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Editorial

Special Issue on Advances in Photoelectric Tracking Systems: An Overview

Jiuqiang Deng [1,2,3,4], Qiliang Bao [1,2,3,4], Yutang Wang [4,5,6,*] and Yao Mao [1,2,3,4,*]

1 National Key Laboratory of Optical Field Manipulation Science and Technology, Chinese Academy of Sciences, Chengdu 610209, China
2 Key Laboratory of Optical Engineering, Chinese Academy of Sciences, Chengdu 610209, China
3 Institute of Optics and Electronics, Chinese Academy of Sciences, Chengdu 610209, China
4 University of Chinese Academy of Sciences, Beijing 101408, China
5 The Key Laboratory of Airborne Optical Imaging and Measurement, Chinese Academy of Sciences, Changchun 130033, China
6 Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China
* Correspondence: ytwang@ciomp.ac.cn (Y.W.); maoyao@ioe.ac.cn (Y.M.)

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1. Introduction

The photoelectric tracking system, which consists of optical, mechanical, electrical, and computer components, is in charge of tracking targets at extremely long distances. Tracking accuracy and stability accuracy are two of the system's most crucial performance metrics. Currently, quantum communication, free space laser communication, aerospace, space observation, and other fields make extensive use of the photoelectric tracking system [1,2]. Quantum and laser communication systems, which are based on the photoelectric tracking system, are able to create high-speed data transmission channels with great flexibility that are resistant to electromagnetic interference, and have low power consumption and huge capacity [3,4].

Tracking accuracy and stabilization accuracy are two crucial performance metrics of photoelectric tracking systems, and they are influenced by a variety of factors, such as mechanical attributes, sensor capabilities, drive characteristics, control algorithms, and more [5,6]. The tracking accuracy indicates how quickly the device can follow a moving target. The photoelectric tracking system often uses a composite axis design, which consists of a coarse tracking axis and a fine tracking axis [7]. The coarse tracking axis has a relatively low bandwidth and an obvious tracking error, due to the frame's large inertia. A tip-tilted mirror is the controlled object of the fine tracking axis, which has a high resonance frequency and low inertia. As a result, the fine tracking axis has a high bandwidth and small tracking error [8]. The coarse tracking axis' error is corrected by the fine tracking axis, so as to further increase the tracking accuracy of photoelectric tracking systems [9]. The ability of the system to suppress various disturbances is referred to as stabilization accuracy. The photoelectric tracking system is subject to external disturbances, including vibrations from the ground, carrier platforms, wind, and other sources [10]. Furthermore, friction, parameter perturbation, torque variation, and other unknown factors, collectively referred to as internal disturbances, are present in the photoelectric tracking system [11,12]. In photoelectric tracking systems, there are two types of disturbance suppression characteristics: passive and active. The vibration isolation structure, such as the spring, provides passive disturbance suppression, while the actuator's driving control provides active disturbance suppression [13,14]. The photoelectric tracking system is dependent on the image data for target recognition and tracking; hence, image signal processing is critical to the system. The photoelectric tracking system's image signal processing presents significant challenges in complicated settings with factors including object occlusion, ultra-long distance, inadequate brightness, and complex backgrounds [15].

The purpose of this Special Issue, "Advances in Photoelectric Tracking Systems", is to present the most recent findings and creative solutions in the field. The following are the original research papers and review paper on optical and mechanical design, image processing, and motion control planning for photoelectric tracking systems.

