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DBA SYSTEMS, INC.

DOCUMENTATION OF PHOTOGRAMMETRIC MISSION SIMULATOR PROGRAM

VOLUME 1

PROGRAM DESCRIPTION

Photogrammetry

Computer Services

Mathematical Research

Electro-Optical Instrumentation

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Final Technical Report

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PROGRAM DESCRIPTION

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TABLE OF CONTENTS

1.0 INTRODUCTION

Due to the considerable expense of lunar photogrammetric missions, it is of utmost importance that the mission planning analyze as many pertinent factors as possible. As a minimum, the acquired photography must be suitable for mensuration and subsequent reduction. The acquired photography will be utilized primarily for the production of maps of the lunar surface. Accordingly, a major objective of mission planning is to insure that the mission will be capable of yielding maps of the desired accuracy.

Given sufficient photogrammetric data, it is possible to determine the positions of the exposure stations by the process of resection. This information can then be used for a determination of the lunar gravitational field. Thus another objective of mission planning is to evaluate the accuracy with which the lunar gravity potential may be determined for a given mission.

A convenient, practical, and economical means of performing pre-mission studies to fulfill these objectives is by means of computerized simulations. The Photogrammetric Mission Simulator Program (PMSP) is designed to perform such simulations. The PMSP represents a powerful analytic tool designed to enable highly sophisticated simulations of lunar photogrammetric missions. While the PMSP was created for the study of lunar missions, it has applications in other space photogrammetric missions as well.

The PMSP is actually comprised of four separate and distinct program modules. Each program module is designed to perform a particular task in the mission planning process. All four modules are likely to be utilized. The combined results of the four modules provide major assistance in the final selection of a mission plan.

Detailed technical descriptions of the four modules are presented in separate volumes. A discussion describing each module and its possible uses for mission planning follows.

2.0 GLOBAL BLOCK ADJUSTMENT MODULE - GBLOCK

A photogrammetric mission whose photography generates a photogrammetric net which entirely covers the lunar surface with isotropic overlap has been found to possess extraordinary geometric strength. This characteristic makes the study of such nets particularly interesting for mission planning. The Global Block Adjustment Module, acronym GBLOCK, is a program module which has been designed to enable the study of photogrammetric nets involving global coverage of the moon.

GBLOCK simulates photography, and performs a least squares adjustment in order to compute the a posteriori estimates of the standard errors for all exposure station parameters of position and orientation, and all ground point coordinates. These statistics may be used to analyze the inherent strength of the geometry of a given photogrammetric net.

The method employed for performing these computations is substantially the method described by D. Brown in "A Unified Lunar Control Network" (Brown, 1968). Exposure station positions and ground point positions are determined by an algorithm which approximates the patterns which result from successive bisections of the icosahedron. Photography is then generated from these two sets of positions using straight-forward projective computations. The subsequent reduction and computation of statistics is performed using well established techniques.

Due to the simplicity of the numerical techniques which GBLOCK utilizes, GBLOCK is especially well suited for basic investigations into the geometric strength of the photogrammetric nets involving global coverage. Orbital constraints may be approximated by appropriate input values. Provision is made for the inclusion of simulated laser ranging measurements into the adjustment. Because of its flexibility, GBLOCK is capable of providing major assistance to the study of trade-offs, such as a densified passpoint pattern (more image measurements) and/or increased photography (more frames) versus the inclusion of external sensors (stellar camera and/or a laser ranging device).

GBLOCK is intended for use in basic studies of the strength of photogrammetric nets of global lunar coverage. It is economically advantageous to perform basic studies using GBLOCK, since the geometric approach, which approximates a dynamic approach, does not involve a numerical integration process.

GBLOCK is predicated upon the assumption of a purely circular polar orbit, and a spherical moon. Accordingly, this program module is not suitable for studies of missions involving orbits of large eccentricity, or missions which do not result in photography having global coverage. The program module MBLOCK (next section) has been designed to handle these situations. GBLOCK is capable of simulating a network of up to 642 photos with a maximum of fifty image points per photo.

A more comprehensive presentation of the program module GBLOCK is given in Volume 2 of this document.

3.0 MULTI-MISSION BLOCK ADJUSTMENT MODULE - MBLOCK

Whereas lunar photogrammetric missions providing global coverage of the lunar surface are of special interest for basic studies, it is well known that existing and prospective photography of the moon does not involve global coverage. Furthermore, the data to be used for map compilations for mapping portions of the lunar surface will result from several different missions involving different cameras and different orbits, but with areas of common ground coverage. The Multi-Mission Block Adjustment Module, acronym MBLOCK, has been designed for the purpose of enabling the study of lunar photogrammetric missions of this nature.

MBLOCK is capable of the simulation of both global and multi-mission short arc photogrammetric missions, and of the reduction of the resultant data. As with GBLOCK, the output of MBLOCK simulations consists of a posteriori estimates of standard errors. MBLOCK computes these statistics for a number of parameters including exposure station positions and orientations, ground point positions, and the orbital parameters.

The computations performed by MBLOCK involve the use of a numerical integration process to determine the exposure station parameters at the time of exposure. The coefficients of a dynamic orbital model are among the required input to this program module. The data reduction procedure for MBLOCK is similar to that for GBLOCK, and is based on the same set of numerical techniques.

MBLOCK is especially well suited for evaluating the effect of orbit stability on attainable accuracies in ground point positions and for determining the effect of combining the photography from different missions with overlapping coverage into a single net by subjecting the combined data to a least squares adjustment. This information may then be used to determine the attainable accuracy of maps based on such photography.

