orientation elements as parameters. The calculation is based strictly upon algebraic variables, such as those involved in the fundamental matrix or trifocal tensor. Furthermore, because speed is often important in IU applications, usually non-redundant solutions without consideration to error propagation are common practice in order to preserve linearity. By contrast, photogrammetric formulation is non-linear and carries all the physical parameters involved in imaging, and applies least squares for estimation with redundant measurements and rigorous consideration of the stochastic model. Although image transfer is not a usual task in photogrammetry, there is an equivalent in what we term extended relative orientation. For comparison, I included in Figure 5 the two forms of coplanarity of two rays used in invariance (the F-matrix) and in photogrammetry (the determinant form). Figure 5 also shows an example with three aerial photographs.

An activity, which falls in both computer vision and photogrammetry, is object reconstruction. Figure 6 shows comparative results from invariance and photogrammetry for both vertical aerial photography and close range photography. Most of the invariance applications in computer vision deal with imagery that has strong acquisition geometry. Conventional aerial photography, with weaker geometry, yields correspondingly less accurate results via invariance analysis compared with photogrammetric analysis. For the close range case, the difference in accuracy is not as marked as that for the aerial case, when the control configuration is strong (#1 in Figure 6). When such configuration is weak, the results from photogrammetry remain essentially the same, while those from invariance deteriorate significantly. Dependence on geometry of acquisition, disposition of points, and other factors (such as estimation of the fundamental matrices), has significant influ ence on the invariance results. Clearly, when

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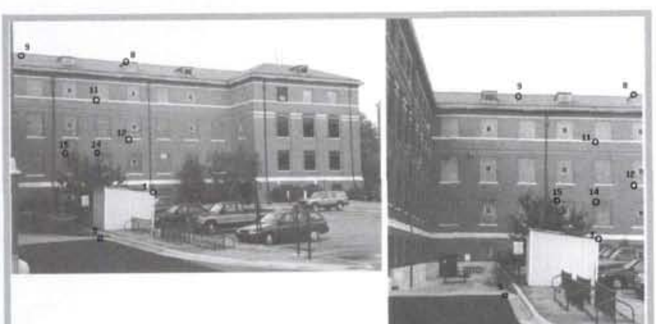
Aerial Photography

RMS (m) at 9 Check Points, Using 6 Control Points, (Bishop, 1:6000)

	Inv.			Pho.		
rms	dX	dY	dZ	dX	dY	dZ
	.218	.127	.156	.055	.031	.146

- Invariance techniques produce less accurate results than photogrammetry

Close-Range Photography



RMS (m) at 9 Check Points, Using 6 Control Points, (Chemical Engg. Bldg.)

	Inv.			Pho.		
rms	dX	dY	dZ	dX	dY	dZ
#1	.179	.098	.124	.149	.091	.116
#2	.746	.462	.344	.198	.091	.086

- Invariance produces results comparable to photogrammetry for the strong control configurations #1. (#1:3,5,8,9,12,15; #2:5,8,9,11,12,14)

