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Accuracy Analysis of Photogrammetric UAV Image Blocks: Influence of Onboard RTK-GNSS and Cross Flight Patterns

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Keywords: self-calibration, (in)direct sensor orientation, block deformation, UAV-based RTK, cross flight pattern, sensor synchronisation

Summary: Unmanned aerial vehicles (UAV) are increasingly used for topographic mapping. Despite the flexibility gained when using those devices, one has to invest more effort for ground control measurements compared to conventional photogrammetric airborne data acquisition, because positioning devices on UAVs are generally less accurate. Additionally, the limited quality of employed end-user cameras asks for self-calibration, which might cause some problems as well. A good distribution of ground control points (GCPs) is not only needed to solve for the absolute orientation of the image block in the desired coordinate frame, but also to mitigate block deformation effects which are resulting mainly from remaining systematic errors in the camera calibration. In this paper recent developments in the UAV-hardware market are picked up: some providers equip fixed-wing UAVs with RTK-GNSS-enabled 2-frequency receivers and set up a processing pipeline which allows them to promise an absolute block orientation in a similar accuracy range as through traditional indirect sensor orientation. Besides the analysis of the actually obtainable accuracy, when one of those systems is used, we examine the effect different flight directions and altitudes (cross flight) have onto the bundle adjustment. To this end two test areas have been prepared and flown with a fixed-wing UAV. Results are promising: not only the absolute image orientation gets significantly enhanced when the RTK-option is used, also block deformation is reduced. However, remaining offsets originating from time synchronization or camera event triggering should be considered during flight planning. In flat terrain a cross flight pattern helps to enhance results because of better and more reliable self-calibration.

Zusammenfassung: Genauigkeitsuntersuchung von photogrammetrischen UAV-Bildverbänden: Einfluss von onboard RTK-GNSS und Kreuzfliegermustern. Flugroboter (unmanned aerial vehicles, UAV) werden zunehmend zur topographische Kartierung eingesetzt. Die Systeme weisen eine hohe Flexibilität auf, jedoch muss im Gegensatz zu konventionellen Befliegungen mehr Aufwand in die Erfassung von Kontrollpunkten am Boden investiert werden. Der Grund dafür liegt in der schlechteren Qualität der Positionierungslösungen auf dem Flugroboter. Hinzu kommt, dass die verwendeten Kameras eine unbekannte geometrische Stabilität haben, und die Parameter der inneren Orientierung normalerweise nicht hinreichend genau fixiert sind. Die Folge ist, dass eine Selbstkalibrierung im Rahmen der Bündelausgleichung durchgeführt werden muss. Diese Selbstkalibrierung ist nicht in jedem Anwendungsfall zuverlässig. Eine gute Verteilung von Kontrollpunkten ist nicht nur für die Bestimmung der Lagerung des Bildverbandes notwendig sondern auch um Blockdeformationen zu verringern. Diese entstehen größtenteils durch bei der Kamerakalibrierung verbliebene systematische Fehler. In diesem Beitrag greifen wir aktuelle Entwicklungen im UAV-Markt auf: einige Hersteller rüsten ihre Geräte mit einem RTK-fähigen 2-Frequenz-GNSS-Empfänger aus und bieten einen entsprechenden Prozessierungsablauf

Accuracy Analysis Of Photogrammetric Uav Image Blocks

Phillip A. Laplante



Accuracy Analysis Of Photogrammetric Uav Image Blocks:

