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This work summarizes the procedures accomplished toward the objective to develop a demonstration capability (Proof-of-Concept) of three dimensional object modeling using close range photogrammetric techniques. Static stereo views and three-dimensional perspective scenes of crystals were to be devleoped using the same technology that is applied in displaying three dimensional earth surfaces. The work inlcuded the creation of close range photogrammetric capabilities to work along with various existing display capabilities. The imagery for this project was provided by the 3M Co. It was acquired using a Scanning Electron Microscope (SEM). The softcopy concept was demonstrated to the Office of Commercial Programs National Aeronautics and Space Administration at Autometric (Alexandria, VA headquarters).

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Introduction

This report summarizes the procedures and work accomplished toward the objective to develop a demonstration capability (Proof-of-Concept) of three-dimensional object modeling using close range photogrammetric techniques. Static stereo views and three-dimensional perspective scenes of crystals were to be developed using the same technology that is applied in displaying three-dimensional earth surfaces. The work included the creation of close range photogrammetric capabilities to work along with various existing display capabilities. The imagery for this project was provided by the 3M Company. It was acquired using a Scanning Electron Microscope (SEM). The softcopy concept was demonstrated to the Office of Commercial Programs National Aeronautics and Space Administration at Autometric (Alexandria, Virginia headquarters).

Process

The process used in developing this modeling and visualization capability involved basic photogrammetry and image processing methods. The process, accomplishments, problems, and suggestions are described below.

Image Acquisition Methods

SEM micrographs of a 3M proprietary surface were provided to Autometric by 3M. The first image stereo pair provided to Autometric was generated by translating the camera along the Y Axis. Due to the acquisition method of the SEM, these images were found to be usable. After a technical meeting between scientists from 3M and Autometric, a second acquisition method was agreed upon and a second imagery set was made by rotating the crystal plus and minus a few degrees along the X axis. This method produced a usable stereo pair. Some of the dimensions and characteristics of the surface were provided, but there was still difficulty in the interpreting the data provided. This data is discussed in further detail in the Image Assumptions sections.

Image Digitizing

Each of the stereo pair photos were digitized by Autometric on a flatbed Ekonix digitizer which generated 1024 by 1024 8-bit images. These images were only small patches of the original image due to the size of the original images. The images were not included in this report because they are 3M proprietary data. However, the pattern digitized was representative of the whole image.

Image Assumptions

In order to obtain accurate surface information, some type of ground/surface control must exist to tie the images together through a triangulation process. Accurate surface control information was not available for the images we were given to work with. In order to generate some type of useful data, we made assumptions about features on the surface. The following are the assumptions we made in interpreting the data provided:

1) All pyramids are of the same dimension, joined perfectly at the corners (Figure 1).

2) The pyramids on the surface are made up of three triangles. Two of the three triangles (faces 2 and 3) have the same dimensions.

3) The angle between Face 1 and the base of the pyramid is 67 degrees, and the angle between faces 2 and 3 and the base are both 57 degrees (Figure 2).

4) Estimating from the photography, angle A = angle B = 54.9 degrees, angle C = 70.2 degrees (Figure 3).

5) Altitude of the base triangle is .007 inches.

Equations for the planes containing faces 1, 2, and 3 are formed and intersected to obtain the normalized coordinates of the tips of the pyramids. Using Assumption 1, we may now find the coordinates of each of the 12 ground/surface coordinates needed for the adjustment.

