Are Satellite-based Orthoimages and GNSS replacing the Maps for a growing User Community

Ashutosh Bhardwaj (1)

[1] Indian Institute of Remote Sensing, Dehradun, 248001, India
Email: ashutosh@iirs.gov.in

KEY WORDS: Capacity building, GNSS, Photogrammetry, Cartography, Orthoimages

ABSTRACT: Map making commonly referred to as Cartography has moved from mental maps to digital maps while aiding the cognitive thinking of human-beings at each step, where orthoimage plays an important role as a geometrically corrected image. Historically, the necessity of a map is driven by an individual's inquisitiveness to explore and was essentially directed by celestial bodies such as the Sun, Moon, and stars. Later, maps emerged in the form of clay tablets and marking or pictures on trees and cave-walls. Maps have been drawn on paper or cloth, since the last few centuries and had finally become digital with the development of computer technology. Today's Cartography is driven by the power of the internet, global navigation satellite system (GNSS), and technologies such as Lidar, updating the features in real-time as point, line, or polygon directly on servers and devices in the hand of users. The digital maps have the choice of a large variety of colours and symbology in the software environment following the basic principles of cartography and theories such as on Bertin's perception properties of visual variables as well as map psychology. The presented study here focuses on the open-source education for capacity building, available to students, professional and general user community that includes a common man during the current era on GNSS, and remote sensing which lays the foundation for rectification of the high-resolution (HR) and very high-resolution (VHR) datasets available for mapping and updations. Cartographic facilities have improved in software's giving opportunities to each user to prepare high-quality maps. Besides on-campus courses globally, E-learning (electronic learning) has become an active method of learning which gives a learner a user-centric experience with flexibility in terms of the topics as well as time along with collaborative learning with learners from various domains. The GNSS and Mapping courses cover various topics beginning from the basics of photogrammetry, GNSS, Differential-GNSS (DGNSS), surveying methods, to advance processing of GNSS data. The application needs range from a standalone user of GNSS receivers for reconnaissance surveys with accuracies in meters to DGNSS surveys providing accuracies having an order of cm to mm for tectonic studies. The use of GNSS in geo-referencing and aerial / satellite stereo data triangulation has significantly optimized cartographic activities while saving time. Today, the dual-frequency embedded GNSS facility with pseudo-range and carrier-phase measurements has emerged in the smartphones, which has become possible due to the availability of raw data for processing in environments such as the Android Nougat 7.0 using signals from NAVSTAR GPS, GLONASS, QZSS, BeiDou, IRNSS, and Galileo. This has now opened a

new era of cartographic applications such as map-updation using smartphones with high accuracy. IRNSS signals are received in Smartphones having Qualcomm Snapdragon 720G, 662, and 460 chips. These developments further increase the challenge and requirements of education on GNSS, Photogrammetry, Cartography, and GNSS enabled cartography. Satellite-based orthoimages are now used in various mediums of information for a commoner, which is gradually replacing the maps for a large user community.

1. INTRODUCTION

Historically, topographical maps have been prepared for marking of territorial boundaries, navigation guidance in a region, and for countless applications, as an essential input by the varied user community. However, recently in the last two decades, the availability of large-scale photographs and satellite datasets has made these topographical maps as supportive data, rather than compulsory input for any task. Along with the recent digital cameras producing and delivering high-quality images with 2 - 5cms or even finer spatial resolution, the user community is becoming highly conversant with the images and its interpretation. This has happened, as the features in such a high-quality data, can be comprehended by a general user based on pure heuristics, without any formal background knowledge of Remote Sensing and Geographic Information Systems (RS&GIS). This development has made the small-scale general maps redundant to users, which were earlier considered as the most important guiding input.