UAV Photogrammetry and Remote Sensing Fernando Carvajal-Ramírez, Francisco Agüera-Vega, Patricio Martínez-Carricondo, 2021-09-06 The concept of remote sensing as a way of capturing information from an object without making contact with it has until recently been exclusively focused on the use of Earth observation satellites The emergence of unmanned aerial vehicles UAV with Global Navigation Satellite System GNSS controlled navigation and sensor carrying capabilities has increased the number of publications related to new remote sensing from much closer distances Previous knowledge about the behavior of the Earth's surface under the incidence of different wavelengths of energy has been successfully applied to a large amount of data recorded from UAVs thereby increasing the spatial and temporal resolution of the products obtained More specifically the ability of UAVs to be positioned in the air at pre-programmed coordinate points to track flight paths and in any case to record the coordinates of the sensor position at the time of the shot and at the pitch yaw and roll angles have opened an interesting field of applications for low altitude aerial photogrammetry known as UAV photogrammetry In addition photogrammetric data processing has been improved thanks to the combination of new algorithms e.g. structure from motion SfM which solves the collinearity equations without the need for any control point producing a cloud of points referenced to an arbitrary coordinate system and a full camera calibration and the multi-view stereopsis MVS algorithm which applies an expanding procedure of sparse set of matched keypoints in order to obtain a dense point cloud The set of technical advances described above allows for geometric modeling of terrain surfaces with high accuracy minimizing the need for topographic campaigns for georeferencing of such products This Special Issue aims to compile some applications realized thanks to the synergies established between new remote sensing from close distances and UAV photogrammetry

Remote Sensing of Geomorphology, 2020-04-20 Remote Sensing of Geomorphology Volume 23 discusses the new range of remote sensing techniques lidar structure from motion photogrammetry advanced satellite platforms that has led to a dramatic increase in terrain information and as such provided new opportunities for a better understanding of surface morphology and related Earth surface processes As several papers have been published including paper reviews and special issues on this topic this book summarizes the major advances in remote sensing techniques for the analysis of Earth surface morphology and processes also highlighting future challenges Useful for MSc and PhD students this book is also ideal for any scientists that want to have a single volume guideline to help them develop new ideas In addition technicians and private and public sectors working on remote sensing will find the information useful to their initiatives

Unmanned Aerial Remote Sensing David R. Green, 2020-07-10 Unmanned Aircraft Systems UAS are a rapidly evolving technology with an expanding array of diverse applications In response to the continuing evolution of this technology this book discusses unmanned aerial vehicles UAVs and similar systems platforms and sensors as well as exploring some of their environmental applications It explains how they can be used for mapping monitoring and modeling a wide variety of different

environmental aspects and at the same time addresses some of the current constraints placed on realizing the potential use of the technology such as s flight duration and distance safety and the invasion of privacy etc Features of the book Provides necessary theoretical foundations for pertinent subject matter areas Introduces the role and value of UAVs for geographical data acquisition and the ways to acquire and process the data Provides a synthesis of ongoing research and a focus on the use of technology for small scale image and spatial data acquisition in an environmental context Written by experts of the technology who bring together UAS tools and resources for the environmental specialist Unmanned Aerial Remote Sensing UAS for Environmental Applications is an excellent resource for any practitioner utilizing remote sensing and other geospatial technologies for environmental applications such as conservation research and planning Students and academics in information science environment and natural resources geosciences and geography will likewise find this comprehensive book a useful and informative resource

New Developments and Environmental Applications of Drones Tomi Westerlund, Jorge Peña Queralta, 2024-01-17 This volume presents the conference proceedings from FinDrones 2023 The book highlights recent drone technology developments by experts and academicians for applications in agriculture forestry and other industries This iteration of FinDrones presents research using autonomous drones in various fields from environmental monitoring to farm robotics and from photogrammetry to search and rescue missions Emphasis is placed on contextualizing the conference presentations and content to Finland and the unique challenges typical to the region The work will interest academicians entrepreneurs and professionals involved in remote sensing applications of unmanned aerial vehicles and enthusiasts of drone technological developments

Unmanned Aerial Systems for Monitoring Soil, Vegetation, and Riverine Environments Salvatore Manfreda, Ben Dor Eyal, 2023-01-18 Unmanned Aerial Systems for Monitoring Soil Vegetation and Riverine Environments provides an overview of how unmanned aerial systems have revolutionized our capability to monitor river systems soil characteristics and related processes at unparalleled spatio temporal resolutions This capability has enabled enhancements in our capacity to describe water cycle and hydrological processes The book includes guidelines technical advice and practical experience to support practitioners and scientists in increasing the efficiency of monitoring with the help of UAS The book contains field survey datasets to use as practical exercises allowing proposed techniques and methods to be applied to real world case studies Includes a summary of technical UAS issues allowing readers to focus on how the exact technology fits their scientific question Provides specific applications enabling readers to understand the benefits and threats within the field Includes a comprehensive literature review in each chapter allowing readers to know the key players and research in the field