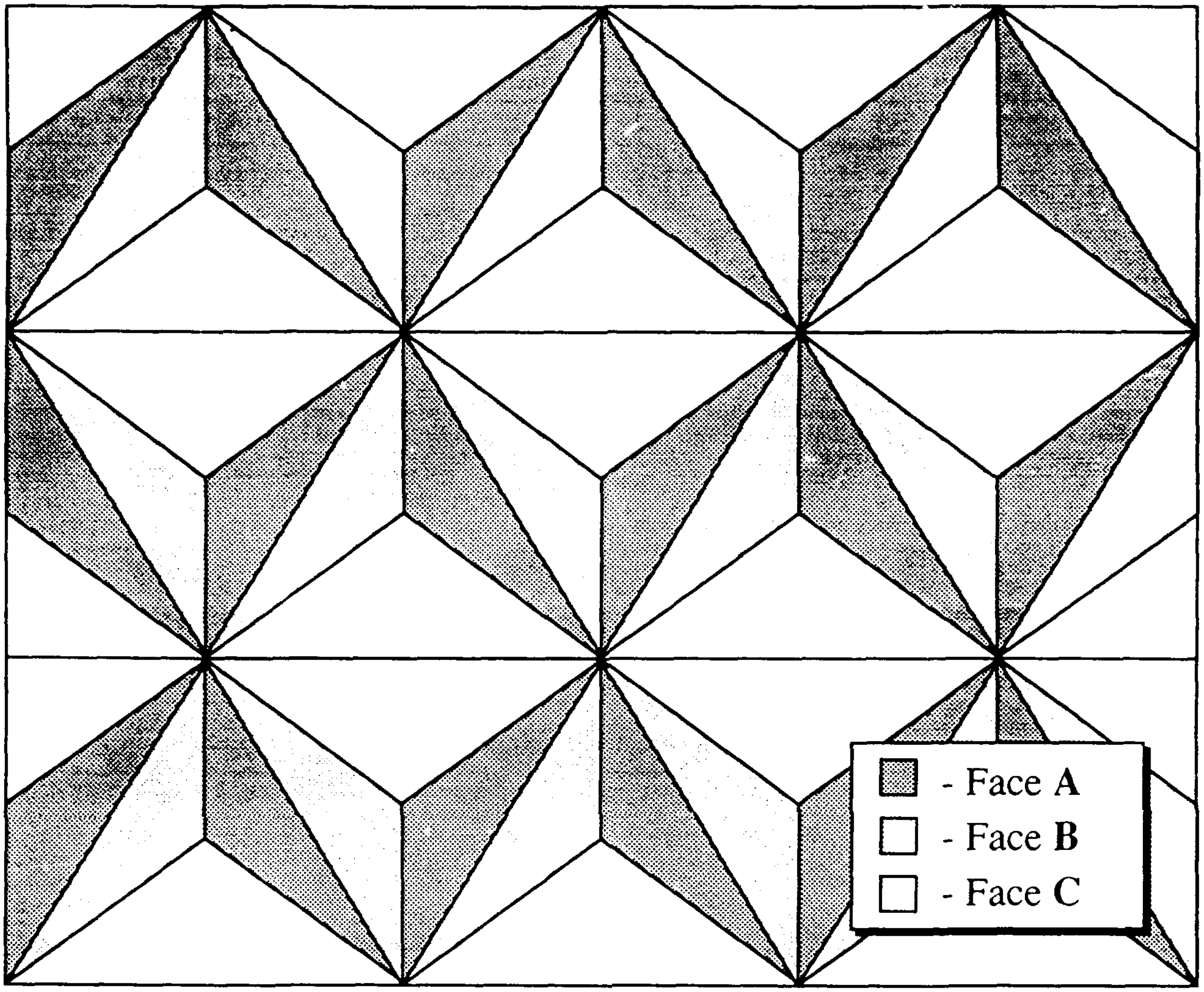

FIGURE 1 SURFACE STRUCTURE

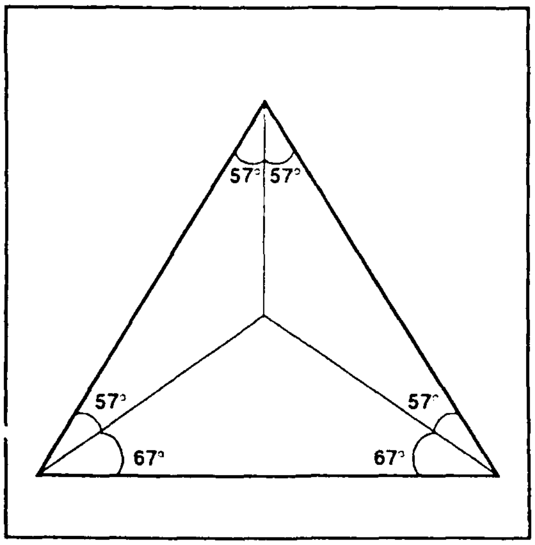

FIGURE 2 FACE DIMENSIONS

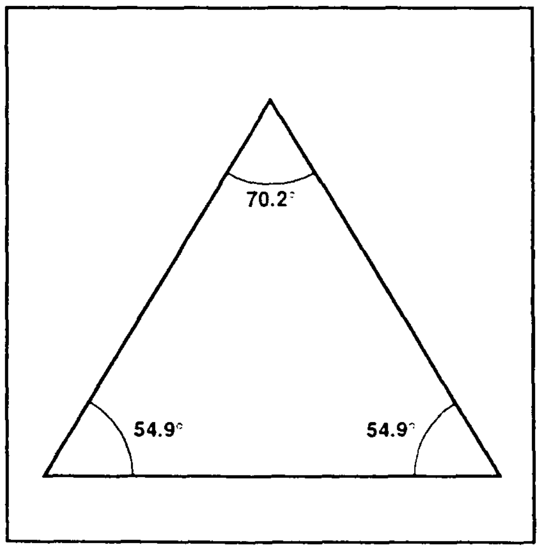

FIGURE 3 BASE DIMENSIONS

Image Control

	Image						
	Left		Right		Ground	(Surface)	
Point	X	Y	X	Y	X	Y	Z
1	-1.6	1.6	-1.6	1.5	20.523	16.339	-0.759
2	-1.5	-0.5	-1.6	-0.6	39.214	16.834	-1.027
3	-1.5	-2.6	-1.6	-2.7	58.219	16.995	1.051
4	2.8	1.6	2.7	1.5	20.483	54.936	-1.000
5	2.8	-0.5	2.7	-0.6	39.364	55.167	0.116
6	2.8	-2.6	2.8	-2.7	58.220	55.559	0.138
7	0.6	2.0	0.5	2.0	17.496	35.544	7.631
8	0.6	-0.1	0.5	-.01	35.718	35.813	8.931
9	0.6	-2.2	0.6	-2.3	54.294	35.940	5.303
10	4.2	0.9	4.2	0.9	26.871	67.092	7.699
11	4.2	-1.2	4.2	-1.2	45.038	67.464	6.463
12	4.3	-3.3	4.2	-3.3	63.241	67.284	8.319

Image Adjustment

An data was then adjusted using Autometric's Standard Close Range Triangulation software. Since most of the imaging event parameters (camera position, camera, attitude, and focal length) were on known and based on assumptions, we found it very difficult to recreate the actual imaging event in the adjustment. After trying various combination and scenarios we found adjustment parameters that appeared to balance out fairly well. The final parameters adjusted to:

	left photo	right photo
X position	28.596	54.024
Y position	42.200	35.7670
Z position	331.932	331.918
X attitude	-2.360 degrees	-0.815 degrees
Y attitude	-1.090 degrees	3.396 degrees
Z attitude	89.895 degrees	90.113 degrees
focal length	37.446	

Image Warping

After the imagery was adjusted, it was warped for stereo viewing. The warping process is performed to restrict the differences between the two images to the X-Dimension for the purpose of defining elevation differences. The warping process uses a numerical model which is a basis for computing the terms of a cubic polynomial that relates the warped image to the original softcopy (digitized) image. The warping of the imagery is done by decomposing the warping polynomial and creating contiguous rectangular "titles" of warped imagery that can be represented by an affine transform. This process creates two images containing x-parallax representing relief displacement and the y-parallax is reduced to an absolute minimum (Bounded by the accuracy of the image adjustment process).

