Track 3: Remote Sensing and Space Exploration

Sep. 18, Room 102	
Presider: Yinnian Liu, Shanghai Institute of Technical Physics, CAS	
14:00-14:30 (Keynote)	**High-accuracy remote sensing for landing and rover missions in Lunar exploration** Xiaohua Tong, Tongji University
14:30-15:00 (Keynote)	**Minerals mapping using the AHSI data of GF-5 satellite across China** Fuping Gan, China Aero Geophysical Survey and Remote Sensing Center for Natural Resources
15:00-15:30 (Keynote)	**China ocean satellite and its application** Mingsen Lin, National Satellite Ocean Application Service
15:30-15:45	Coffee Break
Presider: Xinming Tang, Land Satellite Remote Sensing Application Center, MNR	
15:45-16:15 (Keynote)	**Development and prospect of high precision quantitative remote sensing satellites** Yaohai Dong, Shanghai Academy of Spaceflight Technology
16:15-16:45 (Keynote)	**Feasibility analysis of the scientific goals of water ice exploration in the lunar polar region** Changbin Xue, National Space Science Center of CAS
Presider: Siguan Yang, National Institute of Natural Hazards	
16:45-16:55	ESIT2022-0021-1 **Research on spectral index of soil organic matter in black soil for collaborative monitoring of multi-source hyperspectral data** Kun Shang, Land Satellite Remote Sensing Application Center, Ministry of Natural Resources of P.R.China
16:55-17:05	ESIT2022-0009-2 **Research on bathymetric inversion capability of different multispectral remote sensing images** Wei Shen, Shanghai Ocean University
17:05-17:15	ESIT2022-0005-2 **Overview of geosynchronous high-speed imager** Xia Shen, Shanghai Institute of Technical Physics, CAS

17:15-17:25	ESIT2022-0821-23 **Experimental system of life ecological science on Chinese Space Station** Fangwu Liu, Shanghai Institute of Technical Physics, CAS
17:25-18:30	Poster Session
18:30-20:30	Banquet
	Sep. 19
	Session 1: Earth remote sensing Room 103A **Presider: Liangpei Zhang, Wuhan University**
8:30-9:00 (Keynote)	**Mapping methane super-emitters in China and United States with GF5 spaceborne imaging spectrometer** Yongguang Zhang, Nanjing University
9:00-9:20 (Invited)	**Hyperspectral soil component inversion based on kubelka-munk model and deep regression network** Kun Tan, East China Normal University
9:20-9:40 (Invited)	**Multidimensional airborne SAR images fusion for land cover classification** Feng Wang, Fudan University
9:40-10:00 (Invited)	**Detection and tracking for infrared small target under sea-sky complex background** Chuanmin Zhang, Xi'an Jiaotong University
10:00-10:15	Coffee Break
	Presider: Chenzhou Xiao, Land Satellite Remote Sensing Application Center, MNR
10:15-10:45 (Keynote)	**Technical characteristics and application analysis of wide-range thermal infrared imager** Yanhua Zhao, Beijing Institute of Space Mechanics and Electricity
10:45-11:05 (Invited)	**Intelligent hyperspectral remote sensing** Lianru Gao, Aerospace Information Research Institute, CAS
11:05-11:25 (Invited)	**Research on stray light technology of remote sensing instruments and development trends** Xinyu Li, Shanghai Institute of Technical Physics, CAS

Session 2: Ocean Remote Sensing Room 103B Presider: Junwu Tang, Pilot National Laboratory for Marine Science and Technology (Qingdao)	
8:30-9:00 (Keynote)	**Satellite retrieval of benthic reflectance by combining lidar and passive high-resolution imagery** Xianqiang He, Second Institute Of Oceanography,MNR
9:00-9:30 (Keynote)	**Progress in remote sensing of phytoplankton in coastal oceans** Feng Shen, East China Normal University
9:30-9:50 (Invited)	**Discussion on data Chinese HY-1 series satellite data processing** Liqiao Tian, Wuhan University
9:50-10:10	Coffee Break
Presider: Xianqiang He, Second Institute Of Oceanography, MNR	
10:10-10:30 (Invited)	**The Requirements of 3D remote sensing for upper ocean and Profiling Lidar Technology** Junwu Tang, Pilot National Laboratory for Marine Science and Technology (Qingdao)
10:30-10:50 (Invited)	**Ultra-Violet imagen(UVI) of haiyang-1C/D satellites and their in-orbit status** Deyi Yin, Shanghai Institute of Technical Physics, CAS
10:50-11:10 (Invited)	**Oil spills situation in China Seas revealed by the national ocean color satellites** Yingcheng Lu, Nanjing University
11:10-11:20	ESIT2022-0124-1 **Reconstruction of sea surface temperature data from Sea satellite observation based on convolutional automatic encoder** Yuheng Li, PIESAT International Information Technology Limited

Session 3: Space exploration Room 106A Presider: Xiaopeng Hao, National Institute of Metrology	
8:30-9:00 (Keynote)	**Research progress of key measurement system for spaceborne gravitational wave detection** Zhi Wang, Changchun Institute of Optics,Fine Mechanicsand Physics, CAS
9:00-9:20 (Invited)	**SpectrumSpace optical remote sensing payload technology with high time efficiency:Geometry and Spectrum** Lei Zhang, Xidn University

9:20-9:40 (Invited)	**Bridging tectonic evolution and geological topography on extraterrestrial planets** Haifeng Zhao, Technology and Engineering Center for Space Utilization, CAS
9:40-10:00 (Invited)	**Image and spectrum cooperative detection technology and application** Qiuju Yang, Shanghai Institute of Technical Physics, CAS
10:00-10:15	Coffee Break
Presider: Liu Zhang, Jilin University	
10:15-10:35 (Invited)	**Research progress of hyperspectral radiance temperature standard of infrared remote sensing** Xiaopeng Hao, National Institute of Metrology
10:35-10:55 (Invited)	**Current research status and technical challenges in optoelectronic detection of the jupiter system** Meizhu Wang, Shanghai Institute of Technical Physics, CAS
10:55-11:05	ISIT2022-0820-10 **Near-infrared spectral characteristics and composition analysis of impact craters near the Chang'E-5 landing site** Hui-jie Han, Nanhang Academy of Intelligent Sensing
11:05-11:15	ISIT2022-0826-9 **Test of a 15–20K Stirling/pulse tube hybrid refrigerator for space applications** Kongkuai Ying, Shanghai Institute of Technical Physics, CAS
Session 4: Atmospheric remote sensing Room 1068 Presider: Peng Zhang, Innovation Center for FengYun Meteorological Satellite (FYSIC)	
8:30-9:00 (Keynote)	**Introduction to FY-3 polar-orbiting satellite and application** Xiuqing He, National Satellite Meteorological Center
9:00-9:20 (Invited)	**Quantitative hyperspectral detection technology** Mingjian Gu, Shanghai Institute of Technical Physics, CAS
9:20-9:40 (Invited)	**Application of satellite-gauge merged precipitation products in distributed hydrological modeling** Huiling Yuan, Nanjing University
9:40-10:00 (Invited)	**FY-4B/GIIRS performance after one year on orbit** Lu Lee, National Satellite Meteorological Center

10:00-10:15	Coffee Break
Presider: Lei Ding, Shanghai Institute of Technical Physics, CAS	
10:15-10:35 (Invited)	**Calibration performance assessment of infrared bands of Fengyun-4A/AGRI and its impact on cloud top properties retrieval** Min Min, Sun Yat-sen University
10:35-10:55 (Invited)	**Atmospheric wind field near-infrared remote sensing technology** Tingyu Yan, Chengdu University of Information Technology
10:55-11:05 (Invited)	**FY-3E/HIRAS-II On-orbit performance and future mission** Chengli Qi, National Satellite Meteorological Center
11:05-11:15	ESIT2022-0822-15 **The uncertainty of SNO cross-calibration for satellite infrared channels** Zhong Gu, Chinese Academy of Meteorological Sciences
11:15-11:25	ESIT2022-0804-4 **Research progress of cloud remote sensing technology based on terahertz radiometer** Lei Liu, National University of Defense Technology
Sep. 19, Room 102 Presider: Peijun Du, Nanjing University Mingjian DU, Shanghai Institute of Technical Physics, CAS	
13:30-13:40	ESIT2022-0714-1 **Tensorial polarimetric-spectral multi-view subspace clustering for urban targets using imaging spectropolarimeter** Zhenge Chen, Xi'an Jiaotong University
13:40-13:50	ESIT2022-0820-7 **Development of multi-stage Stirling type pulse tube cryocooler below 20 K in SITP, CAS** Yin Wang, Shanghai Institute of Technical Physics,CAS
13:50-14:00	ESIT2022-0905-1 **Design and verification of partitional thermal control for space CMOS electric cabinet** Jicai Rui, Shanghai Aerospace Control Technology Institute
14:00-14:10	ESIT2022-0808-6 **A false alarm space target detection method based on star information** Haijin Zhou, Beijing Institute of Space Mechanics and Electricity
14:10-14:20	ESIT2022-0810-5 **An unsupervised symmetric tensor network for change detection in multitemporal hyperspetrcal images** Zhao Chen, Donghua university

14:20-14:30	ESIT2022-0819-2 **Research on real-time co-phasing positioning system of segmented mirrors** Zinao Yin, Shanghai Institute of Technical Physics, Chinese Academy of Sciences
14:30-14:40	ESIT2022-0812-7 **An in-orbit real-time blind pixel detection method capable for infrared small target detection** Shuliu Dong, Beijing Institute of Space Mechanics&Electricity
14:40-14:50	ESIT2022-0719-1 **Research on the key technology of martian atmospheric wind field interference imaging** Yangang Wang, Xi'an Jiaotong University
14:50-15:00	ESIT2022-0818-19 **Probabilistic analysis and evaluation of classical line error band models of c-band, G-band, and standard deviation band** Lejingyi Zhou, Tongji University
15:00-15:10	ESIT2022-0812-18 **Superpixel-based spatial weighted sparse nonnegative tensor factorization unmixing algorithm** Ningyuan Zhang, Nanchang Institute of Technology
15:10-15:25	Coffee Break
	Presider: Jun Wei, Shanghai Institute of Technical Physics, CAS Chengtao Xue, National Space Science Center, CAS
15:25-15:35	ESIT2022-0821-19 **Research on spectral index of soil organic matter in black soil for collaborative monitoring of multi-source hyperspectral data** Chen Zhuohao, Shanghai Institute of Technical Physics, CAS
15:35-15:45	ESIT2022-0815-20 **Parameter setting and analysis for the artificial potential functions in the application of small body celestial bodies landing trajectory planning** Lehou Sun, Tongji University
15:45-15:55	ESIT2022-0823-3 **Infrared small target detection based on feature pyramid structure and multilayer feature fution Network** Dandan Li, Shanghai Institute of Technical Physics, CAS
15:55-16:05	ESIT2022-0829-1 **Application of 3D printed titanium alloy lattice structure in high resolution space camera** Yongwei Wu, Beijing Institute of Mechanics & Electricity
16:05-16:15	ESIT2022-0822-9 **High diffractive efficiency electron beam convex blazed grating** Minglang Yao, Nantong Academy of Intelligent Sensing
16:15-16:25	ESIT2022-0820-5 **Cloud detection method of remote sensing image based on improved U-Net Algorithm** Yuanyuan Jia, Shanghai Institute of Technical Physics,CAS
16:25-16:35	ESIT2022-0816-4 **Reconstruction of Bennu asteroid high precision shape model based on keypoints matching using the OSIRIS-REx scanning Laser Altimeter** Song Feng, Tongji University

16:35-16:45	ESIT2022-0619-1 **A rapid star identification algorithm based on radial feature and angular distance between multiple stars.** He Liu, Jilin University
16:45-16:55	ESIT2022-0606-2 **Design and implementation of space target detection camera based on CMOS sensor** Xin Li, Beijing Institute of Space Mechanics & Electricity
16:55-17:05	ESIT2022-0622-10 **Spatial resolution matching of radiometer using convolutional neural networks** Weibing Hu, Beijing Institute of Technology
17:05-17:15	ESIT2022-0606-3 **A CMOS sensor automatic gain adjustment algorithm** Niu Nan, Beijing Institute of Mechanics & Electricity
17:15-17:25	ESIT2022-0612-8 **Unmanned aerial vehicle hyperspectral imaging system monitors urban river water quality** Li Lan, Shanghai Institute of Technical Physics CAS
17:25-17:35	ESIT2022-0621-9 **Long-term monitoring of Fengyun-4A AGRI infrared radiometric calibration** Wan Hui, National Satellite Meteorological Center, CMA Innovation Center for FengYun Meteorological Satellite (FYSIC)

High-accuracy remote sensing for landing and rover missions in Lunar exploration

Xiaohua Tong
Tongji University

This talk addressed high-accuracy remote sensing for landing site pre-selection, for real-time landing obstacle avoidance and for rover navigation and positioning, which consists of three main components as follows. (1) Precise landing site pre-selection for Lunar regions featured with poor illumination, complex topography and the existence of Permanently Shadowed Region (PSR). We produced high-resolution digital surface model of Lunar south pole above 89°, with a resolution of 1.5m/pixel, a 5-m resolution illumination map covering the area above 89 degrees of the lunar south pole, and a 1.5-m resolution illumination map covering the ridge connecting the de Gerlache crater and the Shackleton crater as a specially ROI. (2) The hazardous obstacle avoidance of spacecraft is important to ensure the accuracy of real-time landing control. We proposed two remote sensing detection approaches for hazard avoidance in soft landing mission: larger hazard detection with optical imaging, and precise hazard detection laser imaging. (3) Long distance visual positioning is vital for lunar rover. A double optimizing incremental bundle adjustment method was proposed for stereo vision localization, and a relative error of 4‰ was achieved in the distance trajectory of 3.5km

Invited

Minerals mapping using the AHSI data of GF-5 satellite across China

Fuping Gan
China Aero Geophysical Survey and Remote Sensing Center for Natural Resources

China Ocean Satellite and its application

Mingsen Lin
National Satellite Ocean Application Service

In recent years, China's ocean satellites and satellite ocean remote sensing have made great progress. The development of China's series of ocean satellites has become the main data source of space-based information for global stereo observation in China. This paper introduces the development and application of ocean satellites in China, summarizes the achievements and challenges of ocean remote sensing in China, and focuses on the latest research and operational application results of ocean satellite data in the fields of marine disaster prevention and mitigation, marine environment prediction, marine resource development, marine safety, marine scientific research and so on.

Development and prospect of high precision quantitative remote sensing satellites

Yaohui Dong
Shanghai Academy of Spaceflight Technology

Invited

Full process design and simulation technology of deep space exploration scientific payload based on MBSE

Changbin Xue
National Space Science Center of CAS

Focusing on the overall development needs of China's deep space exploration program, and in light of the problems faced by detection missions, such as the great challenge of program design optimization and the difficulty of developing long-life/low-power payloads, conducting research on the whole-process design and simulation technology of deep space exploration payloads based on MBSE, forming model specifications, develop digital and physical prototypes of typical scientific payloads, building the process management and simulation verification platform, forming the design and simulation capability of the whole process of payloads from exploration mission analysis, program design, system design, payload development and integration to in-orbit operation, and providing support means for China's deep space exploration This will provide support means for the overall design and analysis of China's deep space exploration program.