Moreover, the web-based platforms, which can be accessed on laptops, mobiles, or pocket digital assistants (PDA) are providing sufficient annotation needed by a user for navigation and mapping. Two such platforms with a global context along with the Indian context are the Google Earth (GE) and the Bhuvan platform, respectively. GE started HR digital rendering services beginning in 2005 whereas, the Bhuvan platform is developed by the National Remote Sensing Centre (NRSC), Indian Space Research Organization (ISRO), and provides a lot of thematic information besides the visualization capability with HR digital rendering to a user since 2009. Bhuvan geo-portal provides a free download of satellite datasets and digital elevation models (DEM) for any of the applications such as disaster management, capacity building [1], topographic analysis [2]–[5], and navigation with positioning [6], [7]. The use of remote sensing in social media is also responsible for quick learning of the general mass population on the subject [8], [9]. A user can identify a correct set of perception elements and get situation awareness in a given environment, coupled with higher-level comprehension patterns [8]. A very successful study on the generation and mapping of orthoimages by NRSC highlights aerial photographs acquired at 1:10,000 scale for the mapping of Nizamabad district covering a total area of 10,000 sq.km with a net study area of 6500 sq.km. In this study, the orthoimages were corrected to remove the tilt, terrain effects, and distortions that result from the camera lens providing a uniform scale [10]. A comparative evaluation of Cartosat-2, Kompsat-3, and Pleiades satellite stereo datasets was carried out for the Digital Surface Model (DSM), normalized DSM (nDSM), Orthoimages, and 3D model generation for urban areas at the Delhi site. The RMS error of the nDSM was found to be 0.31 m and 4.1 m for Pleiades data and Kompsat-3 data respectively [11]. The easy availability of training and education aids has increased the awareness of a common person towards RS&GIS in the global arena as well as the Indian scenario. The availability of Indian Regional Navigation Satellite System (IRNSS or NavIC: Navigation with Indian Constellation) signals in mobile chips, and application programming interface (API) services in level 29 of Android devices

further aid in mapping through professional as well as volunteered geographic information (VGI), boosting mapping activities in the Indian sub-continent.

Digital Earth, an idea of a virtual globe, propagated by the then Vice-President of United States of America (USA), Al Gore in 1998 became the most effective approach to turn raw and disaggregated data into understandable, visualized information about the Earth and human influence [12]. Guo et al. (2020) summarize the key achievements to date while predicting the likely direction and future possibilities due to the revolution brought by Digital Earth. 23 types of virtual globes have been developed in the last two decades including, GE, WorldWind, Skyline Globe, GeoGlobe, and Bing Maps 3D. Crowdsourcing is an additional method of accumulating or referring to the spatial or attribute information by a user while utilizing services like Google or Apple TomTom services [13], [14]. TomTom Go navigation is observed to be highly accurate with a background of high-quality images assisting the traveler to navigate. Novel techniques have also emerged for an advanced user using the web-based platform of Google and its Google Earth Engine (GEE) service for engineering as well as scientific applications. The computations and resources used in this case are through Google servers or in the cloud using cloud computing, relieving the advance user from arranging the resources for a task or application [15]. Martin et al. (202) discuss seven learning environments and technologies including social media, massive open online courses (MOOC), special education, mobile learning, game-based learning, adaptive learning, and learning analytics [16]. The current study examines the prevailing resources with ways and means that are making the user more aware of their environments in general and the role of RS&GIS in day-to-day life of a common person.

2. METHODS

The current methodology used by a large growing user community to explore or consume a service is either by using the standalone Desktop, Mobile-based, or web-based platforms and applications. Today on the technology side, remote sensing, photogrammetry, and ground surveys are the main methods contributing data to service providers, along with internet-based tools as well as ground survey datasets in the form of basic data layers or attributes (Figure 1).

Ground control points (GCPs), rational polynomial coefficients (RPCs), and direct georeferencing are some of the common methods used for orthorectification. In this study, the Orthoimages generated from Cartosat-1 datasets, by utilizing the GCPs and RPCs are shown as an example for the execution of the orthorectification process using rational function models (RFM) for four experimental sites [3], [17]–[19]. Similarly, the orthorectification of mono images can be performed based on photogrammetric principles using GCPs and external DEM.

The service providers also adopt methods to provide both, open-source or paid services through a highly user-friendly environment, as most of the consumers are not having a formal knowledge of the technology used in the generation of these services. The entire mapping and navigation methods are thus shifting mostly on open-source platforms providing the orthoimages in the background with the user positions along with the path to reach the destination. The orthoimages are overlaid by the user position obtained through the location-

based services (LBS) using either GNSS or mobiles having input from GNSS receiver or assisted services providing location coordinates. Series of Landsat satellites, Resourcesat satellites, Sentinel satellites, and many other satellites are providing images at a good frequency or temporal resolution, which satisfies a large variety of applications from change detection to projects dealing with forestry and agricultural. Besides the coarse resolution satellite images, service providers use orthoimages based on HR/VHR satellite images such as from IKONOS and Quickbird series of satellites, for visualization over online applications. These orthoimages are also having RPCs, which can be used with GCPs for orthorectification [20]–[23]. The Google platform and open street maps are among the most used platform or services for this purpose with a requirement of added equipment for the input of coordinates on a laptop or mobile device. Earlier the same activity was conducted using toposheets and guide maps while navigation or conducting field surveys for any application.

