PHOTOGRAMMETRIC PERSPECTIVES ON CHALLENGES/DEVELOPMENTS IN MAPPING FROM VERY HIGH RESOLUTION IMAGING SATELLITES

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1. INTRODUCTION

Photogrammetric mapping has moved from its classical objective, which is the process of reconstructing objects from analog frame cameras to more contemporary objectives such as automatic generation of spatial and descriptive information from digital imagery. The advent of Very High Resolution (VHR) imaging satellites opens new challenges and potentialities to geo-spatial mapping community, especially when considering the integration of VHR satellite imagery and other types of data. This paper is focusing on recent photogrammetric development in the field of VHR imaging satellites. The following sections briefly present some of the challenges in photogrammetric mapping from VHR imaging satellites.

2. SENSOR MODELS

Line cameras with one-meter, or better, resolution onboard commercial imaging satellites could bring more benefits and challenges to traditional topographic mapping with aerial images from frame cameras [1]. In this regard, one can note that the large majority of photogrammetric manipulation of frame imagery is based on the rigorous sensor modeling as represented by the collinearity equations. However, the complicated geometry of space-borne imaging systems, the absence of internal and external sensor characteristics, and the geometric weakness of the imaging process (e.g., line cameras with narrow Angular Field of View – AFOV) might not always lead to the rigorous model as the favored choice. Consequently, a variety of approximate sensor models have been developed over the last decade. The wide range of available sensor models are leaving users of high-resolution imaging satellites with the question of which sensor model should they adopt.

Rigorous modeling of line cameras describes the scene formation as it actually happens, and it has been adopted in a variety of applications [2]-[8]. The depiction of the actual imaging geometry has lead to the utilization of rigorous and physical sensor models to denote the same thing. Alternatively, approximate models include the Rational Function Model (RFM), Direct Linear Transformation (DLT), self-calibrating DLT, Gupta and Hartley's model, parallel projection, and modified parallel projection [9]-[11]. The selection among rigorous and approximate sensor model alternatives should be based on the achievable accuracy from a given sensor model, available number of ground control points, availability of the characteristics of the imaging system, validity of the assumptions associated with the approximate sensor model, and numerical stability of the adjustment procedure. The paper will present a brief overview of these sensor models together with a comparative analysis of their performance.

3. EPIPOLAR GEOMETRY

Resampled imagery according to epipolar geometry, usually denoted as normalized imagery, is characterized by having conjugate points along the same row (or column). Such a characteristic makes normalized imagery an important prerequisite for many photogrammetric activities such as image matching, automatic aerial triangulation, automatic digital elevation model and orthophoto generation, and stereo viewing. The normalization process of frame images is a well-established and straight forward procedure [12]. On the other hand, the normalization process of linear array scanner scenes is not as straightforward and is sometimes mysterious. For example, providers of space-borne imagery furnish normalized line scanner imagery while the user community is not aware of the underlying process. In [13], the author made an effort to examine this issue, where the epipolar geometry of scenes captured by line cameras moving along a trajectory, which can be modeled by second-order polynomials for the position and heading and first-order polynomials for the pitch and roll angles, is investigated. It was concluded that such a trajectory would yield non-straight epipolar lines. After such a finding, there was no discussion on how the normalization process would be impacted by the non-straightness of the epipolar lines. This paper presents a brief review of the imaging geometry of line cameras and various alternative stereo coverage configurations. Afterwards, the paper outlines various factors that affect the shape of the resulting epipolar lines including special imaging configurations, which would lead to straight epipolar lines.

4. TRUE ORTHO-PHOTO GENERATION

Recently, with the increasing resolution of modern imaging satellites (e.g., half a meter ground resolution imagery will be offered by OrbView-5, to be launched in 2007), there has been a persistent need for a true ortho-photo generation methodology that is capable of dealing with the imagery acquired from such systems. The performance of differential rectification procedures has been quite acceptable when dealing with medium resolution imagery over relatively smooth terrain. The term ‘true ortho photo’ is generally used for an ortho-photo in which surface elements that are not included in the digital terrain model (DTM) are rectified to the orthogonal projection. These elements are usually buildings and bridges [14]. Kuzmin et al. proposed a polygon-based approach for the detection of these obscured areas in order to generate true ortho-photos [15]. In this method, conventional digital differential rectification is first applied. Afterwards, hidden areas are detected through the use of polygonal surfaces generated from a Digital Building Model (DBM). With the exception of the methodology proposed by Kuzmin et al., the majority of existing true ortho-photo generation techniques is based on the Z-buffer algorithm.

Habib et al. presented the pros and cones of the Z-buffer algorithm for the true ortho-photo generation; then, introduced alternative methods to improve the performance and quality of the final result images [16].

In order to generate ortho-photos using linear scanner images, an additional iterative process is required to find the perspective center corresponding to each ground point. For this problem Habib et al. solve the polynomials of the trajectory using Newton Raphson’s Method [17]. Kim et al. proposed a method of determining 2D image coordinates using 3D object space coordinates; this method requires solving a 2^{nd} order polynomial to find the appropriate exposure station [18]. Habib et al. introduced the ‘Iterative Scan Line Search Method’ as an alternative method [19]. This approach iteratively finds a perspective center; however, it does not have non-linear solution and limitation of the order of trajectory and orientation model. In this paper, the author will cover the comprehensive analysis for true orthophoto generation using very high resolution satellite imagery.

5. DATA INTEGRATION

As we can recognize from the changing definition of photogrammetry, today’s great challenge for digital photogrammetry is the integration of different types of sensors and features. Recently, there have been many sensor types in use such as frame cameras, linear array scanners (e.g. IKONOS, SPOT, QuickBird, Kompsat), panoramic cameras (CORONA, LANYARD), three line scanners (MOMS, ADS40), and airborne/terrestrial laser systems (Leica ALS, Leica Scan Station, Optech ALTM, Optech ILRIS). Each of these sensors has its advantages and disadvantages, and integrating them would benefit the automatic generation of spatial and descriptive information for the area of interest.

To recover the sensor parameters (such as the Exterior Orientation Parameters, EOP, of a linear array scanner), control information is required. Such control could exist in the form of GPS/INS sensors or as Ground Control Points (GCP). It is also expected that the integration of different sensors and/or features could contribute towards the reduction in the required control. In other words, integrating linear array scanner scenes with frame images and/or LiDAR data using linear/areal features could add some constraints and help in recovering the sensor parameters with less control requirement. In this paper, the integration technologies of multi-sensors and multi-primitives for the geo-referencing and mapping from high resolution satellite imagery will be discussed.

6. APPLICATIONS

As the resolution of satellite imagery is increasing, the role of the data is not restricted to traditional remote sensing purposes such as land cover classification and evaluation of vegetation indices. With the increasing resolution of modern imaging satellites, the possibility of using the acquired data for large scale mapping is becoming a reality. Recently, several approaches have been developed for the utilization of satellite imagery for urban mapping. This paper will review some of the work that dealt with man-made object reconstruction using space-borne data.

7. REFERENCES

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