Mapping methane super-emitters in China and United States with GF5 spaceborne imaging spectrometer

Yongguang Zhang
Nanjing University

Hyperspectral Soil Component Inversion based on Kubelka-Munk model and Deep Regression Network

Kun Tan
East China Normal University

Soil is an essential natural resource for human production and life, which plays a crucial role in human survival and development. The research of soil composition inversion based on the hyperspectral remote sensing technology mainly relies on the traditional statistical learning method, which still has many problems, such as unknown sensitive wavebands and the lack of inversion mechanism, overfitting phenomenon under small sample data and lack of physical model-based spectral correction models for removal of soil composition interference factors. Oriented to the mechanical deficiencies of soil organic matter inversion, the theoretical of Kubelka-Munk theory is explored and introduced in this article to obtain the spectral characteristics of soil organic matter with high generalization capability.

Multidimensional Airborne SAR Images Fusion for Land Cover Classification

Feng Wang
Fudan University

With the development of Synthetic Aperture Radar (SAR) imaging and deep learning, the use of deep learning to classify land cover in SAR images has received extensive attention and applied research. A high-resolution airborne multi-dimensional SAR land cover classification dataset is constructed based on the high-resolution airborne data of the Chinese Aeronautic Remote Sensing System (CARSS) for Earth observation. It contains polarization

SAR images in bands of C, Ka, L, P, and S and high-resolution optical images. Land cover objects are divided into water, bare soil, road, industry, vegetation, residence, planting area, farms, and other. Secondly, we use the method of semantic segmentation to perform land cover classification verification on this dataset. And the multi-dimensional SAR is fused and classified through different fusion strategies. The final fusion methods outperform the single-band in the performance of SAR land cover classification.

Detection and tracking for infrared small target under sea-sky complex background

Chunmin Zhang
Xi'an Jiaotong University

As countries pay more attention to the jurisdictional defense of maritime and aerospace fields, the detection and tracking for infrared small targets under sea-sky complex background have played an important role in improving maritime defense capabilities. Based on the radiation difference between the target and the background in the infrared band, this study detects and tracks small targets including long-distance ships and aircrafts. Aiming at the problems of insufficient local and non-local feature extraction and imbalance of accuracy and real-time performance in existing methods, a fast single-frame detection algorithm for small infrared targets based on tensor correlation enhancement and local visual saliency prior is proposed. Besides, we proposed a tracking model using conditional probability. Results on several datasets show good results in detection rate, false alarm rate and running time, which is of great significance in maintaining the safety of ship navigation, realizing maritime monitoring, early warning and defending against attacks.

Technical Characteristics and Application Analysis of Wide-Range Thermal Infrared Imager

Yunhua Zhao[1,2]
1.Beijing Institute of Space Mechanics & Electricity
2.Beijing Key Laboratory of Advanced Optical Remote Sensing Technology

Thermal infrared remote sensing can obtain the radiant brightness temperature of ground objects day and night, which provides basic data for quantitative applications such as surface temperature and evapotranspiration, and plays an important role in the field of optical remote sensing. In order to improve the observation efficiency of long-wave infrared remote sensing, after many years of advance research, engineering development and validation, the specifications of thermal infrared optical instrument reaches the international advanced level. By configuring a scanning mirror with 360° rotating angle and uniform speed in front of a small f-number optical lens, and a high-sensitivity and long linear TDI long-wave detector integrating four bands, wide-range thermal infrared imager realizes the spatial resolution of 100m, NEΔT better than 0.1K, and swath larger than 1500km. The temperature stability of the two large radiation area blackbody with temperature difference of 21°C is ±20mK/25min, which guarantee high precision radiometric calibration and quantitative application in orbit. The instrument can cover most of the regions in China in one day and the whole earth in two days, which will greatly improve the application efficiency of thermal infrared remote sensing data. The data of imager will provide strong support for thermal pollution discharge monitoring, environmental assessment of nuclear power plants, water temperature monitoring of key rivers and lakes/coastal areas, drought monitoring, fire monitoring.

Invited

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Intelligent Hyperspectral Remote Sensing

Lianru Gao
Aerospace Information Research Institute, CAS

The intelligent hyperspectral remote sensing (IHRS) is a new perspective for an Earth Observation (EO) satellite system. The technical design of IHRS will include the following characteristics: 1) a fore-field pre-judgment sensor for regional background information acquisition, which will enforce the capacity of the system to adapt to different scenarios and problems; 2) an advanced and adjustable hyperspectral sensor, which will be able to provide detailed surface observations using optimum data acquisition parameters; and 3) an onboard real-time data processing and analysis subsystem, with the capacity to provide real-time remote sensing products. Moreover, some adaptive methods also should be considered in hyperspectral image information extraction, such as dimensionality reduction, image classification, spectral unmixing, and target detection.

Research on stray light technology of remote sensing instruments and development trends

Xuyao Li
Shanghai Institute of Technical Physics, CAS

The stray light is classified from different angles, the optical instruments that stray light often appears in are explained, the harm and research significance of stray light are described, and the key technical components of stray light are analyzed. On this basis, the stray light engineering process is sorted out, the principle of stray light propagation is introduced, and several stray light softwares are compared and analyzed. The theoretical calculation methods of indexes, such as point source transmittance,Veiling Glare Index, ghost image and instrument background radiation are described. A summary of stray light suppression designs, including classic stops, hoods, and coatings, is presented. The characteristics of stray light theoretical calculation and stray light test are compared. According to engineering experience, the development trend of stray light technology is discussed. Stray light analysis is developing in the direction of multiple mechanisms such as large aperture, low temperature, sub-millimeter scale, second-level small angle, and diffraction with the development of optical systems.

Satellite retrieval of benthic reflectance by combining lidar and passive high-resolution imagery

Xianqiang He
Second Institute of Oceanography, Ministry of Natural Resources

Under the background of global change, increasing attention has been paid to the changes of benthic habitats in shallow ocean ecosystems (e.g., seagrass beds and coral reefs). Optical satellite remote sensing via both active and passive methods plays an important role in monitoring the health of benthic habitats by retrieving benthic reflectance spectra, but it remains difficult to accurately retrieve benthic reflectance spectra from only active or passive remote sensing because of the coupling between water column scattering and benthic reflectance. Here, we developed a semi-analytical model to retrieve benthic reflectance spectra in Case-I waters by combining active lidar and passive high-resolution imagery. Based on two-stream radiative transfer theory, the analytical relationship among the remote sensing reflectance (R_rs) and water column reflectance (R_w), benthic reflectance (R_b), diffuse attenuation coefficient (K_d), and water depth was established. The lidar data at a certain wavelength were applied to derive the water depth and the chlorophyll concentration (chl) along the lidar track. Then, the values of K_d at different wavelengths were estimated from the derived chl. In addition, we established a look-up-table (LUT) for the relationship between R_w and chl and water depth using Hydrolight simulation, and the R_w values at different wavelengths were then estimated by the lidar-derived chl and water depth. Finally, R_b (λ) values at different wavelengths along the lidar track were retrieved from the R_rs (λ) values observed by passive high-resolution

imagery and the values of R_w (λ), K_d (λ), and water depth derived by lidar observation. The accuracy of the model was verified by using the Hydrolight simulated datasets, and the high correlation coefficient (R) revealed promising model performance for different benthic habitats, e.g., $R>0.9$ for typical clean shallow water (chl=0.5 mg/m^3, H=4 m) for the wavelength range of 400–640 nm. The model was further applied to real satellite data from ICESat-2 lidar and passive high-resolution satellite imagery (multispectral imagery of Sentinel-2 and hyperspectral imagery of Zhuhai-1) at two different benthic habitat sites (seagrass beds in Xincun Bay and coral reefs in the Huaguang Reef) in the South China Sea, and the results revealed that the model could reproduce the benthic spectra in both magnitude and shape. Overall, the proposed model can reliably yield benthic reflectance spectra along the lidar track without any requirement on prior knowledge, which should be beneficial for further benthic habitat health monitoring.

Progress in remote sensing of phytoplankton in coastal oceans

Fang Shen
East China Normal University

The ocean covers 71% of the earth's surface and plays an important role in the biogeochemical process of the earth, directly affecting the rate and extent of climate change. Marine phytoplankton is an important part of the marine system, which plays a vital role in the development of the marine ecosystem, ecological balance, environmental health, and even the stability of the entire earth ecosystem.

Satellite remote sensing technology has opened the era of continuous observation covering the global ocean system. Up to date, it has accumulated more than 20 years of ocean color data and generated data products of chlorophyll a concentration for global continuous observation. However, it is difficult to accurately describe phytoplankton diversity and reflect phytoplankton ecosystem by chlorophyll a concentration alone. At present, designing advanced remote sensing technology and developing new methods to retrieve the abundance distribution of phytoplankton taxonomic composition tightly linked with phytoplankton ecosystem has become an emerging research field. Our recent research involves solutions based on biogeochemistry, optics and marine-big-data based machine learning for multispectral and hyperspectral remote sensing of phytoplankton taxonomic composition.

Discussion on data Chinese HY-1 series satellite data processing

Liqiao Tian
Wuhan University

Since the 21st century, China has launched a number of ocean color missions and established an ocean satellite observation system to support ocean monitoring. In view of the key issues such as radiation calibration, atmospheric correction (AC), and ocean color parameter inversion of HY-1 satellites, 1) we conducted radiation attenuation tracking and correction research on HY-1B COCTS sensor through the radiation stable field in the South China Sea; 2) a deep learning AC method for clear waters was proposed for MODIS, and the algorithm has been applied to the AC of COCTS by transfer learning. For turbid waters, a deep learning AC algorithm for CZI was proposed based on Landsat-8 OLI SWIR AC products; 3) we developed the chlorophyll concentration inversion method of COCTS and produced chlorophyll long-time series products. We hope to fully explore the potential application value of ocean color satellites through these studies.

Invited

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The Requirements of 3D Remote Sensing for Upper Ocean and Profiling Lidar Technology

Junwu Tang
Pilot National Laboratory for Marine Science and Technology (Qingdao)

Ultra-Violet Imager (UVI) of Haiyang-1C/D Satellites and their in-orbit status

Dayi Yin
Shanghai Institute of Technical Physics, CAS

Haiyang-1(HY-1) C/D satellite Ultra-Violet Imager (HY-1C/D-UVI) as a new payload for expanding the spectral coverage of ocean color satellite remote sensing detection, improving atmospheric correction capabilities, improving the remote sensing monitoring capabilities of marine chromophoric dissolved organic matter(CDOM), providing exploratory verification means for large-scale marine oil spills and other disasters, is first use of ultraviolet detection methods to carry out marine remote sensing applications of a new type of space payload in China, comprehensive performance indicators are internationally advanced. It has the characteristics of high ultraviolet sensitivity, large swath, dual dynamic range, quantitative observation, small size and light weight. This type of detection system can ensure high UV signal-to-noise ratio and large dynamic observation requirements. HY-1C and 1D satellites formed a morning and afternoon satellite network and were successfully launched in Taiyuan on September 7, 2018 and June 11, 2020 respectively. So far, the UVI has rich levels of on-orbit images, clear detail, wide dynamic range coverage, and is in line with the expected results, and the working state is stable.

Oil spills situation in China Seas revealed by the national ocean color satellites

Yingcheng Lu
Nanjing University

Oil spill represents one of the key targets in marine environment monitoring, and satellite observation can serve as an effective technical assistance for oil spills monitoring. Haiyang-1C (HY-1C) and Haiyang-1D (HY-1D), launched on 7 September 2018 and 11 June 2020, are the first operational ocean color satellites of China. Several marine oil spill incidents in the China Seas were identified from tens of thousands of CZI images obtained from the HY-1C/D in the past three years. And the different oil types, including non-emulsified oil slicks and oil emulsions, could be distinguished by CZI. There were no less than 57 oil spills accidents accurately detected by CZI in the past three years, and more than 47 oil spills occurred in the China Seas, especially in Bohai Sea, Yellow Sea and the South China Sea. In addition, the oil spilled area and oil volume could be derived from these optical remote sensing results. The HY-1C/D satellite project works well through the in-orbit test and operational application, and the HY-1C/D has the advantages of both wide coverage and high temporal resolution, thus can satisfy the demands of the operational monitoring of marine oil spills in the China Seas.

Research progress of key measurement system for spaceborne gravitational wave detection

Zhi Wang
Changchun Institute of Optics,Fine Mechanicsand Physics, CAS

The detection of gravitational waves at mHz frequency band requires an initial reference for the spaceborne drag-free control system with unprecedented residual acceleration and a laser interferometer system that is able to detect exceptionally small spatial deviations between two reference sensors several million kilometers apart.

The report mainly introduces the research progress and follow-up planning of the key measurement system of the spaceborne gravitational wave detection mission.

Space optical remote sensing payload technology with High time efficiency,Geometry and SpectrumSpace optical remote sensing payload technology with High time efficiency,Geometry and Spectrum

Liu Zhang
Jilin University

Bridging tectonic evolution and geological topography on extraterrestrial planets

Haifeng Zhao
Technology and Engineering Center for Space Utilization, CAS

Study of geological features such as lave tube, joints, etc. of extraterrestrial planets is an important subject in planetary research. The detection of faults in Martian rocks and lunar lave tubes may reveal the evidence of habitable environments. It remains to be unclear what happened on the Moon or Mars and whether it will be habitable in future. Tectonic activities through Martian geological history have recorded numerous signatures in rocks and terrains, which are exposed at the surface. For example, in the ancient periglacial and ice-rich terrain, there are diverse geological features on the northern plain of Mars, such as wrinkles, polygons, faults and joints. These interesting features are generated through different geological stress events and thermal variations. Proposing reasonable hypotheses of tectonic evolution are the key to understand geological events corresponding to fractured morphologies. Lacking of wide-range in-situ surveys, the optical images captured by camera instruments from orbiters and rovers provide a major resource to conduct these scientific studies. Thus, the optical images combining with image recognition technique and geomechanical numerical simulation enables a new way to understand the Moon or Mars and their history.