Cultural Data Generation

Once the data is displayed in stereo, it is possible to obtain three-dimensional information about the images or the imaged stereo surface. This data is based on the observed film coordinates projected into the ground coordinate system and on the control points. The collected vector data was stored in a three-dimensional model format so that it could be displayed as a three dimensional model with the correct image texture mapped to each polygon for display.

Conclusion and Suggestions

The project resulted in a successful proof-of-concept in the application of photogrammetric and three-dimensional modeling techniques to close range imagery. Accomplishments include:

1) Photogrammetrically modeling Scanning Electron Microscope images
2) Warping the digital images into viewable stereo
3) Generating feature/model data of the 3M surface
4) Creating "fly by" visualization loops over the 3M surface

To accurately model the data from images, it is important to have metric and support data describing the imaging event as well as object space or surface control. If this information is not available, then only rough estimates can be made as to the size and scale of the objects being modeled. For our example, we had very limited information about the imaging event as well as limited surface control. With this limited information, we were able to estimate the needed information to perform the data triangulation and image warping. The result was viewable and measurable data that represented the 3M SEM surface in the images, but was not dimensioned to any particular scale.

For future efforts, there will need to be more accurate object space control and better record of the imaging event parameters. By participating in the image collection and providing collection requirements before the images are collected, the type of problems such as the ones that we experiences, may be avoided.