Figure 6. Object Reconstruction

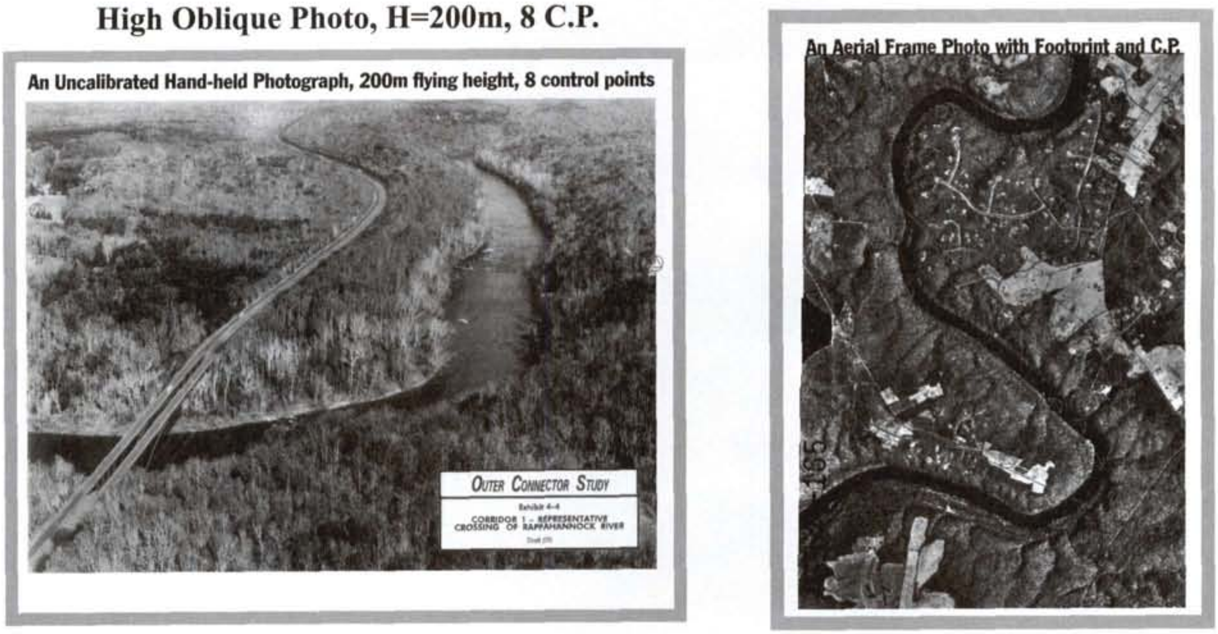


Figure 7. Combined Invariance/Photogrammetric Approach

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ever accuracy is important, photogrammetry is more suitable.

An excellent demonstration of how we in photogrammetry take advantage of supporting developments in other fields is depicted in Figure 7, for a combined photogrammetry and invariance approach. The task involved having an uncalibrated high oblique (hand-held) photograph and an overlapping stereo pair of triangulated aerial frame photographs, and performing rigorous registration of the oblique photograph to the stereo model. The procedure involved the following steps:

1. Extract control point coordinates from stereo model, for points that are visible on the oblique photograph.
2. Apply linear invariance technique to estimate invariance parameters.
3. Derive estimates for real camera parameters from the invariance parameters, which are usually difficult to get.
4. Use these estimates as initial approximations in a rigorous (non-linear) photogrammetric triangulation.

QUESTION #2: WHAT DO YOU THINK ARE THE MOST SIGNIFICANT ADVANCES IN THE FIELD DURING THE PAST DECADE?

Considering the various components of photogrammetry that I listed in Figure 4, I will arrange the comments pertaining to this question accordingly:

1. With Respect to Sensor/Sensing: Significant advances have occurred in sensor technology, particularly digital sensors, which are capable of relaying image data to users in near/real time. Conversion of analog imagery to digital form rapidly and inexpensively in addition to imagery already acquired in digital form, has led to its widespread availability. This has introduced new data sources, ranging from satellite imagery to video, and new non-professional users, but most importantly, has put imagery into the computer. Once the image is in the computer, distribution and processing become easier and the photogrammetrist has started to consider the potential of applying computer vision techniques. Introducing such techniques to aerial and space imagery, as opposed to industrial applications, has posed a significant challenge to experts in computer vision.

An example of video application is shown in Figure 8. In recent years, video cameras on board unmanned airborne vehicles, or UAVs, has offered a fast and inexpensive avenue for acquiring near-real time digital imagery. Although fast, linear computer vision algorithms are often used by other disciplines, rigorous photogrammetric video sensor modeling with complete error propagation yields more accurate results for target location. Figure 8 compares the accuracy for two methods of a single video frame resection using eight control points. As can be seen, the photogrammetric results are significantly better.

Another activity is the emergence of SAR as a mature, accurate image source. We have seen the successful launch of RADARSAT and a high-resolution (3m) follow-on is planned. In addition, NASA and NIMA are cooperating in the Shuttle Radar Terrain Mapping, or SRTM, project, which will produce data of such ubiquitous value that it will be used world-wide in a myriad of applications.