Image and spectrum cooperative detection technology and application

Qiqie Yang
Shanghai Institute of Technical Physics, CAS

Research progress of hyperspectral radiance temperature standard of infrared remote sensing

Xiaopeng Hao
National Institute of Metrology

Aerospace infrared remote sensing technology plays an important role in obtaining global space -time information such as climate research, meteorological forecasting, and homeland security, etc. The precise and quantitative temperature is the most critical in the quantitative parameters of aerospace infrared remote sensing. This report systematically introduces the National Institute of Metrology aim at the problem of brightness temperature tracing for aerospace infrared remote sensing payload laboratory and standard blackbody on satellite in simulated aerospace environment, establishes the brightness temperature measurement standard for aerospace infrared remote sensing payload, implements a new system of brightness temperature tracing for aerospace infrared remote sens-

ing payload, reaches the leading international level, and solves the problem of high precision temperature tracing for aerospace infrared remote sensing payload in China; In allusion to the global problem that the brightness temperature of blackbody on the satellite cannot be verified after entering orbit, and in order to solve the tremendous challenge of 0.1K uncertainty of aerospace infrared radiation measurement proposed by climate change research, we should break through the key technology of micro phase change fixed point in orbit temperature calibration and emissivity in orbit measurement, realize the space reference blackbody of on orbit self calibration, and ensure the long-term effectiveness of on orbit application values. This technology will be applied to operational remote sensing satellites for the first time in the world. breaking the key technologies of the orbit temperature calibration and emissivity in orbit measurement of micro -phase transformations, realize the aerospace reference blackbody of in orbit self calibration, and ensure the long-term effectiveness of in orbit application value. This technology will be applied to operational remote sensing satellites for the first time in the world.

Invited

Current research status and technical challenges in optoelectronic detection of the Jupiter system

Meizhu Wang
Shanghai Institute of Technical Physics, CAS

Introduction to FY-3 Polar-orbiting Satellite and Application

Xiuqing Hu
National Satellite Meteorological Center

FengYun-3 (FY-3) satellites, are China's second generation polar-orbiting meteorological satellites, with substantively enhanced functionalities and technical capabilities. They are designed to enhance China's three dimensional atmospheric sounding capability and global data acquisition capability, in an effort to collect more cloud and surface characteristics data, from which meteorologists may infer out atmospheric, land surface and sea surface parameters that are global, all-weather, three-dimensional, quantitative, and multi-spectral. FY-3 series satellites have already launched five satellites since 2008 and established the ideal three-orbit system at AM, PM and EM cross the equator. The latest FY-3E is the first early obit(EM) satellite and joins two other Chinese polar-orbiting weather observatories, Fengyun 3C and Fengyun 3D, flying in mid-morning and afternoon orbits. These complete polar-orbiting constellation provide global weather measurements to feed into numerical weather prediction models at six-hour intervals and well as other unique no-weather application.

Quantitative hyperspectral detection technology

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Application of Satellite-gauge Merged Precipitation Products in Distributed Hydrological Modeling

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This study discusses the application of multiple satellite-gauge quantitative precipitation estimates (QPEs) in distributed hydrological modeling. First, the distributed Variable Infiltration Capacity (VIC) model is used to

simulate daily streamflow simulations, forced by four latest satellite-gauge QPEs, including NASA's TRMM 3B42V7, NOAAs CMORPH bias-corrected product (CMORPH CRT), CMORPH satellite-gauge merged product (CMORPH BLD) and CMORPH satellite-gauge merged product developed at China Meteorological Administration (CMA) (CMORPH CMA). Compared to the China Gauge-based Daily Precipitation Analysis (CGDPA), the four QPEs generally depict the spatial distribution well over the Huaihe River basin, while the overall streamflow pattern is well captured at multiple time scales by the simulations using these QPEs as the input forcing in the VIC model during 2003-2012. Second, hydrologic uncertainty analysis and ensemble postprocessing of streamflow simulations are conducted. Three global satellite QPEs, including TRMM 3B42V7, CMORPH BLD, and the Global Satellite Mapping of Precipitation (GSMaP) Gauge-calibrated product (GSMaP Gauge), are used to drive the VIC model over the Huaihe River basin, in which a newly developed residual error model accompanied with the Bayesian uncertainty analysis are performed. The streamflow uncertainty intervals of the three global QPEs are then merged using the Bayesian Model Averaging (BMA) method, which provides improved deterministic streamflow predictions and much more reliable probabilistic predictions, which even outperform the outcomes of the high-quality CMORPH CMA. In addition, the uncertainties associated with satellite QPEs are investigated through hydrological ensemble forecasts by adding the perturbations to the QPEs. The SREM2D (two-dimensional stochastic satellite rainfall error model) has been applied to three satellite QPEs (the TRMM/TMPA 3B42RT, CMORPH-BLD, and PERSIANN-CDR products) to generate streamflow simulations in the VIC model over the Huaihe River basin. Overall, SREM2D provides great potential to facilitate the application of satellite precipitation products in water management and decision making over Chinese river basins.

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FY-4B/GIIRS Performance after One Year on Orbit

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The Geostationary Interferometric Infrared Sounder (GIIRS) is a primary payload onboard the FengYun-4B weather satellite of China. It measures the hyperspectral atmospheric upwelling infrared radiance. With low instrument noise, high spectral resolution and thousands of spectral channels, the radiance spectra provide a critical high vertical resolution information to retrieve the atmosphere's structure of temperature and water vapor in retrieval algorithms and numerical weather prediction (NWP) models, and also supply extensive information about trace gases, surface and cloud properties for climate research. Particularly, the unique combination of the Fourier transform spectrometer and the geosynchronous satellite platform enable the GIIRS observe the successive images of moisture and clouds at different altitudes with a high temporal resolution, that will reveal the motion of small-scale thermodynamic features and trace gas features of the atmosphere. The former provides a measure of the atmospheric wind distribution, and the latter provides a measure of the transport of the pollutant and greenhouse gases.

GIIRS was launched on June 3 and the infrared detector was power-on on August 24, 2021. Up to now, this instrument has been on orbit for one year, with first eight months of post-launch calibration and validation, and following four months in quasi-operation. The instrument has a good noise performance with the overall radiance noise levels being less than 0.5 and 0.1 in milliwatts per square meter per steradian per inverse centimeter (mW/m2/sr/cm-1) for the long-wave infrared (LWIR) and mid-wave infrared (MWIR) bands. The estimated absolute spectral calibration uncertainty is less than 7 ppm in the LWIR and MWIR bands. The estimated radiometric calibration bias is about 1 K in the LWIR band and less than 1 K in the MWIR band. The instrument sensitivity and the spectral calibration accuracy are stable within the first year.

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Calibration performance assessment of infrared bands of Fengyun-4A/AGRI and its impact on cloud top properties retrieval

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This study mainly focuses on the diurnal and long-term variation characteristics of the calibration performance of the geostationary meteorological satellite Fengyun-4A/Advanced Geostationary Radiation Imager (FY-4A/AGRI) infrared channels from June 1, 2017 to December 31, 2020. An improved algorithm is developed in this research based on the *in-situ* observations from ocean drifters, which can capture the diurnal variations of the calibration performance of FY-4A/AGRI infrared channels. The results suggest that there are significant and non-negligible diurnal variations of the uncertainties and biases for the brightness temperature (TB) observed by the FY-4A/AGRI, especially the infrared channels at 3.71 **μm**, 8.61 **μm**, 10.83 **μm** and 12.07 **μm**. Among them, the calibration performance from 16:00 UTC to 18:00 UTC (around the time of local midnight at the sub-satellite point of FY-4A) is worse at 3.71 **μm**, while TB biases from 04:00 UTC to 16:00 UTC are relatively large at 12.07 **μm**. Moreover, after the operational calibration and update in June 2020, the long-term TB biases at channel 08 (3.71 **μm**) obviously decrease from about 5 K to 2.5 K, and the TB biases at channel 14 (13.54 **μm**) increase from about 0.5 K to 3 K, implying a possible positive or negative impact of the calibration update on the calibration performance of infrared channels. Besides we find some invalid retrievals in CTP product of FY-4A/AGRI is mainly due to that the radiometric calibration bias of infrared band at 13.5μm. The pixels with brightness temperature lower than 200K show a bias large than 7-8K, which directly induce the invalid retrieval process in the CTP product of FY-4A/AGRI. However, this fault in CTP also inspire us to use the invalid CTP pixel to monitor the on-orbit radiometric calibration bias of infrared band in the future.

Atmospheric wind field near-infrared remote sensing technology

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The remote sensing and scientific research of the global atmospheric wind field by optical interference technology is of great significance to human understanding of the mechanism and development of important climate phenomena such as the circulation of atmospheric materials, global climate change, and sudden stratospheric warmings. The presentation is supported by the key program of NSFC, "New principles and new technologies for stratospheric ozone and atmospheric wind field near-infrared static interference imaging detection" The key technology of static four-sectored passive Doppler wind imaging interferometry is studied. The experimental prototype and wind simulation system of the static four-sectored wind imaging interferometer was built, and the calibration experiment of the system parameters and the measurement of the wind field in the laboratory was carried out. The experiment shows the high precision real-time measurement capability of the instrument for the two-dimensional wind field.

FY-3E/HIRAS-II On-orbit Performance and Future Mission

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The FY-3E satellite was successfully launched from Jiuquan Satellite Launch Center on July 5, 2021. The Hyperspectral Infrared Atmospheric Sounding instrument was activated on October 12, 2021, and the infrared measurement started on October 13. On orbit test results show that the sensitivity and calibration accuracy were greatly improved compared with FY-3D HIRAS. the spectral calibration accuracy has been increased by 3ppm, and the medium-wave radiation calibration accuracy has been increased by 0.5K. It provides continuous spectrum and becomes the second instrument in the world after IASI in Europe that can provide continuous high spectral resolution infrared radiation in the range of 3.9~15.4 um. There was pollution gas absorption on FY-3D/HIRAS, and FY-3E/HIRAS-II has made corresponding improvements, and carried out longer time range monitoring in the ground radiation calibration phase and in-orbit test phase to verify the effectiveness of anti-pollution scheme. The problem of pollution gas absorption in FY-3D/HIRAS has been effectively solved in FY-3E/HIRAS-II. Sensitivity at all FOVs and all channels in long wave meet the requirements, all that in medium wave meet the requirements except 16 channels in the range of 1652.5~1671.25cm-1 (based on 1.25cm-1 resolution), and in short wave most the requirements except the first FOV. The spectral calibration accuracy is better than the requirement. In the future, HIRAS instruments will continue to improve in spatial resolution, spectral resolution, sensitivity and other performance specifications to support better product applications.

Invited

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Research on spectral index of soil organic matter in black soil for collaborative monitoring of multi-source hyperspectral data

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Black soil, which refers to soil with a black or dark black humus topsoil layer, is a precious soil type on earth. Black soil is a high-quality soil type with outstanding properties such as high fertility, and thus is ideal for farming. Black soil in China has shown various degrees of degeneration against long-term agricultural over-exploitation, climate change and many other reasons in recent years. Soil organic matter (SOM) is a very significant component in soil, and its content is considered to be the most essential and critical evaluation indicator of soil quality in cropland. Soil fertility can be diagnosed by monitoring SOM.

Traditional survey of black soil quality is mainly based on field soil sampling and laboratory analysis. Spatial distribution of regional soil parameters is mostly obtained through geostatistical investigation. This method can directly obtain reliable in-situ sampling data, however, its application is severely constrained by the long-period of field sampling, large time span of the collected samples, and high-cost of work labor. These are the reasons why SOM monitoring can hardly be implemented at a large scale or with a high frequency. In recent years, remote sensing technology is playing a more and more important role in black soil survey. Hyperspectral remote sensing can obtain continuous spectral curves of the surface soil, and the information of some significant physicochemical parameters of black soil can be extracted by establishing different inversion models. In recent years, China's successive satellites carrying hyperspectral sensors, such as Gaofen 5 (GF5), ZiYuan1-02D (ZY1-02D), Gaofen 5B (GF5B), and ZiYuan1-02E (ZY1-02E), have provided rich data source for the remote sensing monitoring of soil parameters in black soil, e.g., the SOM.

Therefore, it is necessary to study the SOM spectral index of black soil applicable to the collaborative monitoring of multi-source hyperspectral data, in order to achieve a rapid acquisition of large-scale distribution of black soil quality.

The data of Advanced Hyper-Spectral Imager (AHSI) onboard ZY1-02D and GF5 satellites, as well as the laboratory spectral data, were used in this study. The AHSI image has a swath width of 60 km with a 30 m ground resolution. The AHSI data of GF5 have 330 spectral bands with the spectral resolution of 5 nm for visible to near-infrared (VNIR, 0.4–1.0 μm) and 10 nm for shortwave infrared (SWIR, 1.0–2.5 μm), while the AHSI data of ZY1-02D have 166 spectral bands with the spectral resolution of 10 nm for VNIR and 20 nm for SWIR. The laboratory spectral data used in this study were measured using an ASD spectrometer, with a spectral sampling interval of 1 nm.

The study area of this research is the black soil region of northeastern China, including Heilongjiang province, Jilin province, Liaoning province and eastern Inner Mongolia. The ZY1-02D and GF5 satellite images used in this study were acquired in April 2021 and April 2019, respectively. In April 2021, 173 soil samples were collected within the ZY1-02D imaging area, covering 10 typical soil types, including black soil, chernozem, brown soil, dark brown soil, meadow soil, and albic soil. In April 2019, a total of 100 soil samples were collected within the GF5 imaging area, including black soil, albic soil, meadow soil, dark brown loam, and paddy soil.

To build the SOM spectral index of black soil applicable to multi-source hyperspectral data, three datasets are constructed by matching SOM samples to individual hyperspectral data (ZY1-02D image, GF5 image, and ASD

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spectrum).

First, the original reflectance (OR) and four types of transformed spectral reflectance of the three datasets were calculated, including Reciprocal reflectance (RR), Square root reflectance (SRR), Logarithmical reflectance (LR), First-order differential reflectance (FDR). These spectra were then analyzed to determine the SOM-sensitive bands for each of the five types of spectra.

Second, for different types of spectra, the following two-band spectral indices were calculated, Difference index (DI), Ratio index (RI), Normalized difference index (NDI) and square root index of difference (DSI). The correlation coefficients between SOM and these spectral indices were compared.

Then, the spectral indices were ranked in a descending order according to the correlation coefficients of SOM-ZY1-02D dataset. And for the GF5 and ASD datasets, indices with correlation coefficient larger than a certain threshold were also retained to increase the amount of available data.

Finally, a large number of historical satellite images (including ZY1-02D and GF5 satellites) of the study area were used to calculate the spectral indices. Then the band quality of the spectral index images was evaluated. The evaluation criteria of band quality include image strip noise and relative radiometric error. Based on the quality assessments, the optimal SOM spectral index of the black soil was determined.

Comparing different datasets, ZY1-02D dataset has the highest overall correlation with SOM. The differences between SOM and RR, SRR, LR, and OR are very small. The bands with higher correlation coefficients are generally concentrated between 500 nm and 1300 nm. For ZY1-02D dataset and ASD dataset, the bands with higher correlation coefficients between SOM and FDR are concentrated around 1300 nm and 1800 nm.

For the same type of spectral transform, the DI index can improve the correlation coefficients between SOM and OR, RR, SRR, and FDR. Except for the dual-band indices of FDR, all other indices have high correlation coefficients in the visible and near-infrared spectral range, among which the DI index of OR has the highest correlation coefficient.

Based on the correlation coefficients between SOM and the spectral indices calculated from the three datasets, as well as the quality evaluation results of the spectral indices, the optimal SOM spectral index is DI(OR [560,680]).