2. An Overview of the Published Articles

The composite axis structure, comprising a coarse tracking loop driven by a rack and a fine tracking loop driven by the tip-tilt mirror, is typically used by photoelectric tracking systems. To increase tracking accuracy, the coarse tracking loop's residual tracking errors are corrected by the fine tracking loop. Consequently, designing and optimizing the tip-tilt mirror is crucial. A multi-objective optimization technique, based on a two-parameter coupling performance study, is presented by Contribution 1. The balanced solution of numerous goal functions is attained by introducing physical involvement, and the tip-tilt mirror's overall performance is enhanced. In order to address the issues with the high cross-linking value and poor capacity to rectify high-order wavefront aberration of piezoelectric deformable mirrors, a novel single-piezoelectric-piece deformable mirror driving structure was suggested in Contribution 2. By laser-cutting piezoelectric ceramics, the structure lowers the cross-linking value of deformable mirrors and lessens the coupling between driving units. X-Y polynomials are the basis for a large field of view and low-distortion three-mirror anastigmat system that is proposed for coarse-tracking optical imaging systems in Contribution 3. When compared to the conventional spherical or aspherical three-mirror anastigmat system, the suggested system uses a free-form surface, which increases the system's design flexibility and enhances its capacity to balance aberrations. To enhance the precision of measuring infrared radiation properties in the aviation domain, a double swing solid angle reflector-based infrared Fourier transform imaging spectrometer is devised in Contribution 4. The suggested hood can reduce external stray light point source transmission to an order of 10^{-4}.

One of the research focuses of the photoelectric tracking system is image processing technologies. Referencing partition processing, Jiang, C et al. suggest an enhanced spatial image non-uniformity correction technique to address the issue of uneven skylight background and detector noise in high-resolution imaging of ground-based photoelectric tracking systems in Contribution 5. This technique satisfies the need for real-time processing of high-resolution photographs under prolonged exposure conditions, and efficiently eliminates the uneven background of spatial images. In Contribution 6, an adversarial network with an error correction function is proposed as a joint input generation method to address reconstruction errors in compressed imaging using a high-resolution digital micromirror array. For a higher peak signal-to-noise ratio and improved visualization, the network models the deterioration of image quality brought on by alignment errors. Using the super-resolution technique to improve the optical system's image performance has significant practical implications. Super-resolution reconstruction is achieved through the application of kernel regression technology in Contribution 7, while micro-displacement information is obtained using a 2D scanning galvanometer. The technique enhances the 16-frame image's optical resolution by 39% in a lab setting. Furthermore, the low-altitude bird flock targets' detection ability is strongly impacted by the clutter reduction effect of ground objects. A beam-constraint-based collision detection approach is presented to increase ray tracing collision detection efficiency in Contribution 8.

The photoelectric tracking system is driven by the motion control unit to track and capture the moving target, based on the tracking error of the image processing system's output. The acquisition of moving targets is, hence, the basis for tracking in the photoelectric tracking system. A novel approach to target acquisition issues in airborne radar, laser communication, and other fields, is offered by Contribution 9, which suggests an enhanced scanning acquisition technique based on hexagonal spiral scanning. Liu, C et al. suggest a linear quadratic regulator optimal control approach based on the disturbance observer and reference model controller to enhance the dynamic properties of the photoelectric tracking system in Contribution 10. This technique increases the photoelectric tracking system's rising time, settling time, overshoot, and ability to suppress disturbances. Furthermore, Singh, J et al. suggest a joint transceiver equalization methodology for space division multiplexed multiple-input multiple-output optical fiber communication in Contribution 11. This technique is important for enhancing the spectral efficiency of critical dispersion-impaired transmission links by mitigating the dispersion impairments caused by 1.4 km of multi-mode fiber. To address the issues of sluggish convergence and the low precision of tracking errors in photoelectric tracking systems, a nonlinear differentiator based on the Softsign excitation function is suggested by Contribution 12. The backward step control approach is then used with this solution to address the complexity explosion problem.

3. Conclusions

In summary, photoelectric tracking systems are a typical example of an interdisciplinary research object. Researchers primarily focus on optical mechanical hardware, control algorithms, and image processing algorithms, all of which work together to foster the invention of photographic tracking systems. The growth of laser communication, quantum communication, astronomical observation, and other sectors is being quickly boosted by photoelectric tracking systems. As we come to the end of this Special Issue, we hope that readers will gain an improved comprehension of photoelectric tracking systems, and that this will inspire additional scholars to enter the field to further the world through exceptional research.

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