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Video Frame (25° tilt angle, 8 ft. GSD at nadir)

Linear Transform (LT) versus Rigorous Photogrammetry (RP)

RMS (ft) at 8 Check Points (Blue) Using 8 Control Points (Red)

	LT			RP		
rms	dX	dY	Plan.	dX	dY	Plan.
	27.7	19.8	34.1	6.1	5.6	8.3

Figure 8.

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ERIM generated a high density DEM over Bosnia with their IFSAR aircraft. The UAVs, currently in rapid development, will collect SAR as well. SAR is becoming a major source for mapping, environmental, and intelligence applications.

New spectral sensors that allow looking at objects more universally and providing a major step towards automated spatial feature extraction was another major breakthrough in the last decade.

Related to imaging is the emergence of accurate and reliable auxiliary sensors. GPS has provided a revolution in both civilian and military capabilities, for location, navigation, and mapping. GPS and improved INS play a significant role in platform modeling, particularly for time-dependent imaging sensors.

2. *With Regard to Data Extraction/Processing:* Widespread inexpensive computing power has changed the photogrammetric problem from one of manual manipulation of expensive, single-purpose measurement hardware to one defined by mathematical analysis, limited only by image acquisition constraints and the imagination of the photogrammetrist. This includes all facets of the technology such as computing speed; data storage, transmission, and presentation; software development technology; and the Internet which are rapidly making the dissemination of information derived from photogrammetry a reality. Collectively, these have lead to increased user friendliness of the equipment through powerful user interfaces, permitting computer literate personnel to perform operations which in the past could be performed only by highly trained technicians.

3. *With Respect to Information Extraction:* The photogrammetrically-derived information has also undergone significant change. Photogrammetric products are considered an integral part of GIS. Current production techniques for DEM and orthophoto bear little resemblance to those of a few years ago. Applications of photogrammetry have expanded into many other fields such as environmental sciences, and detection and prediction of weather phenomena in atmospheric sciences.

4. *With Regard to Presentation of Results:* Conversion to the digital domain has revolutionized the presentation of the photogrammetric results. Multi-purpose databases are first constructed, then a variety of products in many different forms are derived. In addition to cartographic (or map) products, new types such as "object models" or "site models" have been added due to working with digital imagery. Often the main criterion for such models may not be absolute accuracy, as in mapping, but may be visual realism and completeness.

We are also witnessing the birth of other representations, such as virtual worlds, visualization, and simulation, of which photogrammetry is an integral part right from the beginning.

QUESTION #3: WHAT DO YOU VISUALIZE AS THE SIGNIFICANT ADVANCES DURING THE NEXT DECADE?

1. *With Respect to Sensors/Sensing:* Sensor technology will continue to improve, particularly in finer spatial and spectral resolution. Although efforts will increase in the design of digital frame cameras, time-dependent sensing will expand significantly both from airborne and space platforms. Video imaging will also advance markedly both from manned and unmanned vehicles with significant increase in on-line transmission. The utility of such abundance of digital image data will be vastly improved through a marked improvement in the quality of sensor/platform model parameters determined by onboard auxiliary sensors. In essence, then, the imagery will be available in a nearly absolutely oriented form.

2. *With Regard to Processing/Extraction:* Considerable progress will be made in merging the activities of photogrammetric processing, multi-spectral and hyperspectral image processing and analysis, image understanding, and GIS. This is expected to be the area of significant improvement and advance, particularly in the extraction of spatial features. While the ultimate goal is automated extraction, the development of efficient and robust tools that can aid the operator in cutting down the data collection time would increase productivity significantly. The synergy between these disciplines has in fact been the foundation of a basic Research Center supported by the US Army Research Office. The Center's research team is composed of two Groups at Purdue — Photogrammetry and Geospatial Analysis, and Remote Sensing; the Institute for Robotics and Intelligent Systems at the University of Southern California; GDE Systems, Inc. as an Industrial Partner; and the US Army Topographic Engineering Center as a collaborating Government Laboratory. Figure 9 depicts the activities of the Research Center in the form of a flow chart showing the interaction between the components in order to accomplish its goal of Rapid and Affordable Generation of Terrain and Detailed Urban Feature Data.