Overall, the optimal SOM spectral index constructed in this study is stable, simple to calculate, showing great potential in SOM estimation of black soil using multi-source satellite hyperspectral data.

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Research on Bathymetric Inversion Capability of Different Multispectral Remote Sensing Images

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Remote sensing has become an indispensable supplementary method for determining the sea depth along the coast in recent years. This paper constructs the random forest model and the band ratio model that adopts different multispectral images to conduct retrieving sounding in Nanshan Port in combination with the WBMS multi-beam sounding system in order to compare the diversities of retrieving sounding ability between domestic multispectral image and foreign multispectral images. The combination of abundant previous research information demonstrates the acceptable performance of the band ratio model and the random forest model in bathymetric inversion that are applicable to many practical scenarios, and have less stringent requirements for water quality and seafloor sediments than other inversion model; hence the above-mentioned band ratio model and random forest model are selected for water depth exploration; Water surrounding Nanshan Port can be regarded as a guaranteed benchmark for the widespread practice of measuring water depth with the help of remote sensing images due to the water near

it is relatively turbid; Remote sensing images adopt GF-6, GF-2, Sentinel-2B and Landsat 8 OLI data that all have popularity and accessibility. The final experiment results by the constant adjustment of the model parameter reveal that the water depth obtained from the four multispectral images lacks certain features when we compare it with the actual one, but it basically complies with the requirements of the Hydrographic Survey Code. The domestic series of GF-6 images presented the best performance in this experiment. The Root Mean Square Error (RMSE) and Mean Relative Error (MRE) that are obtained by the random forest model is only 1.202 and only 0.187 respectively, showing a promotion rate compared with the previous research information.The accuracy of the foreign Sentinel-2B and Landsat 8 OLI data inversion results is not as high as that of the GF-6 image inversion results, but it is higher than the GF-2 image. It shall be subject to the following three motives: (1) The higher ground resolution of GF-2 than that of GF-6 may generate the degradation of the spectral quality of GF-2, resulting in less accurate results when using spectra to measure water depth; (2) The ground resolution of Sentinel-2B has a higher application rate in multispectral data, but it does not function as well as that of GF-6 images. It is hypothesized that the primary cause is that we only utilize the red, green, and blue bands of Sentinel-2B during the inversion process, and do not fully utilize all bands, which leads to a specific loss of spectral information; (3) The results of Landsat 8 OLI images are inferior to those of the GF-6, which may be attributed to that Landsat 8 OLI data is designed for land images, but it is imperfect in water depth detection. The aforesaid study manifests that it is practicable to examine the water depth by domestic remote sensing images that even be superior to that of foreign multispectral images concerning the bathymetry inversion ability by virtue of some bathymetry inversion models or in some waters.

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Overview of Geosynchronous High-speed Imager

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The Geosynchronous High-speed Imager (GHI) is a new and exploratory Earth observing sensor of the weather satellite Fengyun-4B (FY-4B), which was launched on jun. 3, 2021. FY-4B is the second satellite of the new generation of Chinese geostationary weather satellites Fengyun-4. The main purpose of GHI is to have the capability of imaging an area of 2000*2000 square kilometers in geostationary orbit with a higher spatial resolution and a temporal resolution of less than one minute. The high frequency earth-air target observation data has a good observation and monitoring effect on the rapidly changing typhoon, severe convective and other extreme weather, and plays an important role in forecasting the development of weather system and improving the meteorological service ability.

GHI has high resolution visible image acquisition capability, water vapor band and long infrared band. In detail, GHI has 7 reflective and emissive bands (panchromatic, 0.445μm ~ 0.495μm, 0.52μm ~ 0.57μm, 0.62μm ~ 0.67μm, 1.371μm ~ 1.386μm, 1.58μm ~ 1.64μm, 10.3μm ~ 12.5μm) and sampled at 0.25-0.5 km at nadir in the visible (VIS), 0.5 km in the near infrared (NIR), and 2 km in the Longwave infrared (IR) spectral bands. The highest optical resolution is 7 μrad. The VIS bands can be composited to produce color images with a resolution of 250m. These VIS/NIR bands will be used to detect haze, clouds, surface vegetation, cirrus clouds, snow cover and aerosol particle size, among others. And the IR band will be used to observe clouds and surface temperatures. GHI also has quantitative application capabilities, performing observations for radiometric and geometric calibration, such as internal blackbody target, space and stars looks.

There are four optical major components of GHI that work together to collect observations as a system, the scanning mirrors, the Three Mirror Anastigmat (TMA) telescope, the After the Light Path (ALP) and the Focal Plane

Modules (FPMs). The two scanning mirrors operate independently and simultaneously to slew rapidly to the location of interest and then accurately scan the rectangular area. The TMA telescope and the BLP collect photons from the mirrors and image onto the three FPMs: Visible (VIS), Near Infrared (NIR) and Longwave IR (LIR). To obtain a high degree of detection sensitivity, the LWIR FPMs are cooled to 54 K with Stirling cryocooler. Each FPM consists of at least two detector arrays referred to as focal plane arrays, with the longest array column containing 2048 detector elements. There are 9216 detector elements, of which 7424 are in use and others are backup. All of them are read out and downlinked for selection.

The structure system and thermal control system are also very important to achieve instrument performance. The rigid-flexible coupling technique is used to solve the influence of structural thermal deformation on optical system. The damping technique is used to reduce the effect of micro-vibration generated by Stirling cryocooler on optical image quality. And the thermal control system provides the required temperature for each component. To reduce weight, GHI uses integrated electronics technology along with AGRI and GIIRS of FY-4B.

GHI is designed for an on-orbit operation life of seven years. During the orbital test, GHI has played an important role in major meteorological support activities and services for major meteorological disaster events. This paper describes a concise review of the GHI development project, including its missions and functions, technical design, key technologies and in-orbit operation status, etc.

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Experimental system of life ecological science on Chinese Space Station

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Space life science is a subject that studies the life phenomena and laws under the action of special environmental factors (such as vacuum, high temperature, low temperature, weightlessness and cosmic radiation) in space. It is an important part of human space exploration. Space life science experimental instruments provide a solution for the development of space life science experiments. From the initial sounding rockets to recoverable satellites, to the current space stations, and even to the future deep space exploration and planetary bases, the pace of human exploration of space life science has never stopped. The establishment of the Chinese space station has provided long-term, manned and repeatable experimental conditions for space life science. In 1992, the Chinese government formulated the 'three-step' development strategy for the manned space project. The third step of the plan is to build the Chinese space station. The Chinese space station has planned 13 kinds of scientific experimental projects, of which space life science is an important one. The life ecology experiment cabinet and the biotechnology experiment cabinet are the experimental platforms for the life science research of the Chinese space station. Among them, the biotechnology experiment cabinet is a biotechnology experiment platform that focuses on cells, proteins and nucleic acids. The life ecology experiment cabinet is a microgravity scientific experiment platform, which is suitable for studying plant individuals, fish, snails, fruit flies and other biological individuals. The life ecological experiment cabinet includes a general biological culture module (GBCM), a small general biological culture unit (SGBCM), a small centrifugal experiment module (SCEM), a small controlled life ecological experiment module (SCLEEM) and a microbial online monitoring module (MOMM).

The GBCM provides suitable environmental conditions for biological experiments, including temperature, humidity, light, gas concentration, visible light imaging detection, fluorescence imaging detection, program-controlled instructions, etc. The first batch of experiments will be mainly plant space culture experiments. Other types of biological experiments can also be carried out by changing the culture unit.

The SGBCM module internally provides temperature control and imaging monitoring. Other functions are realized

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by the replaceable culture unit. The scientific experiment of the first batch of SGBCM will carry out the radiation experiment of nematodes in the space capsule.

The SCEM can realize 1-2g gravity simulation in microgravity environment, and can support variable gravity biology research and microgravity comparison experimental research.

In SCLEEM, it is planned to carry out a closed aquatic organism culture experiment with algae, fish and snails as members. Algae provide necessary oxygen for fish and snails through photosynthesis.

MOMM is a load used to detect the presence and classification of microorganisms in the environment. It uses two methods to detect microorganisms. One is culture method and the other is nucleic acid amplification detection method.

The experimental cabinet provides support conditions such as structural installation interface, power supply, liquid cooling temperature control and information transmission for the above modules. Each module works independently and has an independent electronic control system with the same architecture. Each module is designed with a universal expansion interface.

Based on the early load development technology, the life ecology experimental cabinet and the biotechnology experimental cabinet of the Chinese space station can be said to be the integrators of the Chinese space life science experimental system. This paper will introduce its basic functions, experimental conditions and expandable interface resources module by module.It provides a basis for space biologists to design experiments and a reference for load engineers.

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Reconstruction of sea surface temperature data from Sea satellite observation based on convolutional automatic encoder

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Sea surface temperature (SST) is a key parameter for monitoring the marine environment and understanding various marine phenomena. It is also a key indicator of climate change. It directly affects the heat, momentum and water vapor exchange between the atmosphere and the ocean. It is an important parameter driving the global water cycle, affects the energy balance of the global surface, and directly affects the thermal process, change law and dynamic process of marine water bodies. Satellite remote sensing data is widely used in the analysis of SST spatial-temporal changes because of its wide coverage and continuous, real-time and all-weather observation. It is an important technical means of SST research at present, but due to the influence of clouds, aerosols, etc., a large number of missing data are produced. In this paper, a neural network model based on improved data interpolating convolutional auto encoder (dineae1.1) is proposed to reconstruct missing data in sea surface temperature data, and its performance is compared with data interpolating empirical orthogonal functions (dineof). The satellite data and its expected error variance are used as input, and the reconstructed field and its expected error variance are provided as output. The neural network is trained by maximizing the possibility of observed values. The model is applied to the infrared radiometer sea surface temperature data and compared with dineof, which is a common method based on EOF (empirical orthogonal function) decomposition to reconstruct missing data. This method has proved to be available and accurate in filling the spatial gap in remote sensing data sets. Using cross validation and field data to quantitatively evaluate the accuracy of these reconstruction methods, the study area was selected as the South China Sea, with boundaries of 103-121 ° E and 0-23 ° n. The verification results show that the reconstruction accuracy of dineae1.1 data is higher than that of dineof, which can slightly improve the spatial distribution of root mean square error (RMSE) between the reconstructed data and the original data. In addition, this paper

also confirms the potential of dincae1.1 prediction. Under the same data reconstruction conditions, dincae1.1 is 4-8 times faster than dineof, and the reconstruction results show higher variability than dineof results. The accuracy of the improved model has been improved.

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Near-infrared spectral characteristics and composition analysis of impact craters near the Chang'E-5 landing site

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Deep space exploration is an important way for mankind to innovate space science and technology, and to promote the development and utilization of space resources. Remote sensing technology plays an extremely important role in these exploration missions. Visible and near infrared reflectance spectra are the effective means to study the composition of celestial objects. The Chang’E-5 (CE-5) lunar exploration mission has achieved China’s first sample return from the moon, helping scientific research on the origin and evolution of the moon. The landing areas of CE-5 and Apollo 12 were located in the north and south of the Oceanus Procellarum respectively. In this paper, the spectral data of the craters near the CE-5 landing site and the similar Apollo 12 lunar rock (12063) spectrum with its mineral composition are compared and analyzed. The band area ratio method and the modified Gaussian model method were applied to study the spectral characteristics and mineral composition of these craters and rocks. The chemical compositions and evolutionary trends of major constituent minerals are consistent with the basalts returned by the Apollo missions. The spectral deconvolution results indicate that the mafic minerals in the crater rocks near the CE-5 landing site are dominated by clinopyroxene, followed by orthopyroxene and olivine, which is significantly lower than the orthopyroxene mineral abundance in the Apollo 12063 lunar rock. It may indicate that the young basalts of CE-5 landing area originate from the lunar mantle source region, which is rich in clinopyroxene and contains a small amount of olivine material. Remote sensing and space exploration help us solve many meaningful scientific problems. In general, remote sensing is an important and useful even the only means for us to understand the solar system and extrasolar celestial bodies.

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Test of a 15~20K Stirling/pulse tube hybrid refrigerator for space applications

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In deep space exploration, a low-temperature environment is essential and certain electronic detectors should be cooled to improve their sensitivity and accuracy. With the development of space exploration technology, there is a growing demand for lower cooling temperatures and higher efficiency. To meet the cooling power required below 20 K for space-borne infrared sensors, a two-stage configuration is usually used, meanwhile, the first stage can be used to precool the simultaneous optical circuit and thermal shield.

The two stages gas-coupled Stirling/pulse tube refrigerator (SPR) with the first stage of Stirling refrigerator and

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the second stage of pulse tube is a promising spaceborne refrigerator. The SPR has many advantages because of the unique configuration combining each feature of the Stirling refrigerator and the pulse tube refrigerator, such as compact structure, high reliability, and outstanding performance, which is expected to become an essential type of refrigerator for space applications. Meanwhile, the SPR has the unique ability to shift inter-stage cooling capacity by actively controlling the first stage Stirling displacer (phase angle and piston displacement), which enables the SPR to meet the needs of time-varying heat loads.

A SPR-20 driven by one linear compressor has been designed and manufactured for working at 15–20 K in Shanghai Institute of Technical Physics Chinese Academy of Sciences (SITP, CAS). When all of the regenerators are filled with stainless-steel mesh, the SPR-20 can reach a no-load cooling temperature of 15.4 K and obtain 2.6 W at 70 K plus 0.1 W at 20 K with 160 W total input power. While the second stage regenerator is mixed filled with magnetic material and stainless-steel mesh, the cooling capacity of the SPR-20 can be improved to 2.5 W@70 K plus 0.45 W@20 K with 200 W electric input power plus 17 W displacer input electrical power. By actively controlling the displacer phase from 80° to 90°, an adjustment of cooling capacity to 2.9 W@70 K plus 0.40 W@20 K with 200 W electric input power plus 18 W displacer input electrical power can be obtained. Similarly, with the displacer phase angle of 65°, the SPR can obtain 0.5 W at 70 K plus 0.57 W at 20 K with 175 W electric input power plus 11 W displacer input electrical power.

While lower the second stage temperature to 15 K, the SPR can obtain 0.32 W at 15 K plus 0.65 W at 65 K with 250 W compressor input power plus 20 W displacer input electrical power or 0.16 W at 15 K plus 0.65 W at 2.33 K with 250 W compressor input power plus 28 W displacer input electrical power by shifting the displacer phase from 90° to 70°. With an electric input power of 261W, the refrigerator can provide a cooling power of 0.37 W at 15 K, while the first stage temperature is 54.9 K. The no-load second temperature is 10.5 K at the second stage cold end while the first stage temperature is 55.1 K with 240 W compressor input power plus 23 W displacer input electrical power. The performance of the developed Stirling/pulse tube hybrid refrigerator (SPR-20) has a relative advantage among 20K high-frequency refrigerators. The development of SPR-20 provides an additional option for satisfying the further cooling requirements of aerospace.