The Need for a High-Accuracy, Open-Access Global Digital Elevation Model Guy Jean-Pierre Schumann, Paul Bates, 2020-12-31 This eBook is a collection of articles from a Frontiers Research Topic Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series they are collections of at least ten articles all centered on a particular subject With their unique mix of varied

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Applications of Small Unmanned Aircraft Systems J.B. Sharma, 2019-10-18 Advances in high spatial resolution mapping capabilities and the new rules established by the Federal Aviation Administration in the United States for the operation of Small Unmanned Aircraft Systems sUAS have provided new opportunities to acquire aerial data at a lower cost and more safely versus other methods A similar opening of the skies for sUAS applications is being allowed in countries across the world Also sUAS can access hazardous or inaccessible areas during disaster events and provide rapid response when needed Applications of Small Unmanned Aircraft systems Best Practices and Case Studies is the first book that brings together the best practices of sUAS applied to a broad range of issues in high spatial resolution mapping projects Very few sUAS pilots have the knowledge of how the collected imagery is processed into value added mapping products that have commercial and or academic import Since the field of sUAS applications is just a few years old this book covers the need for a compendium of case studies to guide the planning data collection and most importantly data processing and map error issues with the range of sensors available to the user community Written by experienced academics and professionals this book serves as a guide on how to formulate sUAS based projects from choice of a sUAS flight planning for a particular application sensors and data acquisition data processing software mapping software and use of the high spatial resolution maps produced for particular types of geospatial modeling Features Focus on sUAS based data acquisition and processing into map products Broad range of case studies by highly experienced academics Practical guidance on sUAS hardware sensors and software utilized Compilation of workflow insights from expert professors and professionals Relevant to academia government and industry Positional and thematic map accuracy UAS curriculum development and workflow replicability issues This book would be an excellent text for upper level undergraduate to graduate level sUAS mapping application courses It is also invaluable as a reference for educators designing sUAS based curriculum as well as for potential sUAS users to assess the scope of mapping projects that can be done with this technology *Methods and Applications of Geospatial Technology in Sustainable Urbanism* Tenedório, José António, Estanqueiro, Rossana, Henriques, Cristina Delgado, 2021-04-09 While megacities are a reality so too are the environmental disturbances that they cause including air and water pollution These disturbances can be modeled with technology and data obtained by modern methods such as by drone to monitor cities in near real time as well as help to simulate risk situations and propose future solutions These solutions can be inspired by the theoretical principles of sustainable urbanism *Methods and Applications of Geospatial Technology in Sustainable Urbanism* is a collection of innovative research that combines theory and practice on analyzing urban environments and applying sustainability principles to them Highlighting a wide range of topics including geographic

information systems internet mapping technologies and green urbanism this book is ideally designed for urban planners public administration officials landscape analysts geographers engineers entrepreneurs academicians researchers and students

Computational Science and Its Applications - ICCSA 2019 Sanjay Misra, Osvaldo Gervasi, Beniamino Murgante, Elena Stankova, Vladimir Korkhov, Carmelo Torre, Ana Maria A.C. Rocha, David Taniar, Bernady O. Apduhan, Eufemia Tarantino, 2019-06-28 The six volumes LNCS 11619 11624 constitute the refereed proceedings of the 19th International Conference on Computational Science and Its Applications ICCSA 2019 held in Saint Petersburg Russia in July 2019 The 64 full papers 10 short papers and 259 workshop papers presented were carefully reviewed and selected from numerous submissions The 64 full papers are organized in the following five general tracks computational methods algorithms and scientific applications high performance computing and networks geometric modeling graphics and visualization advanced and emerging applications and information systems and technologies The 259 workshop papers were presented at 33 workshops in various areas of computational sciences ranging from computational science technologies to specific areas of computational sciences such as software engineering security artificial intelligence and blockchain technologies