Early results of research activities in the MURI Center are shown in Figure 10. The top multi-color image is the as-collected HYDICE 210 band hyperspectral strip. As we all know, a push-broom system from an aircraft flying at relatively low altitude (resulting in a 2m GSD) will suffer from significant distortions as is apparent in the wiggly appearance of

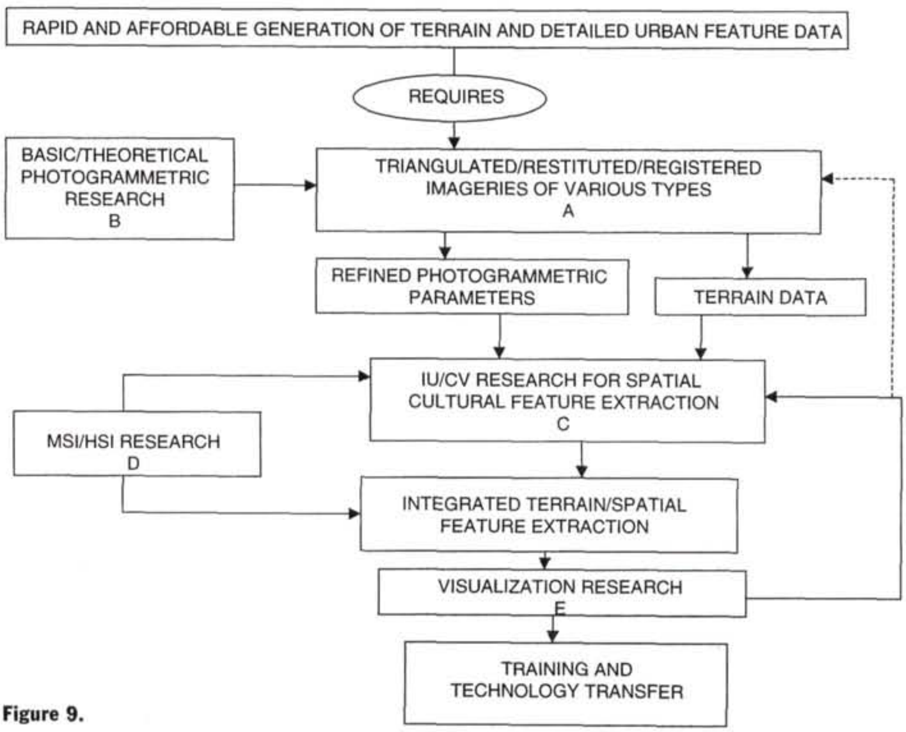

Figure 9.

Original HYDICE Image with Distortions

Orthorectified Image Using Rigorous Modeling by Gauss-Markov Process

Figure 10.

straight features. The spectral classification of such an image will retain the same geometric distortions unless the image is properly rectified. Sophisticated photogrammetric sensor modeling based on Gauss-Markov stochastic process, and rigorous linear feature-based photogrammetric modeling, results in minimization of the distortions in the orthorectified image. This allows accurate registration of the spectrally classified image to frame photographs. Semi-automated and automated algorithms for spatial feature extraction are applied to these photographs, taking advantage of the transferred feature labels from spectral classification.

The establishment of the Research Center, with Photogrammetry as the lead, is not only an indication of its relevance but also its importance in influencing future development. As a result of these and similar efforts, we expect steady improvement in the automation of different modeling functions, in addition to extraction of cartographic features, such as image orientation, surface extraction, and various object models.

Another advance will likely be in providing users with photogrammetric tools which they can apply to partially processed imagery and associated support information to derive the required products themselves. One individual called these *"user friendly images."* Sensor modeling, processing of imagery, and producing the support information will remain the function of the expert photogrammetrist. This is anticipated to be the case for many products, except for those of large scale with varied and dense details.

One of the individuals who responded to this question had excellent imagination. He foresees the development of sensors which, when pointed at the surface of the earth or planets, return **information** about them as well as precise location; examples cited include existence of human life, viability of atmosphere to support life, mineral deposits, etc., *all in real time*! I don't know about such capability happening during the next decade — but I admire a photogrammetrist who dares to dream a big dream.