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The Uncertainty of SNO Cross-Calibration for Satellite Infrared Channels

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Onboard calibration of remote sensing instruments is a fundamental task in quantitative remote sensing applications. A widely used calibration method is the cross-calibration based on the Simultaneous Nadir Observation (SNO), which uses remote sensing instruments with high radiometric calibration accuracy (reference instruments) to calibrate other onboard remote sensing instruments with lower accuracy (monitored instruments). The SNO cross-calibration method requires the reference instrument and the monitored instrument to strictly match the observation time, observation spatial, observation field geometry conditions and instrument spectra, whose corresponding matching thresholds are selected to introduce errors into the calibration results. In addition, the linear regression method also introduces errors to the calibration results. In this study, we propose to analyze from two aspects, including sample matching error and sample fitting method error. According to the error transmission chain analysis of the SNO cross-calibration method, a generalized model for the uncertainty assessment of the SNO

cross-calibration method for meteorological satellite infrared channels is constructed. Further, the study takes the payload parameters of the Hyperspectral Infrared Atmospheric Sounder (HIRAS) and Medium Resolution Spectral Imager (MERSI)on board the FY-3Ds actual cases, uses a two-dimensional Gaussian function model as the system point spread function, and constructs numerical simulation analysis results of the cross-calibration error of MERSI under typical bright temperature, different uniform background fields, and different matching threshold conditions using the actual HIRAS infrared channel data as the benchmark. The results indicate that the proposed model completely portrays the error transmission chain of the SNO cross-calibration process of the reference instrument and the monitored instrument, which can be used for the error analyses of SNO cross-calibration and also for the inverse selection of the sample matching threshold after the determination of the radiation calibration accuracy.

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Research Progress of Cloud Remote Sensing Technology Based on Terahertz Radiometer

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The frequency of terahertz wave is in the range of 0.1~10 THz (wavelength 3 mm~30 μm), which is located between the microwave and infrared bands. Its wavelength is similar to the size of typical ice cloud particles, and it has great potential in ice cloud remote sensing. The successful operations of airborne radiometers in field campaigns, for instance, MIR, CoSSIR and ISMAR, which were designed as demonstrators for future spaceborne missions, have proved the potential and feasibility of radiometric measurements of ice clouds in terahertz wave band. This report summarizes the current research status and progress of cloud measurement technology based on terahertz radiometer, including the development of the instruments, airborne tests, and common cloud parameter inversion methods. Firstly, the basic principle of terahertz remote sensing of ice clouds was summarized. Then, the key technologies were introduced in detail from three aspects, including the measurement instrument, the forward radiative transfer model and the inversion method of the terahertz remote sensing of ice clouds. In particular, the key parameters of the existing terahertz radiometers, the characteristics of terahertz radiative transfer simulators and the advantages and disadvantages of different inversion methods were discussed and analyzed. In addition, the work of our research team in terahertz remote sensing of cloud is introduced. Finally, the summary and prospect of the terahertz remote sensing of ice clouds were proposed, in order to provide a reference for the future research of terahertz wave passive remote sensing of ice clouds.

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Tensorial polarimetric-spectral multi-view subspace clustering for urban targets using imaging spectropolarimeter

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Polarimetric hyperspectral images (PHSIs) can provide complementary representations of a scene from the perspectives of images, spectra, and polarization at the same time and are expected to improve the quality of scene description. In this article, the clustering for PHSI is deemed to be a multiview clustering task, and a tensorial polarimetric-spectral multiview subspace clustering (TPS-MSC) algorithm for PHSI is proposed. It constructs a small size dictionary, instead of a large self-representative dictionary, by pre-clustering each view independently

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to give a sparse representation of all the data. Then, the view-specific representation matrices are tensorized to explore the low-rank structure among different views, and the consistency of all views in pre-clustering is incorporated into the representation learning framework to strengthen the interview correlations. The proposed model is efficiently optimized by the alternative direction minimization of multipliers (ADMM) algorithm. Some experiments are carried out to validate the capacity of PHSI for target identification and to demonstrate the accuracy and efficiency of the proposed TPS-MSC algorithm.

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Research on the Key Technology of Martian Atmospheric Wind Field Interference Imaging

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Martian atmospheric wind field detection can not only provide dynamic information for martian atmospheric models but also provide an important guarantee for the safety of Mars probes. The light source of the passive remote sensing detection is the 1.27 μm airglow of the O_2 molecules present in the Martian atmosphere. We introduce the preliminary scheme of Martian atmospheric wind field passive interference detection, summarizing the photochemical reaction model of Mars dayglow and nightglow. Based on the Mars Climate Database v5.3 and HITRAN 2016 database, the volume emission rate of O_2 1.27 μm airglow with altitude change was simulated, and the Mars wind imaging interferometer was designed. Also, the deep learning-based wind field interferogram denoising model is constructed with good denoising effects. All of this provides the basis for Martian atmospheric wind field interference imaging.

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Design and Verification of Partitional Thermal Control for Space CMOS Electric Cabinet

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The structure of a space electric cabinet based on a commercial CMOS chip is presented. Analysis is conducted according to the temperature specifications and the environmental constraints, which indicates the partitional thermal control method has higher energy efficiency than conventional TEC cooling. A flexible graphite thermal cable is used to build an independent cooling path for the focal plane component. The camera hood is utilized to cool down the peripheral circuit. Copper sinks are designed for high power electronic components. The thermal control design is verified by finite element simulation analysis and thermal balance test. The experimental results show that the partitional thermal control measures are effective and feasible, which can ensure the -30℃operating temperature of CMOS chip and the derating requirements of components with high power consumption.

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A False Alarm Space Target Detection Method Based on Star Information

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Space security has become a global concern due to the intensifying competition for global space dominance, the increase in space debris, and the development of space countermeasure technology. Space situational awareness includes detection, tracking, identification, cataloging, and characterization of space targets, evaluation and verification of space events, and monitoring and prediction of the space environment. It is the basis for understanding and responding to space threats and space security, and in recent years has attracted a great deal of attention from space-using countries. For the detection of space targets, the triangle matching algorithm in the star map recognition algorithm is more general, but the triangle as the algorithm identification primitive is almost unavoidable due to the low feature dimension of the triangle, which leads to redundant matching and misidentification. A series of researches have been carried out on the false alarm problem of space target recognition, which are usually according to the different characteristics of different types of false alarms in the image.

In this paper, for targets that have similar pattern with projected star points, a false alarm space target detection method based on star information is proposed, and the central idea is, if the target is coincided with the same projected star point for n consecutive frames, the target is recognized as the false alarm target. The implementation steps of this method are as follows. Firstly, calculate the exact optical axis pointing quaternion based on the coarse positioning optical axis pointing quaternion and the triangle matching result, project the stars into the image plane based on the exact quaternion, and put the identities of the stars into the data structure of projected star points. Secondly, based on the matching result of the projected star points and the imaging star points, get the imaging points corresponding to the stars and identify the non-star targets. Thirdly, match every non-star target and all projected star points, if the Euclidean distance of the target and any projected star point is less than a certain threshold, which is set to 1 pixel in this paper, the non-star target is added to the queue of predefined false alarm targets, and the identity of the projected star point is placed in the data structure of the predefined false alarm target. Fourthly, if the identity of the predefined false alarm targets is the same for n consecutive frames, the count of the target is accumulated to n, and the target is regarded as a confirmed false alarm target and removed from the queue of non-star targets. Otherwise, if the intended false alarm target does not coincide with any projected star points or the identity is different from the previous frame, the false alarm target count is cleared. Simulation experiment shows that the method can effectively identify and reject false alarm targets, reduce the false alarm rate. Since the number of consecutive coinciding frames can be adjusted, this method can ensure real-time performance.

The results of this paper also have some implications for space target identification and detection based on triangle matching method.

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An Unsupervised Symmetric Tensor Network for Change Detection in Multitemporal Hyperspectral Images

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Change detection (CD) is an important topic in remote sensing image analysis. It aims to recognize and identify the differences among the multitemporal images. Since hyperspectral images (HSIs) contain a large amount of

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spectral information, they can provide detailed spectral information and enable accurate CD. However, there are many challenges in HSI CD. First, the spectral heterogeneity of HSIs may lead to false alarms and miss detections, thus reducing detection accuracy. Second, the deep neural networks prevalent in CD these days usually rely on manual labels to perform well in representation learning, while it is expensive to annotate real HSIs. Expressed as high-order tensors, multitemporal HSIs can be effectively processed by tensor analysis. Moreover, it is viable to weave tensor decomposition models into networks to represent deep features. Therefore, we propose an unsupervised symmetric tensor network (USTN) for HSI CD. Instead of solely dealing with spectral features, USTN processes spectral and spatial information simultaneously. One of its major parts is a pair of symmetric tensor networks for horizontal and vertical spatial feature extraction. Each tensor network includes three tensor analysis layers, whereas Tucker Decomposition is adopted. Another part of USTN is a CNN-based encoder-decoder for temporal-spectral feature reconstruction. The main contributions of this paper are as follows. (1) It proposes a novel multidimensional symmetric tensor framework. (2) It integrates a spatial edge loss into the original reconstruction loss to preserve detailed spectral–spatial information. (3) To enhance physical interpretability, it fuses the features learned by the spectral encoder-decoder and slow features yielded by slow feature analysis [1] before separating them into change and background clusters. The fused features can effectively suppress the invariant components (i.e., the background) and highlight the variant components (i.e., temporal changes). Experiments on two sets of multitemporal HSIs, Hermiston and BayArea, demonstrate the effectiveness of USTN for binary change detection. It is compared with CVA+K-Means [2] and ASCD [3] as baselines, and SSTN [4] and TDRD [5] as SOTA. The experimental results on Hermiston show that the overall accuracy values are 98.43% by USTN, 97.06% by CVA+K-Means, 82.09% by ASCD, 98.19% by SSTN, and 95.07% by TDRD. The Kappa coefficients are 0.929 by USTN, 0.874 by CVA+K-Means, 0.516 by ASCD, 0.919 by SSTN, and 0.806 by TDRD. The experimental results on Bay Area show that the overall accuracy values are 78.89% by USTN, 73.54% by CVA+K-Means, 74.50% by ASCD, 78.35% by SSTN and 75.37% by TDRD. The Kappa coefficients are 0.313 by USTN, 0.275 by CVA+K-Means, 0.294 by ASCD, 0.305 by SSTN, and 0.301 by TDRD. These indexes indicate that USTN outperforms the competing models. Moreover, high Kappa coefficients suggest little background-change confusions for USTN. Apart from the quantitative criteria, CD masks are visualized for qualitative evaluation. It can be observed that the CD mask produced by USTN is the most similar to the ground truth for each data set. UMap scatter plots of the features learned by USTN demonstrate the representation power of the proposed method. Smooth loss curves indicate the efficiency and stability of USTN. For future work, USTN will be modified to self-supervised versions to improve detection results.

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Superpixel-based Spatial Weighted sparse nonnegative tensor factorization unmixing algorithm

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Hyperspectral images containing tens or even hundreds of narrow-band information, which have the property of high spectral resolution and have been widely applied in many fields. However, due to the limitations of optical instrument's performance and imperfect spectral acquisition techniques, the spatial resolution of hyperspectral images is low, which results in a pixel that may contain more than one type of ground object signature. The existence of mixed pixel seriously hinders the development of fine-grained and quantified hyperspectral image processing, hyperspectral unmixing is an effective way to deal with this question. Many hyperspectral unmixing methods have been proposed, including the longstanding geometry-based, statistics-based and non-negative matrix factorization (NMF)-based unmixing methods. The traditional NMF-based method expands the three-dimensional hyperspectral data into matrix form and decomposes it into the product of the endmember and the abundance, which causes a certain degree of information loss. The matrix-vector nonnegative tensor factorization algorithm solves this problem well by processing hyperspectral data as a tensor and pioneers a new model based on tensor decomposition. However, such methods still suffer from underutilization of image information and unstable performance at low signal-to-noise ratios (SNR).

To solve this problem, we proposed a new superpixel-based spatial weighted sparse nonnegative tensor factorization unmixing model (SupSWNTF), which better exploits the spatial information and improve the sparsity of the solution by adding constraints to the abundance matrix. First, the simple linear iterative clustering algorithm is employed to segment the hyperspectral image into many homogeneous superpixel blocks, whose shape and size are adaptive. And based on this, the reconstructed coarse hyperspectral images are obtained. Subsequently, the reconstructed image is unmixed by solving the sparse constrained optimization problem, thus the corresponding coarse abundance map is estimated. Then, a spatial weight W1 is constructed based on the coarse abundance map, each entry of which is inversely proportional to the ℓ2 norm of a row vector in the abundance matrix. The other spatial weight W2 takes into account the high spatial correlation of hyperspectral images between neighboring pixels by performing a spatial correlation function on the neighborhood of a pixel. The combination of two weights together constitutes the final weight, which not only preserves the spatial-spectral structure information of the original hyperspectral image, but also further enhances the joint sparsity between all pixels and the segmental smoothing of the abundance map.

The proposed SupSWNTF algorithm has two advantages: one is that it can promote the piecewise smoothness in the abundance maps, the other one is that the algorithm has better noise resistance, which can mitigate the effect of noise on the unmixing results. A series of comparative experimental results on synthetic and real-world data sets show that our algorithm achieves the best unmixing results compared to other state-of-the-art algorithms.

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Research on real-time co-phasing positioning system of segmented mirrors

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The research on segmented primary mirrors of space telescopes is an important research field for future deep space exploration. Through sub-mirror splicing, it can break through the limitations of existing mirror manufacturing capacity and rocket carrying capacity, and greatly improve the size of the main mirror and the imaging performance of the telescope system. In order to achieve the performance of mirrors with the same aperture after splicing multiple sub-mirrors, alignment, co-focus, and co-phase adjustments are required for the posture of the sub-mirrors. This adjustment process is accompanied by the whole life of the telescope. In order to ensure spatial reliability, the adjustment range needs to reach the millimeter level, and the adjustment accuracy needs to reach the nanometer level. The mirror attitude adjustment system is generally composed of macro and micro two-level adjustment systems. For example, there are seven attitude adjustment actuators behind James Webb Telescope to form the position adjustment system. Each actuator can meet the adjustment stroke of 21mm and the positioning accuracy of 7nm in the space cryogenic environment by coarse and fine stage. To verify the dynamic adjustment process of co-phasing and realize the positioning adjustment with large stroke and high accuracy, we developed a macro dimensional two-level attitude adjustment system based on the six degree of freedom positioning platform and the piezoelectric positioning platform. Combined with the multi wavelength interferometer measurement system, a scaled segmented mirror system with three mirrors is built, which verifies the adjustment process of real-time co-focusing and co-phasing. The system lays a foundation for the iteration and evolution of the subsequent splicing technology. This real-time confocal phase system is composed of a parallel six degree of freedom platform and an off-plane three degree of freedom piezoelectric positioning platform, which are connected in series to form a macro micro two-level adjustment system. The positioning system can provide stable support for the segmented sub-mirror, and can achieve a travel range of 5mm and a positioning accuracy of 20nm. The six degree of freedom parallel positioning platform can realize the movement stroke of 5mm with 2μm positioning accuracy, which can meet large stroke coarse adjustment such as sub-mirror alignment and coarse co-phasing. The off-plane three degree of freedom piezoelectric positioning platform can achieve 100μm positioning stroke with 20nm positioning accuracy. The nano-platform is connected to the back of the sub mirror by three backward flexible amplification legs through flexible hinges, and the platform posture is adjusted by driving the piezoelectric actuator. Using multi-wavelength interferometer to detect the displacement and deflection of the sub mirror, the control matrix of the macro-micro positioning system can be corrected to further improve the accuracy of the platform. Combined with the multi wavelength interferometer common phase measurement system and the edge capacitance sensor measurement system, the real-time confocal common phase of three sub mirrors is finally realized. The experimental results show that the deflection stroke of 1 mrad and the translation stroke of 0.1 mm can be achieved through the whole system, and the positioning error of the splice mirror tip / tilt is not more than 0.2 μrad. The positioning error of piston is not more than 20nm, which meets the requirement of co-focusing and co-phasing adjustment of segmented mirrors.