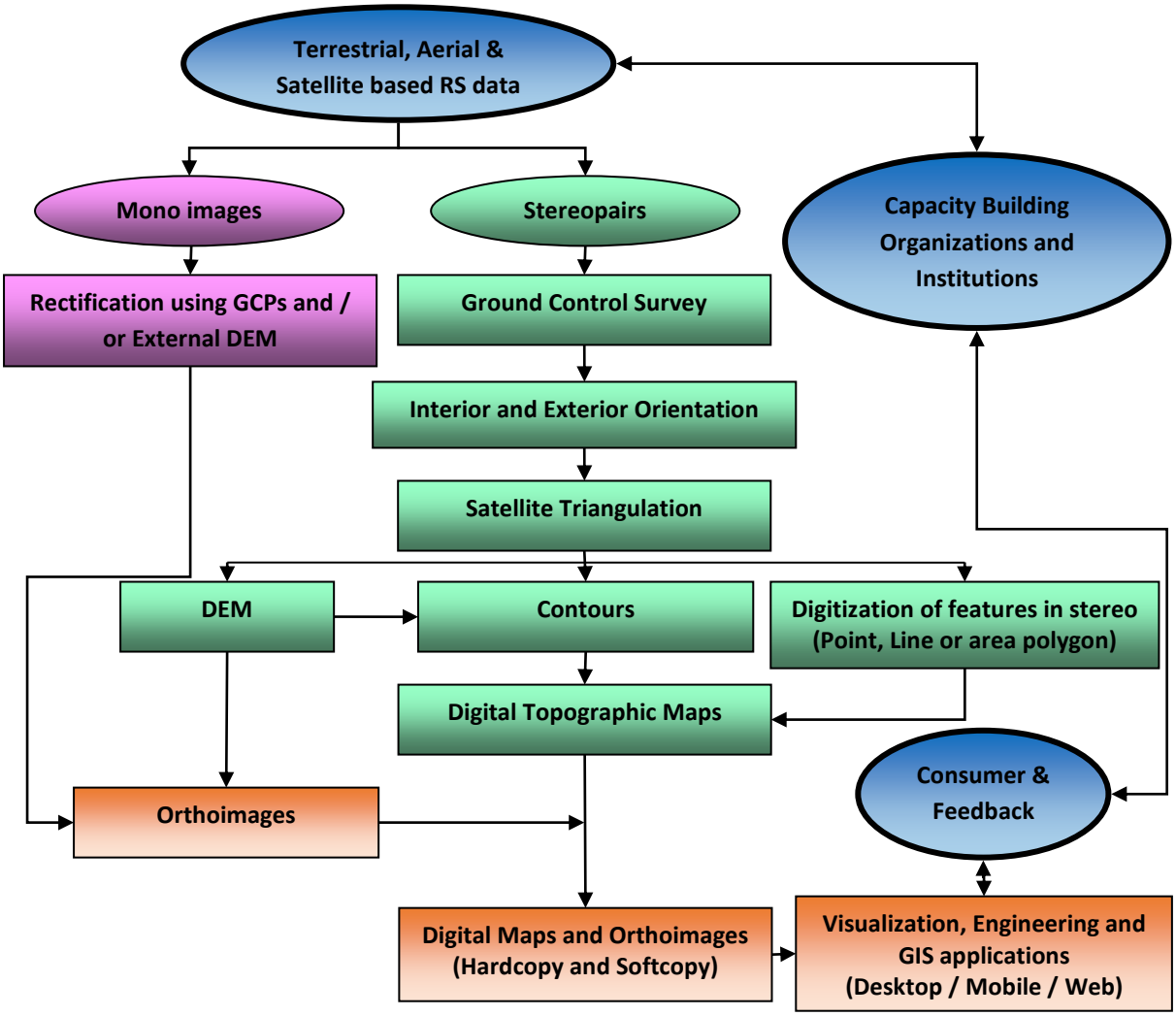

Figure 1: Methodology for Map Generation using RS&GIS and Photogrammetric procedures for consumers using different platforms such as standalone Desktop, Mobile-based or Web-based platforms or applications