Earth Observation Applications to Landslide Mapping, Monitoring and Modeling Viorel Ilinca, Zenaida Chitu, Ionuț Șandric, 2024-11-14 Earth Observation Applications to Landslide Mapping Monitoring and Modelling Cutting edge Approaches with Artificial Intelligence Aerial and Satellite Imagery focuses on the applications of drone and satellite imagery for mapping landslides Topics covered include the use of ultra high aerial imagery obtained with drones for mapping and predicting landslide activity like runoff volume displacement exposure to risk etc Subjects related to EO data assimilations into landslide hazard prediction models are also included The primary aim of this book is to advance the scientific understanding and application of technologies to address a variety of fields related to landslide mapping and monitoring Because of the intensification of the catastrophic events in the last 20 years landslide monitoring gained considerable interest from the geoscience community This book will be beneficial for the postgraduates PhD research scholars professors and scientists geospatial experts modelers oceanography scientists and conservation communities environmental consultants big data compilers and computing experts Recent developments in landslide monitoring and mapping algorithms Provides clear and detailed case studies and methods that can be easily replicated and implemented in landslide monitoring systems Provides detailed methods for applying research to landslide monitoring and mapping

UAV Sensors for Environmental Monitoring Felipe Gonzalez Toro, Antonios Tsourdos, 2018-03-05 This book is a printed edition of the Special Issue UAV Sensors for Environmental Monitoring that was published in Sensors

Asia-Pacific Forest Sector Outlook: Innovative forestry for a sustainable future Pingault, N., Roshetko, J.M., Meybeck, A. (eds.), 2021-11-05 Young students and people formally or informally engaged in the forest sector will be the guardians and managers of tomorrow's forests Technology savvy the youth can play an instrumental role in the uptake and scaling up of innovative technologies whether digital

technologies biological technologies technical innovations on processes and products or innovative finance and social innovations able to advance sustainable development in the forest sector in the region Young people can bring in the innovation debate forward looking perspectives and out of the box thinking This is why FAO and CIFOR FTA decided to strengthen their voice in the debate relaying their experiences and propositions for sustainable innovation in the forest sector This FAO and CIFOR co publication gathers 13 youth contributions carefully selected These contributions illustrate in various contexts the potential of innovative technologies to advance sustainable forestry and sustainable forest management in the Asia Pacific region *Geomatics and Geospatial Technologies* Enrico Borgogno-Mondino, Paola Zamperlin, 2022-01-18 This volume constitutes selected papers presented at the 24th Italian Conference on Geomatics and Geospatial Technologies ASITA 2021 held as five sessions taking place between 1 and 23 July 2021 Due to the COVID 19 pandemic the conference was held online The 28 papers were thoroughly reviewed and selected from 139 submissions They are organized in topical sections on remote sensing applications geomatics and natural hazards geomatics for cultural heritage and natural resources sensors performance and data processing geomatics and land management **UAV-Based Remote Sensing Volume 2**

Felipe Gonzalez Toro, Antonios Tsourdos, 2018-04-27 This book is a printed edition of the Special Issue UAV Based Remote Sensing that was published in *Sensors* *Advances in Unmanned Aerial Vehicles - Technology and Applications - Big Issues Solved with Drone Technology* Antoni Grau, Rodrigo Munguia, 2025-09-03 In your hands you hold a book that will be of great help in understanding and demystifying Unmanned Aerial Vehicles UAVs those robots that for many are nothing more than flying machines Here you will discover that behind these mysterious devices lies highly advanced technology backed by years of experience which enables UAVs to fly intelligently and autonomously There are no secrets just years of development and the expertise of technologists who have joined forces to create these machines that continue to amaze us all UAVs have a wide range of applications and this book presents exemplary cases of their responsible use in environmental protection and conservation across various ecosystems Flying robots offer a unique perspective one that differs from the human viewpoint giving them a special role in the beneficial use of technology Additionally general purpose applications are presented to help the reader understand how flying robots are utilized and how they can support humanity in noble and meaningful ways