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An In-orbit Real-time Blind Pixel Detection Method Capable for Infrared Small Target Detection

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In the field of infrared small target detection, the blind pixels severely interfere with the detection accuracy of the target. Therefore, the way how to correctly detect and eliminate blind pixels is of great importance. The blind pixels are usually classified into groups of fixed blind pixels and random blind pixels. The fixed blind pixels are also called the dead pixels, which refer to the pixels whose response rate is lower than 1/10 of the average response rate. The fixed blind pixels are relatively stable and able to be identified through the method of laboratory calibration. The random blind pixels usually refer to the overheated pixels, which means the pixels with excessive noise. The distribution of the random blind pixels is related with the gain, the integrated time and the environmental circumstances of the imaging system, and it presents random characteristics. Thus the random blind pixels cannot be identified in advance via the laboratory calibration procedure. The representative detection methods for blind pixels include the single point calibration method (of the Military Standard of China) and the double reference-source detection method, along with the scene-based detection method that being researched at high popularity at present. The reference-source based methods suffer from problem of excessive loop iteration, and are not conductive to hardware implementation, while the scene-based methods are post-processed, which means the blind pixels and the target objects are overlapped into the image to be processed, and the possibility of misjudging point-targets as blind pixels universally exists in the scene-based methods in the implementation of in-orbit infrared small target detection.

In this paper, an in-orbit real-time blind pixel detection method that combines the time-domain noise of imaging sensor and the characteristics of non-uniform correction coefficients is proposed. Firstly, according to the in-orbit working condition of the remote sensing camera, the imaging data of the reference source that under high and low temperature circumstances is acquired, and the pixels of which the noise exceeds the threshold are marked out through the real-time analysis of time-domain noise of the imaging data. In order to reduce the consumption of hardware storage resource, the time-domain noise is obtained by using iterative recursive approximation. Secondly, the imaging data of reference sources that under high and low temperature is filtered in time-domain in order to reduce the interference of noise. The gain correction coefficient and the offset correction coefficient of each pixel are obtained through the processing of two-point correction of the filtered imaging data, and the limiting operation is carried out for the coefficients that are beyond the bit width range or cannot be corrected by hardware. Then the statistical distribution chart of coefficients is acquired through the statistical analysis of the gain coefficient and offset coefficient, and the pixels of which the distribution of its coefficients exceeds "±3σ" boundary are marked out according to the statistical characteristic value "μ" and "σ". Finally, the "union" of the two marking position sets that obtained before is carried out, and the marking position of the "union" indicates the coordinate position of the blind pixel detected in real time in orbit. By taking the use of the in-orbit calibration mode of the remote sensing camera, the method proposed in this paper realizes the in-orbit real-time detection of blind pixels. Comparing to the reference-source based laboratory blind pixel detection method, this method has its superiority in accuracy of blind pixel identification as the imaging mode and the environmental circumstance of the camera are based on actual working condition, and it also be a kind of detection method that proceeds before ground imaging, which do not lead to the misjudgment of infrared small targets to blind pixels. According to the experiment data comparison, the method proposed in this paper provides a matching rate of blind pixel identification of above 90% to the result obtained through the way of the Military Standard of China under the same condition, which demonstrates it has

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the capability to be widely applied to the infrared remote sensing camera with reference-source attached.

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Probabilistic analysis and evaluation of classical line error band models of ε-band, G-band, and standard deviation band

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The line error band models have been extensively used for evaluating the position errors of the line features in surveying, remote sensing, etc. With the development of space exploration to the celestial bodies, the precise evaluation of the line features' errors, such as the path of rover, the outline of the crater also requires the line error band model. Although there have been several classical line error band models, the shape and the probabilities of those models have not been unified. In this paper, the probabilities of line segment falling in its several representative line error bands, namely ε-band, G-band and standard deviation band, are estimated though simulated experiments. A probability-related evaluation index is proposed to evaluate the error models with the aim to provide suggestions for selection of different error models in various scenarios. The main contents are as follows.

First, the differences in the shape of the error bands (including area differences, inclusion relationships between error bands) are compared. In order to make the shapes of the error bands comparable, this paper is discussed in the case that the error ellipses at the endpoint of line segments are of the same size. And an R-times standard deviation error ellipse is exploited, in which its major and minor axes are R times the standard deviation ellipse's. Under the condition that the error ellipses at the end points of the line element are all ellipses of R-times standard deviation, the error bands are drawn and the area of the error bands S(R) are calculated. It's obvious that the ε-band is the minimum convex hull of the G-band, the standard deviation band is contained in the G-band, and the boundaries of the two error bands coincide in most positions . In addition, $S_\varepsilon(R)>S_G(R)>S_{SD}(R)$.

Second, a simulation method for estimating the probabilities of line segment falling in its error bands is proposed. Line segment falls in its error band only if every point of the line falls in it. However, the G-band and the standard deviation band are concave, it is difficult to calculate its probability. Therefore, on the basis of the probability density function of the endpoint, for better estimation, enough pairs of endpoint coordinates are selected randomly, and each of them can determine one line element. The probability P(R) is estimated by counting how many line segments falling in the error band, then, according to the probabilities P(R), these line error band models are arranged as ε-band, G-band and standard deviation band in descending order, i.e., $P_\varepsilon(R)>P_G(R)>P_{SD}(R), \forall R>0$.

Thirdly, a probability-related evaluation index for evaluating line error band models is put forward, i.e., trustability per unit area (TUA), which is equal to the ratio of "probability of a line segment falling in its error band" and "area of its error band", i.e., TUA=P/S. TUA measures the average probability per unit area, which means if TUA is larger, the line segment can be included by a smaller area with equal probability. There are generally two ways to compare the TUA between error band models. On the one hand, when the parameter R of the error ellipses at the endpoints of the line segment is fixed as r, TUA=(P(r))/(S(r)). The calculation results show that the trustability per unit area from large to small are standard deviation band, G-band ε-band respectively, i.e., $[TUA]_{SD}>[TUA]_G>[TUA]_\varepsilon$. On the other hand, let the probabilities P of all the three line error band models to be p, and the corresponding R value ($R_{\varepsilon,p}$, $R_{G,p}$, $R_{SD,p}$) can be obtained from the results of the above simulated ex-

parments, then the corresponding areas (S_c (R_(c,p)), S_G (R_(G,p)), S_SD (R_(SD,p))) can be calculated and substituted into the formula TUA =pS(R_p) . In accordance with calculation results, the size order of the TUA is consistent with the results of the first comparison method, that is, ⟨TUA⟩ _SD> ⟦TUA⟧ _G> ⟨TUA⟩ _c.

The trustability per unit area of standard deviation band is larger than that of the other two models, which means that when we need to choose a line error band model to describe the obstacle boundary, the standard deviation band with larger TUA can bring a wider space for moving objects.

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Parameter setting and analysis for the artificial potential functions in the application of small body celestial bodies landing trajectory planning

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The targets of landing missions on small celestial bodies usually have high scientific value but complicated terrain. Therefore, there are high demands for the landing trajectory planning method with regard to the safety and precise landing. The artificial potential field (APF) is one of the commonly used methods in trajectory planning for small celestial body landing. It is performed by applying attractive force from the target and repulsive force from the obstacles to the moving spacecraft. The attractive and repulsive forces are generated by the corresponding potential functions, which involves several parameters need to be determined. Improper parameters may lead to low efficiency of trajectory calculation, collision with obstacles or failure of reaching the target. However, the parameter values in the artificial potential functions are usually set as empirical values without consideration of different application scenarios. In this paper, the effects of different settings of the weight matrix in the attractive potential, the parameter k in the acceleration function, and the parametersk_1, k_2 of Gaussian repulsive potential function are studied by several simulation experiments under different initial states of the spacecraft and the different simulated terrains, and suggestions are given on the setting of these parameters under different conditions.(1) The attractive potential function can be divided into two parts. One is related to the position of the spacecraft and the corresponding weight matrix, the other part is related to the velocity of the spacecraft and the corresponding weight matrix. The effects of the weight matrices of the position and velocity on the trajectory are studied by numerical experiments. According to the results, it is suggested that the weight matrices should satisfy the relation that the part in the potential function that related to the position of the spacecraft is about 100 times of the part that related to the velocity. (2) By comparing the trajectories under different value of parameter k, it is found that the parameter k mainly controls acceleration caused by velocity. On the basis of determining the initial state of the spacecraft, the value of in (0.01,0.1) interval will lead to a slow acceleration change to make the acceleration always large, which may cause the speed of the spacecraft to be too high and cause the spacecraft to land before landing at the target point. The value of $k$in (1,10) may cause the acceleration part that affected by the speed and the other part affected by the position to be basically the same, resulting in the whole acceleration being small, oscillating, and prolonging the trajectory planning time. On this basis, the suggested reasonable value interval of k is obtained as (0.1,1). (3) When the distance between the spacecraft and the obstacle is larger than the standard deviation and close to the standard deviation, the Gauss repulsion function value increases rapidly. Therefore, the standard deviation k_2 can be set as the radius of the spherical obstacle, so as to ensure that the repulsion force increases rapidly when the spacecraft approaches the obstacle and successfully avoids the obstacle. By fitting the parameter k_1 with the distance between the spacecraft and the obstacle, the change curve of the distance between the spacecraft and the ob-

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stacle with the changing of the parameter k_1 is obtained. In order to make sure that the spacecraft does not need to detour too far when avoiding obstacles, the corresponding k_1 values is determined on the obtained change curve. It is found that the selected k_1 value is basically equal to the k_1 value obtained from the repulsion potential function at the boundary of the sphere and the attractive potential function at the initial position. However, since the direction of repulsion force always points from the center of the obstacle to the spacecraft, the lander always rises to avoid the obstacle. The suggested parameter setting method and possible value interval are given for the APF and tested by extensive numerical experiments. In this paper, the suggested setting method and possible value interval for the parameters in the APF method are given and tested by extensive numerical experiments. The purpose is to give suggestions on the appropriate parameters in different simulated scenarios of small celestial body landing trajectory planning.

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Radiance Consistency and Deviation Characterization in Co-observed Regions of the New Generation Geostationary Earth Orbit Meteorological Satellites

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The combination of various Geostationary Earth Orbit (GEO) satellites can realize simultaneous and continuous global observation with high temporal resolution, which is significant to the fine weather forecast and global climate change research. Here the radiance consistency and deviation characterization are analyzed for the co-observed regions of three new generation GEO satellites, including the Advanced Himawari Imager (AHI) onboard the Himawari-8 satellite, the Advanced Baseline Imager (ABI) onboard the Geostationary Operational Environmental Satellite-17 (GOES-17) and the Advanced Geostationary Radiation Imager (AGRI) onboard FengYun satellite-4A (FY-4A). The result shows that the radiance has higher consistency for visible and near-infrared (VNIR) channels with correlation coefficient R0.98 than infrared (IR) channels with R0.90 in the co-observed regions of different GEO satellites. For FY-4A & Himawari-8, the average percentage deviation (APD) of VNIR channels is 5.54%-9.03%, and the brightness temperature (BT) bias of IR channels is 1.16-2.5K. For GOES-17 & Himawari-8, the APD of VNIR channels is 4.48%-6.71%, and the BT bias of IR channels is 0.96-2.76K. The radiance deviation in the co-observed regions is significantly influenced by solar-viewing geometries in which the influence of satellite zenith angle (SAZ) difference is the most significant. The analysis of radiance deviation effect on cloud detection shows that the deviation of reflectivity of 10% and BT of 4K may cause about 50% of cloudy pixels undetected. The future work is to determine the radiance fusion method in the co-observed regions of different GEO satellites and achieve cloud detection in large space with high frequency by combining multi-source GEO satellites.

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Development of multi-stage Stirling type pulse tube cryocooler below 20 K in SITP, CAS

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Long-life mechanical refrigeration technology is an important technology which provides support for space scien-

tific researches and exploration. The cryocooler can reduce the background noise and improve the signal-to-noise ratio, sensitivity, and resolution of the optical detector. The cryocoolers play an important role in infrared detection that provide an essential low temperature working environment for infrared detectors and equipment. Nowadays, the sensitivity requirements of infrared detectors have increased, and it is gradually necessary to provide a cooling temperature region below 20 K. It is also necessary to provide cooling in the liquid helium temperature region for the very long waves and microwaves infrared detection. Stirling type pulse tube cryocooler (SPTC) has become one of the most popular mechanical refrigerators due to its advantages of no moving parts at the cold end, low vibration, high stability, and simple structure. In the form of multi-stage coupling, the SPTC can realize the space application in the temperature range of 4–20 K, and a series of multi-stage cryocoolers have been developed in Shanghai Institution of Technical Physics of Chinese Academy of Sciences (SITP, CAS).

A two-stage SPTC operating in 20 K (PT2C-20) has been developed for cooling infrared detectors and per-cooling helium JT cryocooler. For easy adjustment and high efficiency, the driven compressor of the SPTC is designed as two independent linear compressors. The second stage cold finger uses an active warm displacer as phase shifter to maximize the cooling performance. By optimizing the operating parameters of the active warm displacer piston and the pre-cooling temperature, the cryocooler can obtain a maximum cooling capacity of 1.31 W at 20 K with the total input electrical power of 470 W and the pre-cooling temperature of 80 K. For the multi-stage pulse tube cryocoolers working at 20 K, the design of the regenerator in the low temperature section is the key to improving the cooling capacity and efficiency of the refrigerator. In order to further lower the no-load temperature and improve the efficiency of the cryocooler at 15 K, we studied the influence of the regenerator in the low temperature section of the second stage pulse tube refrigerator by simulation and experiments. The structural parameters of the regenerator and other key components were optimized and improved, and a new two-stage SPTC (PT2C-15) was designed for the 15 K temperature region. The cryocooler can obtain a cooling capacity of 0.91 W at 15 K with a total input electrical power of 386 W whose cooling capacity and efficiency are greatly improved.