The organizations and institutions involved in capacity building measures (CBMs) are playing a key role to spread education as well as awareness among both the students and the

general consumer base. The feedback from the openly accessible and commercial activity as well as the academia goes back into refining the methods of teaching as well as designing, the applications as per the convenience of the user increasing productivity while saving time. The orthoimage production needs knowledge of photogrammetric procedures and GNSS, which can be learned through the online courses on RS&GIS, photogrammetry, cartography, and GNSS. The GNSS courses include the standalone use of GNSS, differential GNSS (DGNSS) method description, procedures, and demonstrations for collecting the DGNSS field data over ground control points (GCPs) that are needed for rectification of data. Whereas, the photogrammetric courses will teach to perform aerotriangulation, satellite triangulation, DEM generation, orthoimage generation, and production of 2D or 3D maps using classic mono or stereo-environments. Similarly, GIS courses will delve into the generation of point, line, and area-based layers by the delineation of various features. Various institutions involved in CBM activities, also made available various courses under MOOC platforms, which have grown in the recent past due to lockdowns that occurred due to global pandemic COVID-19.

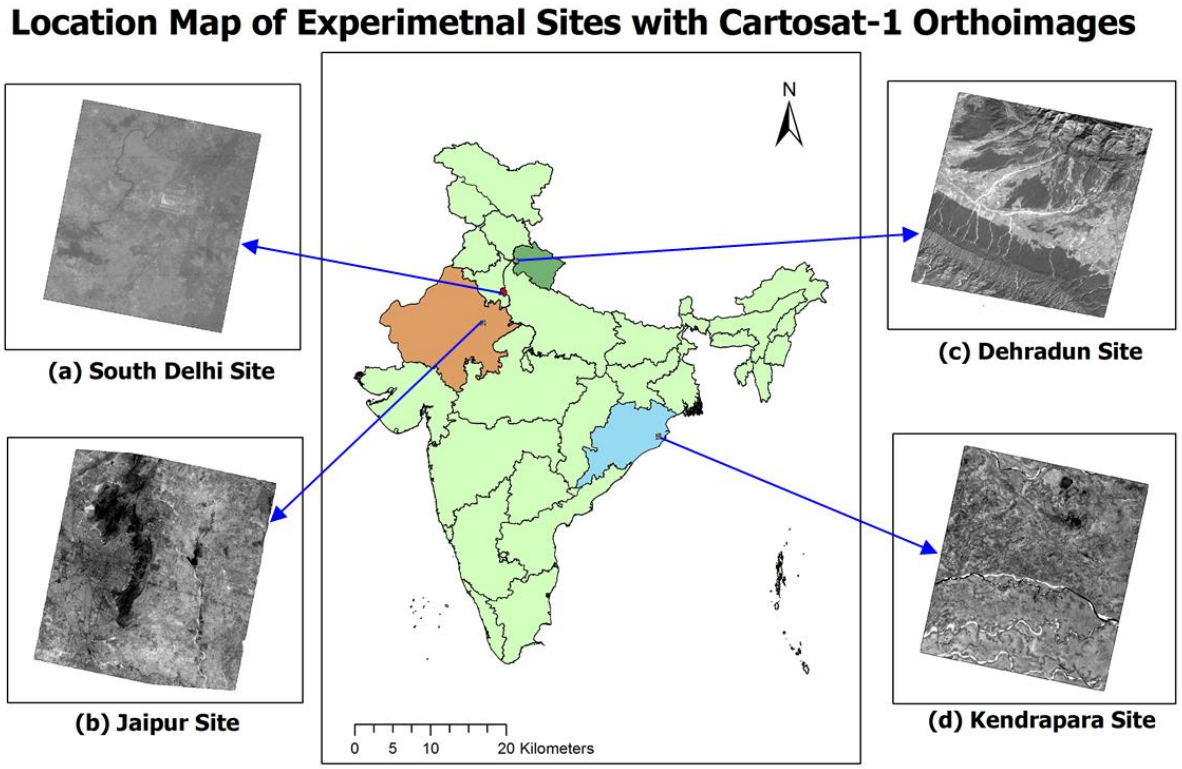

Figure 2: Orthoimages for the experimental sites in India at Dehradun, Jaipur, Kendrapara region, and Parts of South Delhi