3. *With Regard to Presentation of Results:* We should expect to see during the next decade very sophisticated virtual environments with unthinkable levels of detail. These will require massive photogrammetric systems to generate the required data and photogrammetrically correct stereo viewing systems to present convincingly immersive environments. An example is the development of site visualization for commercial realty. Imagine giving "Ramada and Marriott Hotels" the ability to place their building models into VR, seeing what the other developments are in their area, visiting each room to see the view out of the window, etc. I suspect that not many people appreciate the amount of photogrammetry that goes into the construction of a VR model.

The processes needed to provide such massive data for virtual reality would hasten the development of true 3D topologically structured data. This will allow objects that share topological relationships of nodes, edges, or areas, "on top of or under," to be unambiguously captured from stereo imagery within the error limits of the photogrammetric solution.

To illustrate the current state of visualization data base requirement, I will show a "fly through" of about 3 minutes. All the work involved in this illustration was performed by GDE Systems, our industrial partner. For this visualization task, imagery from four different sources was used. The first two consisted of 9x9 inch frame photography, flown with 60% overlap. One strip of 6 images was flown at 25,000 feet; and one strip of 10 images was flown at 12,000 feet. The project also had eight small format photographs taken from a helicopter (high oblique) using a 50mm lens, and approximately 100 25mm photographs to be used for high resolution feature textures. (See web site http://www.es.com/simulation/rapidsceneapps.html for flythrough.)

The strip taken at 12,000 feet used 12.5 micrometers scanning resolution, while the one at 25,000 feet, and obliques used 25 micrometers. Image scan times were on the order of 7 minutes per image for the 12.5m and 4.5 minutes for the 25m.

Triangulation: Images were triangulated with HATS, the Helava Automated Triangulation System. Automatic point measurement failed for the oblique imagery, but the two nadir strips had excellent results. The oblique images were treated in a classical manner and added individually by making better estimates for the projection centers. Overall triangulation RMS was 1/3 pixel.

The two vertical strips were then used to create digital terrain matrices. The Adaptive Automatic Terrain Extraction technique was used to produce a 20 foot post spacing for higher altitude images which required approximately 3 hours of editing; while the lower altitude imagery had a five foot post spacing, taking 3 hours to generate the file, and another 10 hours of detailed editing. Orthophoto/Mosaic was generated, batch process, as a background, and only required 1 hour per mosaic.

Feature Extraction: Some 300 features needed to be precisely extracted and modeled. Semi-automatic processes were used. The 300 features took approximately 20 hours to collect. Once the features were collected, the data was viewed with SOCET SET's perspective scene tool, in order to decide if default-building textures were adequate, or if and where hand-held textures needed to be applied.

The hand-held photographs were scanned on a standard desk-top scanner, imported into the project as generic texture images, and then in a semi-automated routine, applied to the appropriate features. This procedure was very involved and required approximately 40 hours. Also in this process was the addition of "Generic Features" such as cars, trees, and poles.

The database was then exported and

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viewed with the visualization system. Several synthetic flight paths were created and used to create the MPEG "fly through" animation files.

The database was used for the measurement proposed in the visualization system and found to be accurate within 1 foot at several known positions. The database has since become the NIMA standard database for testing visualization systems.

It should be abundantly clear, first how much photogrammetry is involved in realistic visualization. Second, we have a long way to go to increase the efficiency of photogrammetrically constructing such data bases.

QUESTION #4: DO YOU AGREE WITH THOSE WHO CLAIM THAT PHOTOGRAMMETRY AS A FIELD OF ACTIVITY IS BECOMING OBSOLETE?

Almost all the respondents strongly disagreed. And we shouldn't be surprised in view of my discussion so far. Some respondents said that photogrammetry as a discipline has matured or that it is "morphing." But then, aren't most of the engineering and applied science fields, as they are impacted by advancing technologies and innovations in related fields? A friend forwarded to me information on a company named Synthonics Technologies. Their primary trademarked product is Rapid Virtual Reality (RVR) which they say "has its roots in photogrammetry, a complex science which allows measurements to be made from photographs." I guess it is far from obsolete!

THE FINAL QUESTION I ASKED: DO YOU THINK THE DIVERSITY OF CURRENT ACTIVITIES WARRANTS A CHANGE IN NAME?