UAV or Drones for Remote Sensing Applications Felipe Gonzalez Toro, Antonios Tsourdos, 2018-11-23 This book is a printed edition of the Special Issue UAV or Drones for Remote Sensing Applications that was published in *Sensors*

Applying Remote Sensing and GIS for Spatial Analysis and Decision-Making Batchi, Mouhcine, Moumane, Adil, 2024-11-01 Remote sensing and Geographic Information Systems GIS have become indispensable tools for understanding our planet's complex systems and addressing a wide range of environmental social and economic challenges With several environmental and social factors coming to a head it is important that our society utilizes every tool at its disposal in order to identify these issues and make comprehensive action plans in order to avoid negative social and environmental consequences Applying

Remote Sensing and GIS for Spatial Analysis and Decision Making offers a comprehensive exploration of the applications of remote sensing Geographic Information Systems GIS and emerging technologies in spatial analysis and decision making across various domains The book explores fundamental principles methodologies and advanced techniques pertinent to remote sensing and GIS while also discussing the integration of emerging technologies such as unmanned aerial vehicles UAVs hyperspectral imaging LiDAR machine learning and artificial intelligence AI Covering topics such as climate change modeling land resources and spatial data analysis this book is an excellent resource for researchers and academicians urban planners practitioners professionals policy makers postgraduate students and educators and more

Intelligent Systems for Crisis Management Orhan Altan, Madhu Chandra, Filiz Sunar, Tullio Joseph Tanzi, 2019-02-06

In the past several years there have been significant technological advances in the field of crisis response However many aspects concerning the efficient collection and integration of geo information applied semantics and situation awareness for disaster management remain open Improving crisis response systems and making them intelligent requires extensive collaboration between emergency responders disaster managers system designers and researchers alike To facilitate this process the Gi4DM GeoInformation for Disaster Management conferences have been held regularly since 2005 The events are coordinated by the Joint Board of Geospatial Information Societies JB GIS and ICSU GeoUnions This book presents the outcomes of the Gi4DM 2018 conference which was organised by the ISPRS URSI Joint Working Group ICWG III IVa Disaster Assessment Monitoring and Management and held in Istanbul Turkey on 18 21 March 2018 It includes 12 scientific papers focusing on the intelligent use of geo information semantics and situation awareness

Encyclopedia of Image Processing Phillip A. Laplante, 2018-11-08 The Encyclopedia of Image Processing presents a vast collection of well written articles covering image processing fundamentals e g color theory fuzzy sets cryptography and applications e g geographic information systems traffic analysis forgery detection Image processing advances have enabled many applications in healthcare avionics robotics natural resource discovery and defense which makes this text a key asset for both academic and industrial libraries and applied scientists and engineers working in any field that utilizes image processing Written by experts from both academia and industry it is structured using the ACM Computing Classification System CCS first published in 1988 but most recently updated in 2012

Applications of Remote Image Capture System in Agriculture Ginés García-Mateos, José Miguel Molina-Martínez, 2020-12-04 Remote image capture systems are a key element in efficient and sustainable agriculture nowadays They are increasingly being used to obtain information of interest from the crops the soil and the environment It includes different types of capturing devices from satellites and drones to in field devices different types of spectral information from visible RGB images to multispectral images different types of applications and different types of techniques in the areas of image processing computer vision pattern recognition and machine learning This book covers all these aspects through a series of chapters that describe specific recent applications of these techniques in interesting problems of

agricultural engineering

Unveiling the Magic of Words: A Review of "**Accuracy Analysis Of Photogrammetric Uav Image Blocks**"

In some sort of defined by information and interconnectivity, the enchanting power of words has acquired unparalleled significance. Their capability to kindle emotions, provoke contemplation, and ignite transformative change is truly awe-inspiring. Enter the realm of "**Accuracy Analysis Of Photogrammetric Uav Image Blocks**," a mesmerizing literary masterpiece penned by way of a distinguished author, guiding readers on a profound journey to unravel the secrets and potential hidden within every word. In this critique, we shall delve in to the book is central themes, examine its distinctive writing style, and assess its profound affect the souls of its readers.

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