3. RESULTS AND DISCUSSION

Figure 2, shows the orthoimages generated using Cartosat-1 stereo datasets for four of the experimental sites at Dehradun, Jaipur, Kendrapara region, and Part of Delhi. Similarly, the service provider's generate orthoimages using RS&GIS and photogrammetric methods for visualization on web-based platforms like GE and Bhuvan.

The primary result of the developments due to RS&GIS is that the consumer is using the digital platforms for meeting its needs for positioning and navigation. The mobile has become a direct source of interfacing with such applications and platforms along with quick learning because of the ease of handling of operations on handy platforms and portable devices. The user irrespective of age and educational background can use the features available in it by self-exploration or is capable of using it after bare minimum training. The convenient citizen-centric options in the digital environment like GE or Bhuvan platforms enable generation or utilization of point, line, and area-based information layers besides convenient visualization, along with the addition of more data or information into existing databases using VGI.

Online portals like the Bhuvan geo-portal have found a place among the advanced user community, who have enhanced requirements for various applications beyond navigation alone. The online courses from various institutions like the Indian Institute of Remote Sensing (IIRS), various Indian Institute of Technology (IITs), and other institutions (both government and private) have played a significant role in the capacity building of a large population as direct or indirect user community, among the general population with interest in the subject of RS&GIS. These all organizations and institutions together provide successful alternatives to use or generate maps for a variety of common users and the researcher community replacing the traditional toposheets at a relatively coarser scale of 1:50000 or guide maps at 1:10000. In the era, before the web-based maps and applications, the dependence was majorly on the toposheets at 1:50000 scale due to its generic multi-disciplinary authentic content satisfying the need for large user bases having different requirements. The orthoimages in both hardcopy and softcopy forms were found extremely useful during the conduction of the fieldwork for DGNSS surveys. The online web-based navigation services were also used extensively for reaching the planned GCP locations and were found extremely useful in saving time and effort with the optimization of the number of GCP locations covered in a day.

4. CONCLUSION

The orthoimages and GNSS have been used by a large number of users with a growing scope due to the awareness of academia and a common citizen. A citizen is becoming more and more aware of the remote sensing data and services through web-based platforms along with the CBM activities by a large growing number of institutions or social media. The current learning environment enables the user community to consume the easily available digital resources with a possibility, ways and means to consume, even generate and add more to the existing databases for personal, voluntary, or commercial activity. The developments are enabling the upliftment of the citizens in general by empowering them with timely information, helping in right as well as judicious decision making at the ground level improving the socio-economic conditions. It has become feasible for a researcher to work on complex and data-hungry problems due to the convenient availability of a large number of openly accessible data layers as well as temporal datasets, such as detailed large-scale

mapping, change detection, environmental and climate change besides the simpler problem of navigation.

5. References

[1] Y. V. N. K. Murthy *et al.*, "Capacity building for collecting primary data through crowdsourcing - An example of disaster affected Uttarakhand State (India)," *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.*, vol. XL–8, no. 1, pp. 1249–1252, 2014.

[2] A. Bhardwaj, R. S. Chatterjee, and K. Jain, "Assimilation of DEMs generated from optical stereo and InSAR pair through data fusion," *Sci. Res.*, vol. 1, no. 3, pp. 39–44, 2013.

[3] A. Bhardwaj, K. Jain, and R. S. Chatterjee, "Generation of high-quality digital elevation models by assimilation of remote sensing-based DEMs," *J. Appl. Remote Sens.*, vol. 13, no. 04, p. 1, Oct. 2019.

[4] S. Mukherjee, S. Mukherjee, A. Bhardwaj, A. Mukhopadhyay, R. D. Garg, and S. Hazra, "Accuracy of Cartosat-1 DEM and its derived attribute at multiple scale representation," *J. Earth Syst. Sci.*, vol. 124, no. 3, pp. 487–495, 2015.