This was the one question that evoked the strongest reaction from several individuals; two examples:

> I find that the search for new names is often a crutch to hide a lack of innovation in the true discipline. Sensorgrammetry, or imagegrammetry might be alternatives, but the general public still thinks of any image as a photograph. A radar image in the newspaper would probably be considered a "picture" or a "photo" by most readers. We have the same problem with sanitation engineers, building engineers, train engineers (why isn't a pilot called a plane engineer?), etc. Clearly the term "engineer" has become non-specific, and could be argued to have lost its meaning entirely. On the other hand, no one is changing it!

> I think, for reasons of historical continuity, and to acknowledge the richness of its past, we should retain the name "photogrammetry." But we should also accept, and even demand, that the connotation of the word is much broader than it was 50 years ago. We should not insist, for example, that someone pursuing a career in image processing should begin to call himself a photogrammetrist, but we should insist that he possess a knowledge of the fundamentals of photogrammetry so that he does not make silly mistakes and easily preventable misstatements. For purposes of public relations, empire building, and other regrettable ambitions from which we suffer, we should stand willing to shamelessly use other terms where they seem useful, i.e. "geospatial image analysis," etc. but let's face it, they are too cumbersome to achieve common usage. So we just use whatever term seems most useful in each particular context.

The majority of the respondents were by far strongly in favor of keeping the term, particularly in view of its expanded definition given in Figure 2. A few respondents suggested alternatives, to which I added several, shown in Figure 11. One can coin a number of names "under" photogrammetry as I have done, only to emphasize that it is indeed inclusive. Perhaps sensogrammetry or pictogrammetry is a possibility. But I am not promoting that!

I agree with the experienced photogrammetrist who wrote: "There is an 'image' problem — (1) People may equate photogrammetry with 'old' — like hardcopy and photographs, and (2) People may see photogrammetry as being just common sense geometry — anyone can do it." A new name would only partly address this problem. Powerful advocacy needs to come from the professional societies who must lead in the continued pursuit of fundamental knowledge that underlies photogrammetric analysis and in the aggressive development and assimilation of new techniques. This will guarantee that photogrammetry and its related disciplines will continue to be the rich source of innovation and accomplishment that have characterized its history up to now.

NAMES

PHOTOGRAMMETRY

- **RADARGRAMMETRY**
- **SARGRAMMETRY**
- **HOLOGRAMMETRY**
- **IRGRAMMETRY**
- **MSGRAMMETRY**
- **HSGRAMMETRY**

IMAGEGRAMMETRY

SENSOGRAMMETRY

PICTOGRAMMETRY

Figure 11.

CONCLUDING REMARKS

Is there any doubt in any one's mind that photogrammetry is as relevant now as it has ever been? With the diversity of sensors and the ever increasing demand for topologically structured three-dimensional data bases, I see an enhanced and expanded role for the photogrammetrist in the future. Of course that photogrammetrist will have learned many more subjects and trained to use different technical tools than his predecessor. No matter how much some people claim to the contrary, automated image interpretation and understanding is a long way from being achieved. You can pit a relatively untrained and modestly educated individual against the largest multinode parallel computer, and he would win every time in understanding an image almost instantly and with near perfect reliability. Therefore:

(1) conventional manual and manually assisted photogrammetry has a long and productive life ahead

(2) there is lots of exciting research to pursue with huge payoffs for each incremental step forward.

Modeling, simulation and entertainment specialization will provide added driving need for the photogrammetry profession in the future. At the same time, the photogrammetric field may be more adaptable to addressing the complexities in exploiting spectral imagery. Spectral imagery mensuration is going to be a significant challenge and the photogrammetric rigor may prove to be an important underpinning.

Due to the technological advances in photogrammetry and the widespread use of digital imagery, there are more diverse problems to be solved. Therefore, scientists and engineers from other disciplines may perhaps contribute to photogrammetric research more now than in the past. However, none of the contributions will replace the work performed by the photogrammetrist. This is particularly true for non-frame imagery soon to be commercially acquired from space at comparably high resolution to current aerial photography.