The inclusion of a numerical integration process results in significant execution time requirements. For this reason, it is important to exercise some care in the choice of simulations to be run. The choice of simulations should be based on a set of pre-selected objectives, the results of previous runs, and prior knowledge. MBLOCK is better suited for the evaluation of refinements in mission plans than for basic research.

MBLOCK can handle up to a total of one hundred (100) photographs from a maximum of thirty (30) different strips. The full range of input options is discussed in detail in Volume 3 of this document.

4.0 MISSION ANALYSIS MODULE - MANCE

As stated in the Introduction, it is a basic requirement that a photogrammetric mission yield mensurable photography. The Mission Analysis Module, acronym MANCE, is designed to enable studies of the mensurability of lunar photography.

MANCE simulates photography, computes ground coverage and computes exposure values for image points of the simulated photography. The exposure value is a measure of the total amount of light which impinges upon a point in the image plane during the time that the shutter is open. The image density, and thus its mensurability, is a function of the photographic emulsion.

A number of factors are considered in the exposure computations. These include brightness (given as a function of the albedo and the photometric constant), irradiance of the camera system (percent transmission of the lens system), duration of the exposure, and lens aperture. Full details of the exposure computation are found in Volume 4 of this document.

The ground coverage computations are performed simultaneously with the simulation of the photography. The photography is generated by means of a numerical integrator according to input values which describe a dynamic orbital model. Complete details of this procedure are contained in Volume 4 of this document.

MANCE can be used to evaluate the expected imagery in terms of image quality and measurability. MANCE can also be used to evaluate expected ground coverage of a photogrammetric mission. This program module should always be exercised before final acceptance of a mission plan to insure that the planned photography is suitable for mensuration. It may be appropriate to use this module at earlier stages in the planning as well. For example, it may be helpful to the mission planning process to run a series of simulations covering an area under various conditions of illumination, or with different orbits and/or cameras.

The primary factor limiting the use of MANCE should be execution time requirements, due to the fact that a numerical integrator is utilized. Other restrictions, which are given in detail in Section 3 of Volume 4, are felt to be of no practical concern.

5.0 GRAVITY RECOVERY MODULE - RSTATE

The positions of the exposure stations for a lunar photogrammetric net may be obtained by resection. Given sufficient data, it is then possible to perform a weighted least squares adjustment to solve for lunar gravity potential and to compute estimates of the standard errors of the spherical harmonic coefficients used to define the model. The Gravity Recovery Module, acronym RSTATE, is a program module which has been designed to enable studies into the determination of the lunar gravity potential from photogrammetric data.

RSTATE is capable of generating simulated observational data, and performing least squares adjustment computations. The orbit times of the simulated photography will be either equally spaced or based on photogrammetric coverage of the lunar surface, according to the option selected by the user. A numerical integration process is utilized for these computations. The least squares adjustment computations reduce the simulated data to obtain a solution for the lunar gravity potential and to obtain estimates of the standard errors of the coefficients used to define the model. Established procedures, which include a provision for appropriate weighting of parameters, are utilized for the least squares computations.

The program module RSTATE should be most useful in assisting in the selection of a meaningful spherical harmonic model of the lunar gravity potential field. Spherical harmonic functions are frequently used to express potential functions such as gravity. This choice is supported by the numerical ease of evaluating such a function, and because of the fact that the coefficients have physical meaning for interpretation purposes. The results of RSTATE runs should provide a basis for the selection of the order and degree which are best suited for expressing the lunar gravity potential, and for the determination of estimates of the standard errors associated with each of the coefficients.

RSTATE is capable of handling spherical harmonic models to (14, 14) that is degree 14 and order 14. However, the computational effort required in handling the more complex models is substantially greater than for a simple model. Also, the use of a numerical for the simulations requires a significant amount of execution time. As a consequence of these considerations, it is imperative that discretion be exercised in the selection of runs.

A comprehensive discussion of the program module RSTATE is the subject of Volume 5 of this document.

6.0 PROGRAM UTILIZATION

The objectives of the four program modules of PMSP have been presented in the preceding sections. Specific usage of these modules must remain at the discretion of the user, however, certain usage procedures apply to all four modules.

Before running a program, it must first be affirmed that the desired computations are indeed those performed by one of the PMSP program modules. Then the assumptions inherent in the selected computer program should be reviewed in terms of the problem at hand. A complete review of the Volume of this document which is devoted to the selected module is in order.

Job set-up must be in strict accordance with the specifications given in Section 3 of the appropriate Volume of this document. Specific elements to be checked for conformity are system control cards, file assignments, and/or tape input, and job execution estimates including maximum execution time and maximum printed output.

Of fundamental importance to the successful utilization of PMSP, as with all computer programs, is a recognition of its limitations. The limitations of PMSP fall into two general categories. The first category is program assumptions. Due to programming considerations certain assumptions are inherent in the programs. Some assumptions are imposed in order for the storage and data handling of a program to conform to hardware limitations. Other assumptions have been imposed to achieve simplified computational or input-output requirements. Such assumptions are always imposed in accordance with the specific objectives of the given program unit.

Limitations of the PMSP program modules belonging to this first category of limitations are given in the respective program module volumes, Volumes 2 to 5 of this document.

The second category of limitations for PMSP may be characterized as "permitted misusages". To insure that the computations specified by program input are meaningful or even determinate, a prodigious amount of checking would have to be performed.

The PMSP is designed for maximum flexibility, and a minimum number of checks are performed. Thus, it is extremely important that care be taken in the selection and preparation of input. Accordingly, evaluation and interpreation of computational results requires consideration of the possibility that the computations performed are not meaningful.

Properly utilized, the PMSP is capable of being of invaluable assistance in the planning of a lunar photogrammetric mission.