[5] S. Mukherjee, A. Mukhopadhyay, A. Bhardwaj, A. Mondal, S. Kundu, and S. Hazra, "Digital Elevation Model Generation and Retrieval of Terrain Attributes using CARTOSAT-1 Stereo Data," *Int. J. Sci. Technol.*, vol. 2, no. 5, pp. 265–271, 2012.

[6] A. Bhardwaj, "Evaluation of DEM, orthoimage generated from Cartosat-1 with its potential for feature extraction and visualization," *Am. J. Remote Sens.*, vol. 1, no. 1, pp. 1–6, 2013.

[7] S. K. Srivastav *et al.*, "Evaluation of GAGAN and IRNSS Data in Himalayan Terrain," in *Second GNSS User Meet*, 2015, pp. 32–33.

[8] J. Yin, A. Lampert, M. Cameron, B. Robinson, and R. Power, "Using Social Media to Enhance Emergency Situation Awareness," *IEEE Intell. Syst.*, vol. 27, no. 6, pp. 52–59, 2012.

[9] J. Li, J. A. Benediktsson, B. Zhang, T. Yang, and A. Plaza, "Spatial Technology and Social Media in Remote Sensing: A Survey," *Proc. IEEE*, vol. 105, no. 10, pp. 1855–1864, 2017.

[10] P. Srinivas, V. R. Venkataraman, and I. Jayalakshmi, "Digital Aerial Orthobase for Cadastral Mapping," *J. Indian Soc. Remote Sens.*, vol. 40, no. 3, pp. 497–506, 2012.

[11] K. Gupta, S. John, A. Bhardwaj, P. Kumar, and A. S. Kumar, "Comparative Evaluation of Pleiades, Cartosat- 2 and Kompsat-3 Stereo Data Products for DSM and 3D Model Generation," in *38th Asian Conference on Remote Sensing - Space Applications: Touching Human Lives, ACRS 2017*, 2017.

[12] M. F. Goodchild *et al.*, "Next-generation digital earth," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 109, no. 28. National Academy of Sciences, pp. 11088–11094, 10-Jul-2012.

[13] C. Capineri *et al.*, *Handing quality in crowdsourced geographic information.* 2016.

[14] G. Huadong, M. F. Goodchild, and A. Annoni, *Manual of Digital Earth*. Springer: Springer Nature Singapore Pte Ltd, 2020.

[15] C. Dineshkumar, S. Nitheshnirmal, A. Bhardwaj, and K. N. Priyadarshini, "Phenological Monitoring of Paddy Crop Using Time Series MODIS Data," *Proceedings*, vol. 24, no. 19, p. 06205, Jun. 2019.

[16] F. Martin, V. P. Dennen, and C. J. Bonk, "A synthesis of systematic review research on emerging learning environments and technologies," *Educ. Technol. Res. Dev.*, vol.

68, no. 4, pp. 1613–1633, 2020.
[17] E. Baltsavias, S. Kocaman, D. Akca, and K. Wolff, “Geometric and radiometric investigations of Cartosat-1 data,” in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2007, vol. 36, no. 1/W51, pp. 1–13.
[18] K. Jacobsen, “ISPRS-ISRO Cartosat-1 Scientific Assessment Ptogramme (C-SAP) Technical report - test areas Mausanne and Warsaw,” in *ISPRS COM IV, GOA 2006, IAPRS, Vol. 36, Part 4*, 2006, pp. 1052--1056.
[19] P. K. Srivastava *et al.*, “Advanced studies in strip pair processing of Cartosat-1 data,” *Photogramm. Rec.*, vol. 23, no. 123, pp. 290–304, 2008.
[20] I. J. Dowman, K. Jacobsen, G. Konecny, and R. Sandau, *High resolution optical satellite imagery*. Whittles Publishing, Caithness, UK, 2012.
[21] K. Jacobsen, “Geometric potential of IKONOS- and QuickBird-images,” *Photogramm. Week*, pp. 101–110, 2003.
[22] J. Grodecki and G. Dial, “Block adjustment of high-resolution satellite images described by Rational Polynomials,” *Photogramm. Eng. Remote Sensing*, vol. 69, no. 1, pp. 59–68, 2003.
[23] C. S. Fraser, G. Dial, and J. Grodecki, “Sensor orientation via RPCs,” *ISPRS J. Photogramm. Remote Sens.*, vol. 60, no. 3, pp. 182–194, 2006.