In order to realize the applications of liquid helium temperature region, we have developed the three-stage pulse tube cryocooler technology, especially for the large cooling capacities. A third-stage SPTC is thermally coupled with the developed two-stage SPTC (PT2C-20) and successfully obtained a three-stage SPTC (PT3C-7) which can work at 4-10 K. Within the total input electrical power of 500W, the PT3C-7 with He-4 as working fluid can obtain a minimum temperature of 3.96 K, and a typical cooling capacity of 145mW at 7 K.

The development in the multi-stage SPTC working in the temperature range of 7–20K of SITP, CAS will provide very low-temperature technical support for detection in the field of infrared astronomy.

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Helium Joule-Thomson cryocooler below 4.5 K for infrared detectors

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Mechanical cryocoolers are one of the significant technologies for earth and space scientific exploration. Many space instruments require cryocooler to improve dynamic range and expand detection wavelengths. For detectors in the infrared and sub-millimeter wavelengths, to reduce the influence of the dark current of the detector and improve the signal-to-noise ratio, it is often necessary to cool the detector to a low-temperature. In the past few decades, the application of cryocoolers has mainly focused on instruments operating in the relatively high cryogenic temperature (50 K-170 K). With the development of detection technology and mechanical cryocooler technology, the applications of cryocoolers gradually focus on the lower temperature region to support the study of the

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origin of the universe and the search for planets around distant stars. NASA developed a 6 K cryocooler for the Mid-Infrared Instrument (MIRI) on the James Webb Space Telescope (JWST) and JAXA developed a 4 K cryocooler for the submillimeter wave receiver on the Submillimeter-Wave Limb-Emission Sounder (SMILES). For mechanical cryocooler working below 4.5 K, compared with pulse tube cryocooler and Stirling cryocooler, helium Joule-Thomson cryocooler have become the main cryocooler for space application due to its advantages of high efficiency, low vibration, and high cooling capacity. To meets the needs of future detectors below 4.5K, a helium JT cryocooler has been developed by the Shanghai Institute of Technical Physics of Chinese Academy of Sciences (SITP, CAS).

A prototype helium JT cryocooler (SJT-4.5) has been developed. As the two important components of the helium JT cryocooler, the precooler and the JT compressor are both developed by SITP. The precooler is a two-stage pulse tube cryocooler, and the JT compressor is the valved linear compressor, all of which can achieve long-life operation. To accelerate the cooling of the cryocooler, a bypass structure is added to the prototype cryocooler, which could ensure that the cryocooler would reach the working temperature within a few hours. After 10 hours cooling time, the cryocooler successfully reached the liquid helium temperature, and the no-load cooling temperature of the cryocooler is 3.8 K. Subsequently, the cooling capacity of the cryocooler is tested by applying a simulated heat source, and a cooling capacity of 110 mW@4.2 K can be measured. Furthermore, the longtime temperature stability is tested of about 10 hours with heat load. The long-term temperature fluctuation of the cryocooler is ±25 mK (1h) and the short-term temperature fluctuation is within ±5 mK (5 min). For the helium JT cryocooler, the cooling temperature can be appropriately reduced by adjusting the JT compressor, but it cannot be further reduced to a lower temperature due to the limitation of the initial design of the JT compressor and the pressure drop of the tube-in-tube heat exchangers. Therefore, to achieve a much lower cooling temperature, the JT compressor is modified to 4-stage, which can obtain a low suction pressure (about 10 kPa) and high-pressure ratio (over 100). And the internal heat exchanger was redesigned to effectively reduce the pressure drop in the low-pressure channel. A cooling temperature of 2.5 K can be obtained and enlarging the cooling capacity is being designed. The helium Joule-Thomson cryocooler below 4.5 K will be an important guarantee for the follow-up space exploration cryogenic system.

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ESIT2022-0822-3

Infrared Small Target Detection Based on Feature Pyramid Structure and Multilayer Feature Fution Network

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Infrared small target detection plays a key role in remote sensing applications. However, the low resolution of most infrared images and the lack of texture and detailed information could cause the target to be lost in a relatively noisy background. Therefore, in recent years, researchers have paid special attention to the problem of small infrared target detection. In this paper, we propose an Infrared Small Target Detection Based on Feature Pyramid Structure and Multilayer Feature Fusion Network, which consists of a simultaneous up sampling two-layer feature pyramid network module and a fusion structure. First, the multilayer structure of FCNNs is able to learn shallow and deep features of images autonomously, however, due to the small size of the infrared small target, successive convolutional layers may result in loss of target information. For this reason, we introduce an up-sampling feature pyramid network layer (N2) on top of a single FCNN layer (N1), which can improve the image resolution, and, the extraction of target features by N1and N2is intersecting, while there is variability in the misclassification of background, noise, and other interference information. Therefore, after the detection results of N1and N2are fused,

the features of the target are enhanced, while the background is weakened, and a highly confirmed target detection result can be obtained by the CNN. In addition, for the small target detection task, since the direct fusion of shallow spatial information and deep semantic information may lose some small target features, we propose a fusion structure to solve this problem. The (pure) high-level features with little spatial information cannot effectively use the low-level features, the fusion structure is to introduce more semantic information into the low-level features, and the high-level features can then optimize themselves by aligning with the nearest low-level information. Besides, we design a pre-processing method for pre-detection images, before the images were fed into the network, we first did target contrast enhancement on the dataset. Although the targets are small, the luminance of small targets is often higher than the local background area. For this reason, with the premise of ensuring image coherence, we set the part of the image with the highest pixel value to 1 and the lowest part to 0, and mapped the rest in equal proportions. The SCR of the enhanced image is improved, which is beneficial to the subsequent detection. To visualize the effect of the fusion structure and the pre-processing method on the detection results of the network, we did experiments with and without the above structures and found that they both improved the detection results of the network. Last but not least, to demonstrate the superiority of our approach, we compared it with six state-of-the-art algorithms, three of which are deep learning algorithms proposed in the last three years and the other three are classical traditional detection algorithms, the experimental results show that our network outperforms other six state-of-the-art methods in terms of combined evaluation metrics (F_1-score) and mean intersection ratio (mIou). The detection results show that our method can greatly suppress background noise and accurately detects the target.

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Application of 3D printed titanium alloy lattice structure in high resolution space camera

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With the increasing demand for lightweight space optical remote sensors, traditional manufacturing processes such as machining and casting are difficult to achieve lightweight manufacturing of complex configurations in limited design space. Additive manufacturing based on 3D printed titanium alloy technology provides a way to solve this problem. In order to solve the goal of ultra lightweight and high stability of a high resolution space camera structure, this paper combines the advantages of light weight and high specific stiffness of porous lattice materials with 3D printed titanium alloy technology to carry out detailed design. Firstly, the theoretical model is established to analyze the performance of the lattice structure, and the structural performance is evaluated and verified by the combination of sample test, simulation analysis and mechanical test. The results show that the linear expansion coefficient of the optical mechanical structure is 6.0124×10^{-6}/K, the maximum stress of the material is 60.4MPa, and the first-order constrained frequency is 158Hz. The structure has passed the vibration test of 6.8g sinusoidal and 6.5grms random. The flatness change of the mounting surface before and after vibration is less than 0.002. The mechanical stability of the structure is excellent and meets the application requirements of space optical remote sensors.

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Deep Low Temperature Medium-Wave Infrared Convex Blazed Grating

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High-spectral resolution imaging spectrometer is one of the major innovation breakthroughs of remote sensing technology, the spectral system of which has a direct impact on the structural complexity, working performance, and volume and weight of the whole imaging spectrometer system. The imaging spectrometer can be divided into dispersive type and interferometric type according to different spectral-splitting mode. Among them, dispersive imaging spectrometer is the most mature imaging spectrometer and is most widely used with its high performance and high environmental-adaptability. The spectral-splitting element used by dispersive imaging spectrometer includes the prism, PGP (prism-grating-prism), grating. The imaging spectrometer of symmetric Offner spectroscopic system using convex reflection grating has the characteristics of compact structure, large field of view, small spectral distortion, small spectral bending and so on, which make it be the first choice for the spectroscopic system of wide band imaging spectrometer. Convex blazed grating is suitable for all spectral bands and is the most used as the best performance spectroscopic element. Its process characteristics and difficulties are as follows: the groove lines of a single scribe line keep the arc direction of the grating spherical base consistent; the position and angle of the groove of the adjacent scribe line is constantly changing by keeping consistent with the arc direction of the spherical base; the shape of the groove itself is consistent while maintaining the change of the position angle of the adjacent groove. The grating is processed on using the process method with electron beam exposure as the core by approximating the blazed surface of the grating with several steps. The groove shape accuracy is the highest, the diffraction efficiency of the grating is the highest, and the surface shape is better. The medium-wave infrared convex blazed grating developed in this paper has excellent performance. The wavelength band range is 2.65μm-5.15μm, the blaze angle is 2.19 °, the anti-blaze angle is 59.8 °, the diffraction efficiency is 89%, and the average diffraction efficiency is more than 60%, PV value of grating surface is 0.586 λ(λ= 632.8nm), RMS value is 0.051 λ (λ= 632.8nm). The performance of the grating is not degraded, meeting the needs of aerospace grade deep and low temperature after being subjected to high and low temperature test from - 183 ℃ to 30 ℃. This paper is the first time in China to use the electron beam exposure method to stitch groove, exposure focused on convex surface and control the accuracy of the groove shape of the medium-wave infrared convex blazed grating. The convex blazed grating has excellent performance which filling the blank of the medium wave infrared electron beam convex blazed grating technology in China, breaking through the technological bottleneck of the grating electron beam exposure, and solving the low diffraction efficiency of the grating in China. Compared with domestic holographic ion beam and other grating preparation methods, the blaze angle accuracy of the grating is higher, the anti-blaze angle is larger, the wavelength shift of the blaze wavelength is reduced, and the overall diffraction efficiency and peak diffraction efficiency of the grating are improved.

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Cloud detection method of remote sensing image based on improved U-Net Algorithm

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Clouds in optical remote sensing images will block ground information to varying degrees, resulting in ambigui-

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ty and lack of surface observation information, reducing the accuracy of atmospheric correction, and resulting in poorer application effects of remote sensing data. According to the International Satellite Cloud Climate Project, more than 66% of the world's area is covered by clouds. Therefore, the development of remote sensing image cloud detection technology has become one of the most popular directions in the field of remote sensing image recognition. The traditional method based on spectral threshold has been very mature, but it is greatly affected by the sensor parameter settings and the background of the ground object, and the robustness is low, while the texture analysis method based on traditional machine learning is usually based on a large amount of prior knowledge. Model construction and feature extraction often require manual intervention to effectively capture image features when complex underlying surfaces are in front of them, so as to achieve the purpose of cloud detection. From the perspective of deep learning, the cloud detection of optical satellite images can be attributed to the problem of image semantic segmentation. The deep learning algorithm represented by the U-Net network can automatically mine the characteristics of the data set, and has achieved remarkable results in the field of image segmentation. At present, most existing deep learning based on approaches usually adopt the U-type coder-encoder network structure. However, the original U-Net network structure directly splices shallow features and deep features during feature fusion, and the learned features are only related to the final fusion feature map, losing the edge and detail information of the shallow network. Although the traditional decoding and deconstruction network can effectively use the spatial location information of the encoding end, the entire network has too many parameters and a large amount of calculation, which is not conducive to the accurate identification of cloud pixels in remote sensing images. Therefore, based on the theory of deep learning and the U-Net framework, this paper constructs a new multi-level feature fusion U-Net network cloud detection model. The method adds a multi-level feature fusion module to the coding layer of the network, and fuses all the extracted feature maps to obtain a multi-level encoded feature map, which makes up for the information difference of direct feature splicing and enriches the semantic information contained in the predicted feature map. The skip connection method is improved in the decoding layer with adopted a new U-shaped encoding and decoding structure, which built context-semantic fusion connection to link corresponding layers in coding and decoding end to ensure the full use of feature information and reduce the amount of model calculation parameters. The experimental results on the common benchmark Landsat8-38 Cloud dataset show that the overall accuracy of the model verified is higher than the original U-Net model results. The proposed new U-Net can efficiently realize the feature extraction and representation of remote sensing images, and is more effective in detecting thick clouds under complex background, which provides a new perspective for realizing the accuracy of cloud detection.

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Reconstruction of Bennu asteroid high precision shape model based on keypoints matching using the OSIRIS-REx scanning Laser Altimeter

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The primary mission of OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer) is to return samples from the asteroid (101955) Bennu. The spacecraft's onboard science instruments accurately measured the properties of the asteroid. As an instrument on board this spacecraft, the OSIRIS-Rex Laser Altimeter (OLA) is the first scanning lidar (light detection and ranging) instrument to fly a planetary mission. The OLA scans Bennu for about a month during the Orbit B mission phase and obtains 911

frames of point clouds. The shape model of asteroids has important engineering and scientific significance for exploring asteroids. Fine terrain model is the prerequisite for landing and sampling return. In order to establish a self-consistent Bennu shape model, the three-dimensional (3D) offset between overlapping point clouds caused by the uncertainty of spacecraft position and pointing information should be eliminated.

The iterative closest point (ICP) algorithm is the most commonly used technique to correct 3D offset. During each iteration, it is necessary to determine the point correspondence between the data sets and find the optimal rigid transformation to adjust one of the point clouds to minimize the offset between the corresponding points. The main drawback of this technique is the high computational cost, especially for high-resolution datasets. if there is no careful initial alignment, the algorithm may erroneously converge to the local minimum.

In order to avoid this disadvantage of ICP, this paper takes two stages to reconstruct the asteroid 3D model. In the first stage, a database is established according to the overlap degree of point cloud, and then the point cloud data covering Bennu is automatically screened. In the second stage, we project the point cloud into two-dimensional (2D) image data, and use scale-invariant feature transform (SIFT) to identify image features and build image feature database. The images are matched to obtain the 2D corresponding points. The corresponding 3D key points are obtained using the cubic convolution interpolation method. Random Sample Consistency (RANSAC) is used to remove mismatches while retaining more key matches. In this paper, coarse adjustment and global optimal adjustment strategies are used to minimize the offset between overlapping point clouds. For faster convergence in the global alignment phase, an adjustment order is first determined, and then the offsets between keypoint pairs are minimized sequentially in the coarse adjustment phase. After this step, each point cloud is under the same framework. To minimize the propagation error introduced in the coarse registration, a set of transformation matrices are first determined for each point cloud, and then the global minimization of key point offsets is performed using the block adjustment method. Finally, the original offset point cloud is strictly converted to the global optimization position.

The main contributions of this paper are as follows. Firstly, the automatic point cloud screening method proposed in this paper can easily obtain Bennu global point cloud data without using all the point clouds collected in the Orbit B mission phase. This paper only uses about 1 / 6 of the data of Orbit B, which greatly reduces the overall data volume. Secondly, this paper project the 3D point cloud into the 2D image, thus reducing the data density of the single point cloud (3 million laser points to about 12000 key points) and significantly improving the calculation efficiency. Thirdly, this paper adopts the keypoints matching and block adjustment to solve local convergence of traditional methods.

In this paper, a high-resolution (50cm) global digital terrain model is constructed using the adjusted laser data, which provide information for the scientific interpretation of asteroids.