It is clear that while the field of photogrammetry is as vibrant and needed as ever, there is that little doubt that other areas of technology with fancier names and visible applications (such as robotics) may present a threat. To erase that doubt, marketing the vi

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tality of photogrammetry is critical, and that is the role of the professional societies. In a sense, we perhaps are becoming victims of our success, which reminds me of a short story:

Three scientists, one in computer graphics, another in computer vision, and a photogrammetrist were convicted to die by the Guillotine. The first approached, said his prayer, placed his head in the proper position, but the mechanism failed and the Guillotine did not fall. The authorities said that the process cannot be repeated and he was set free. Next, the computer vision scientist went through the same steps and again the mechanism malfunctioned. Now it was the photogrammetrist's turn. As he approached, he stopped and told the guards: "You know, I have watched the mechanism carefully, and if you want me to, I can certainly fix the problem first!"

ACKNOWLEDGMENTS

I would like to express my sincere thanks to the many friends, colleagues, and graduate students, past and present, who responded to my questions.

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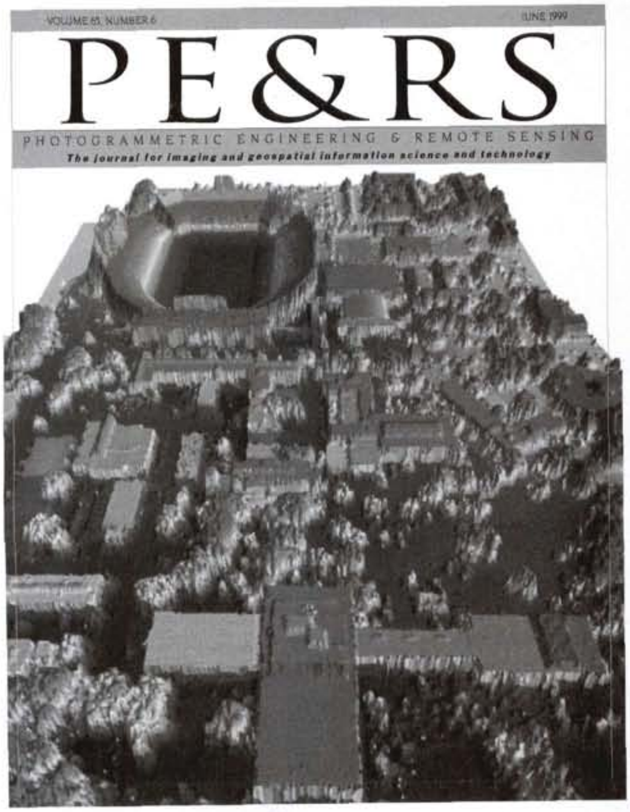

IMPORTANT NOTICE

Due to a printing error, the Cover Image text on page 641 of the June 1999 of PE&RS issue is incorrect. The June cover image was provided by Applanix Corporation, NOT DAT/EM Systems International. The correct text is printed below. We regret the error and advise you to place the errata sheet that came with the journal inside the front of your June issue for future reference.

Applanix's integrated inertial/GPS Position and Orientation System for Airborne Vehicles (POS/AV) has found a wide range of applications with airborne sensors. One of the more interesting ones is airborne laser scanning. In order to remove the aircraft motion-induced geometric distortion effects and provide precise geographical coordinates of the ground data, the position and orientation of each laser pulse must be precisely measured, time-aligned and recorded. This process results in high-accuracy Digital Terrain Models (DTM) that can be turned around in a matter of hours.

The DTM on the front cover of the June 1999 issue of *PE&RS* is of the University of Florida campus in Gainesville. The image was obtained using Optech's ALTM 1210 — 10 kHz, and Applanix's POS/AV at 2000m AGL. There are four separate flight lines tied together to create this image, which consists of 350,000 points and took two minutes to collect. The elevation accuracy is better than 10 cm.

For further information on POS/AV, contact Applanix Corporation at 905-475-2221, info@applanix.com, or www.applanix.com. For additional information on ALTM, contact Jim Green at Optech Inc., 416-661-5904, jimg@optech.on.ca, or ⟨http://www.optech.on.ca⟩ www.optech.on.ca.