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A rapid star identification algorithm based on radial feature and angular distance between multiple stars

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The star tracker is the most precise and least drifting space attitude measuring instrument so far. Star identification is one of the key technologies in the development of star tracker. In order to further improve the timeliness and robustness of the star tracker in star identification, an all-sky star identification algorithm that can identify multiple stars at once time by combining the radial feature of star maps and the angular distance between stars was proposed. First, the radial feature library is constructed by using equal-area circle strips to ensure that the probability

of the companion star falling in each circle strip is the same. Compared with the construction method of equally spaced circle strips, the data in the feature library matrix is more uniform, and the radial feature library capacity is significantly reduced. Secondly, in the process of radial recognition, all possible circle strips within the position deviation of the companion star are selected, and different weights are given to the circle strips labels to ensure that the companion star features are not missed, while reducing the error caused by redundant matching, and improving the accuracy of the radial initial matching process. Due to the influence of such factors as the position noise of the star point and the missing of the star point, the main star obtained after radial matching needs to be verified again. Thirdly, the companion star library of the main star is constructed by using the labels of companion stars and circle strips. In addition, an optimization strategy for the selection of companion stars around the main star is proposed to remove redundant companion stars, so that the companion stars around the main star are approximately evenly distributed and the capacity of the companion star library is reduced. Finally, sort the radially identified primary stars according to their matching degree, use the circle strips labels of the companion stars in the actual star map, match the star labels corresponding to the circle strips label in the companion star library. Calculate the angular distance between stars in the actual star map and the angular distance between matched stars in the star library, add tolerance error, and verify whether they match. If the number of successful verifications is greater than 4, the identification is deemed successful. The spiral reference point method was used to generate 1000 simulated star maps that were approximately uniformly distributed in the entire celestial sphere. The sensitive star magnitude is 6.0Mv, the pixel size is 5.5um, the image size is 1280*1024, and the focal length is 25mm. The 6-core processor with 2.4GHz main frequency is used to identify the simulated star map on MATLAB R2021b platform. The simulation results show that the recognition rate is 99.5% when the standard deviation of position noise is 1 pixel, 99.8% when the standard deviation of magnitude noise is 0.5 Mv, 98.4% when 3 stars are missing, and the average star map recognition time is 0.746ms. The proposed method has high star identification efficiency and robustness, and further improves the attitude calculation accuracy by identifying multiple stars.

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Design and Implementation of Space Target Detection Camera Based on CMOS Sensor

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With the development of global space resources, space debris is increasing day by day. The impact of space debris on a satellite can cause surface damage, attitude or orbit changes, or even the disintegration of the satellite. The need for space target detection is becoming more and more urgent. Space target detection is mainly divided into ground-based detection and space-based detection. At present, ground-based detection is widely used in the world because it is not limited by volume, weight and power consumption. However, due to the interference factors such as atmosphere, ground-based detection is limited in detecting small space targets and target details. Space-based exploration is a good way to avoid this problem. Space-based detection usually completes the image of the target through a camera, and transmits the image to the subsequent image processing module to obtain the location of the target and other information. The whole system is complex and requires multiple processors to complete. In this paper, a space target detection camera based on CMOS sensor is proposed. The space target extraction algorithm is integrated into the camera, which effectively reduces the weight and power consumption of in-orbit equipment, reduces the risk caused by data transmission, and improves the system reliability. The camera uses planar array CMOS as the detection sensor, FPGA as the control core, and DDR3 as the high-speed image data cache to achieve high-definition imaging of space targets. At the same time, in the camera, based on the gradient

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maximum method, to achieve the spatial point target extraction accuracy of 0.5 pixels; Based on the analysis of connected domain, the space multi - faceted target is extracted. After the camera is powered on, it receives external commands through RS422 to obtain relevant parameters of the camera driver. Drive the sensor as instructed. After that, the image data output by the sensor is sampled. The received image data are stored into two groups of external DDR3 respectively. Read a group of DDR3 image data for digital image transmission. Another set of DDR3 data is read, and the denoised image data is obtained after threshold segmentation. Row cache was applied to the data, and 5 rows of image data were cached. The first derivative of the 5 rows of data was calculated, and the calculation results were stored in the row cache to obtain 3*3 derivative data. The derivative data were compared by the comparator to obtain the center position of the anchor point target, and then the sub-pixel offset of the point target was calculated to obtain the complete centroid coordinates of the point target. At the same time, the denoised image is binarized, and the surface target information is obtained through connected domain analysis. The point target and surface target information are output through RS422. The results show that the camera system runs stably, the imaging quality is high, the detection ability is strong, and the accuracy of point target and surface target extraction is 100%. It provides effective image data, target position and feature information for space target detection.

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Spatial Resolution Matching of Radiometer Using Convolutional Neural Networks

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For the continuous monitoring of the environment across the world, passive multi-frequency microwave sensors are essential tools. These data may be used to obtain a variety of atmospheric and surface metrics, including sea ice concentration, cloud liquid water, and precipitation rate. However, they frequently struggle with challenges related to low and non-linear spatial resolution when multi-frequency observations must be combined, leading to low resolution and even estimation errors of the retrievals. The apparent answer to this issue is to average the better spatial resolution high-frequency channel to match the low-frequency channel. However, it is undesirable when retrieval parameters are employed in regional-scale investigations or when geophysical quantities, such as rainfall, are strongly nonlinear with the radiances. Therefore, it is advisable to raise the low-frequency channel's spatial resolution to match the high-frequency channel.

The antenna design, the integration time, the scan geometry, and the receiver sensitivity are a few degradation factors that should be decreased in order to improve the spatial resolution of the microwave radiometer data. In particular, the observed data are smoothed by the large beam width of the antenna pattern due to the small size and long working distance of the satellite antenna, resulting in the low spatial resolution.

Numerous analytical strategies have historically been put forth to lessen these degradation factors in order to increase spatial resolution. Direct inverse-based techniques include the Wiener filtering method and the Backus-Gilbert (BG) approach. The spatial resolution can be increased by using the BG approach to reconstruct a smaller equivalent antenna layout using redundant overlapping footprint information. Additionally, this technique has been widely utilized to match the resolution of various frequency channels. In order to lessen the degradation brought on by the antenna pattern and the change in scan geometry, the Wiener filtering approach restores the image with space-variant filters in the frequency domain.

Recently, learning-based techniques that directly learn an end-to-end mapping between low- and high-resolution images have also been applied for microwave radiometer data spatial resolution enhancement. Convolutional neu-

ral network (CNN)'s mapping ability on image restoration issues and effective training techniques on recent GPUs allow for complete learning of complex degradation factors during training.

The accommodative spatial resolution matching framework, which consists of the flexible degradation model, the deep residual convolutional neural network (CNN), and the adaptive feature modification layers, is proposed as a means of adaptively enhancing and matching the spatial resolution. To generate appropriate datasets for various degrees of matching tasks, a flexible degradation model based on the microwave radiometer's imaging process is initially presented. Second, a deep residual CNN is added to jointly understand the intricate aspects that contribute to the data's degradation, enabling the resolution to be matched up to fixed levels with cutting-edge quality.In order to manage arbitrary and continuous-resolution matching issues between a start and an end level, the adaptive feature modification layers are finally introduced to the network. The method's validity and efficacy have been demonstrated using both model data and actual microwave radiation imager (MWRI) data from the Fengyun-3C (FY-3C) satellite.

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A CMOS Sensor Automatic Gain Adjustment Algorithm

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CMOS image sensors have the advantages of high integration, low cost, strong compatibility and low power consumption , so they are not only widely used in machine vision, security monitoring and industrial measurement and other fields, but also by more and more It is applied to the fields of star sensors, remote sensing cameras and target tracking . With the continuous improvement of semiconductor integrated devices, light and small camera systems with high frame rate and low power consumption with CMOS as the core have been developed rapidly .

In the imaging process of CMOS image sensor, the exposure time has a great influence on the image quality. The pixel output voltage of the CMOS sensor is determined by the light intensity and exposure time. In the case of a fixed exposure time, if the light intensity is low, the output signal will still be less than the noise at the end of the exposure time, resulting in insufficient exposure, which will result in too dark images. If the light intensity is high, the signal has been saturated before the exposure time has ended, resulting in overexposure, which will result in an overly bright image. In both cases, image detail is lost, and it is difficult to recover color even in subsequent image processing, reducing the visual quality of the image. The existing automatic exposure algorithm can automatically adjust the exposure time to adapt to the change of the incident light intensity, so as to achieve a suitable imaging effect. However, the space remote sensing image scene has its particularity. The image either has a large area of deep space background, or is in the case of direct strong light, the scene changes greatly, and the unknown is strong. In order to obtain as much information as possible, high frame rate CMOS cameras are increasingly used, and high frame rate means that the maximum exposure time of the sensor is correspondingly limited. At the same time, the minimum exposure time of the sensor is determined by the control clock. Since the exposure time is restricted by the frame rate and clock, even if automatic exposure technology is adopted, there will still be situations where the exposure time range cannot meet the changes in ambient light intensity.

Therefore, it is of great significance for aerospace remote sensing CMOS cameras to study an algorithm that can obtain better imaging results in scenes with extreme lighting conditions (too strong or too weak). In order to make up for the limited exposure time range, this paper provides an automatic gain adjustment algorithm based on the characteristics of the sensor itself. According to the different scenes, the digital gain of the CMOS sensor is adaptively adjusted to adapt to the change of the incident light intensity. More extreme scenes also have good imaging effects, require less hardware, and are easy to transplant.

The automatic gain adjustment algorithm of CMOS sensor based on image features proposed in this paper divides the image into corresponding regions by setting a series of threshold ranges (such as P1, P2, P3, P4, KM, etc.), and then counts the pixels in each region. It can reasonably judge the gray level distribution of the image, so as to obtain the appropriate digital gain adjustment coefficient and improve the identifiability of the image. The algorithm can adaptively adjust the digital gain of the sensor according to the brightness distribution characteristics of the scene. Under the condition of limited exposure time range, it can achieve better exposure effect for scenes with drastic changes in illumination. The algorithm is easy to implement, does not require high hardware equipment, is easy to transplant, and has strong versatility. The parameters such as threshold and adjustment coefficient in this algorithm are adjustable parameters, which can be obtained according to the statistical analysis of similar scenarios. Different parameters can be used for different target scenarios, which improves the flexibility of the system and has broad application prospects.

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Unmanned aerial vehicle hyperspectral imaging system monitors urban river water quality

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Rivers are an important part of urban ecosystems. With the development of human activities and social economy, the problem of urban river pollution is prominent. Many cities in China have different levels of urban river pollution and water quality degradation. The prevention and control of urban water pollution require timely and accurate access to the water quality of urban rivers. The existing water quality monitoring methods need to collect water samples manually, and then analyze and assay the samples through laboratory physical-chemical methods to obtain accurate water quality data, however these methods are inefficient, and the assay process may also produce secondary pollution. For many years in the past, satellite remote sensing technology has the technical characteristics of large-scale, global and real-time monitoring, and has been successfully used in water quality monitoring research on coastal and inland large lakes. However, current satellite monitoring network is limited by its own spatial and temporal resolution and cannot completely satisfy the monitoring needs of urban rivers. With the development of UAV technology and hyperspectral technology, new solutions have been provided for the problem of urban river water pollution. The unmanned aerial vehicle(UAV) hyperspectral imaging system has the characteristics of high spatial resolution, flexibility and convenience, and also has extremely high spectral resolution. It can obtain vast spectral information while obtaining ground images. The unique advantages of human-machine hyperspectral imaging technology in urban river water quality monitoring and water pollution prevention can fully meet the monitoring needs of urban rivers. In this study, four typical water quality parameters, including permanganate index (COD_{Mn}), dissolved oxygen (DO), ammonia nitrogen (NH_3-N) and total phosphorus (TP), were selected as the research objects, and Suzhou City, Jiangsu Province was selected as the research area for flight and synchronous sampling. In the experiment, the synchronous sampling data includes water quality data and water spectral reflectance data. The quantitative relationship between the spectral reflectance of water and water quality parameters was constructed using the synchronous sampling data combined with multiple machine learning model methods, and then the hyperspectral imaging of the unmanned aerial vehicle was used. The system acquires the hyperspectral image data of urban rivers, applies the model to the hyperspectral image, and conducts the verification in combination with the synchronous test data. The research results show that the accuracy of the best model of permanganate index (COD_{Mn}) is RMSE=1.515mg/L, MAPE=19.16%, and the accuracy of the best model of

dissolved oxygen (DO) is rmse=1.742mg/L, MAPE=21.44%, the accuracy of the best model for ammonia nitrogen (NH_4-N) is rmse=0.236mg/L, MAPE=36.08%, and the accuracy of the best model for total phosphorus (TP) is rmse=0.0365mg/L, MAPE =36.85%. The results show that the method proposed in this study can accurately invert the water quality of urban rivers and monitor the status of river water quality, which confirms the feasibility and application potential of UAV hyperspectral technology in urban river water quality monitoring and water pollution prevention. The cost of water quality monitoring in urban rivers provides an auxiliary means for regulatory authorities and environmental protection authorities.

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Long-term monitoring of Fengyun-4A AGRI infrared radiometric calibration

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Fengyun-4 (FY-4) is China's second-generation geostationary meteorological satellite, which introduces a new generation of three-axis stabilized satellites. As one of the optical payloads onboard FY-4A satellite, the Advanced Geosynchronous Radiation Imager (AGRI) is used to replace the Visible and Infrared Spin Scan Radiometer (VISSR) onboard Fengyun-2 satellite. Increased from five bands of the VISSR, the AGRI has 14 spectral bands, and the imaging quality of AGRI is greatly improved. The Modulation Transfer Function (MTF) and the power spectral of the AGRI instrument were analyzed. The results show that the performance of the instrument reaches its design specification. The AGRI adopts a multi-detector parallel scanning scheme, and a 4-element detector is used in the infrared band. An important issue of the multi-element detector is the response non-uniformity in the detector array, which causes obvious stripe noise on the images of all of the eight infrared channels of the AGRI. Moreover, this noise comes from the inconsistency of the spectrum, so that it changes with the difference of the observation target. To solve this issue, a wavelet filter has been designed, and the Weight Sum Variance of Digital Number Probability (WSVODP) was adopted as a parameter to evaluate the non-uniformity of the image. After filtering, the single-channel image becomes uniform, and the pattern noise is reduced to below 0.2 K. This improvement ensures the uniformity of the AGRI products such as cloud mask and sea temperature. In addition, the AGRI carries a surface blackbody as the on-orbit calibration source. By rotating the scanning mirror to point to the blackbody, the blackbody data of each band can be obtained. At present, the infrared bands are calibrated every 15 minutes. The evaluation results from long-term monitoring of the AGRI calibration show that the radiometric accuracies of its most infrared channels are better than 0.5 K, while some of them reach 0.2 K; the trend of sensitivity change is stable, decreasing by only 0.01 K in four years; and the radiation cooling shows a similar trend to sensitivity. These results provide a reference for the development of the instrument.

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