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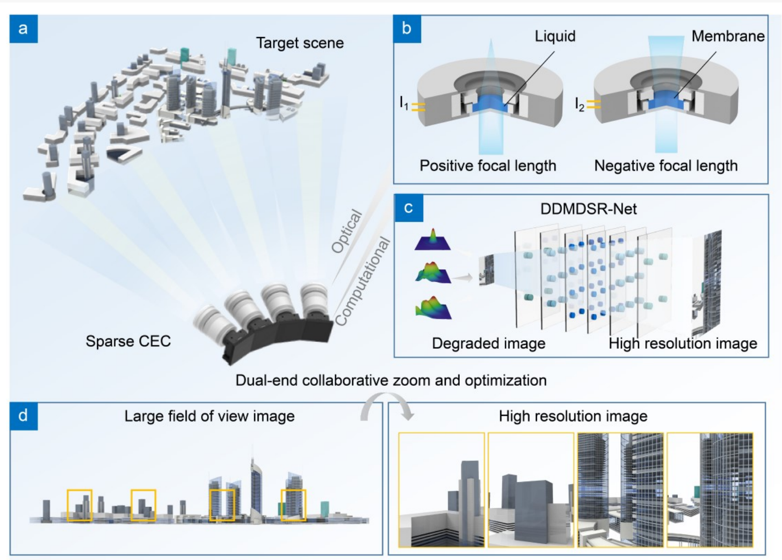
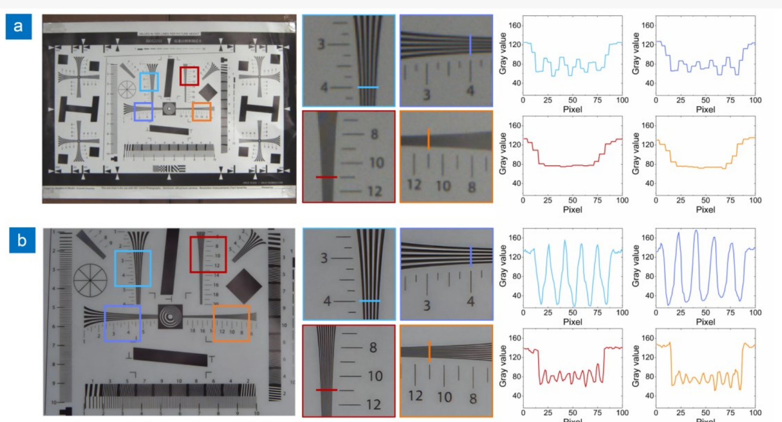
Fast-zoom and high-resolution sparse compound-eye camera based on dual-end collaborative optimization

The proposed CEC has important application value in fields such as geodesy, search and track, urban traffic monitoring.



Concept of fast-zoom and high-resolution sparse CEC based on dual-end collaborative optimization.



a) Resolution test results in the original imaging state; (b) Resolution test results after dual-end collaborative optimization.

CHENGDU, SICHUAN, CHINA, May 30, 2025 /EINPresswire.com/ -- Research background

The popularization and diffusion of compound-eye array camera technology faces formidable challenges. On the one hand, the high-resolution realization of compound-eye array camera systems usually relies on a large-scale number of cameras and high-pixel-density image sensors, with high system complexity and limited imaging real-time. Zoom imaging technology is expected to reduce the number of cameras and the need for sensor pixel density and improve imaging adaptability while taking into account the large field of view and high-resolution imaging capability of the compound eye. However, the traditional mechanical zoom method is slow and lacks dynamic responsiveness, and the introduction of compound-eye array cameras will cause a drastic increase in the size, weight, and power consumption, which makes it difficult to apply to compound-eye array cameras. On the other hand, the compound-eye array camera is susceptible to the interference of the imaging environment during the actual imaging, resulting in the degradation of the imaging quality and difficulty in giving full play to its resolution advantage, and due to the variability of the environmental interference factors and the inherent manufacturing tolerances caused by the variability between the sub-camera units, the traditional image processing algorithms are often difficult to complete the image information demodulation and enhancement of the compound-eye array camera. Therefore, the realization of fast optical zoom and high-fidelity resolution enhancement in compound-eye array cameras remains a key challenge to be solved.

Highlights of the paper

To address the above problems, the Beihang University team of Prof. Qiong-Hua Wang proposed a fast-zoom and high-resolution sparse compound-eye camera (CEC) based on dual-end collaborative optimization, which improves the resolution and imaging adaptability of the CEC through the synergy of the fast zoom at the optical end and the information demodulation at the computational end, and provides a cost-effective and efficient technological solution for the compatible realization of large-field-of-view, high-resolution, fast, and strongly adaptive imaging, as shown in Fig. 1 (a).

In the optical end, the team innovated a method for fast zoom compound eye imaging through liquid lenses. Each sub-camera in the compound eye camera they designed contains two liquid lenses, and the changes in the liquid-lens liquid interface can be controlled by the electromagnetic driving method, so that the imaging focal length and imaging aberration of the camera can be quickly adjusted, as shown in Fig. 1(b). The introduction of liquid lens technology both ensures the integration of the compound eye camera and endows the compound eye camera with zoom imaging capability with millisecond response time. In the computational end, the team proposed a disturbed degradation model driven super-resolution network, as shown in Fig. 1(c). They first constructed an image-physical degradation model taking into account environmental disturbances, manufacturing tolerances of the designed camera, and acquisition noise, and then generated a library of degradation functions and used them to train the image reconstruction network by applying reasonable perturbation factors, thus eliminating the complex calibration process of degradation functions. At the same time, they introduced a channel attention mechanism into the training and reconstruction process of the network, which enhanced the ability of the network to extract effective feature information. Coupling the image reconstruction network with optical zoom enables the CEC to acquire high-resolution images of key targets with high robustness and fidelity while maintaining a large field-of-view imaging capability, as shown in Fig. 1(d).

To verify the effectiveness of the proposed dual-end collaborative optimization mechanism, the team conducted imaging resolution tests using this compound-eye camera. In the original imaging state, the CEC can capture a large field-of-view image and the line pairs of the fourth group elements can be distinguished, which means the initial angular resolution reaches 71.6", as shown in Fig. 2(a). After dual-end collaborative zoom and optimization, the CEC was able to clearly distinguish the line pairs of the eleventh group elements, with the angular resolution improved to 26.0", and a significant improvement in the low-frequency imaging contrast was also observed, as shown in Fig. 2(b). The imaging performance test results indicate the proposed method cannot only enhance low-frequency information, but also successfully overcome the interference of blur and noise, extracting and amplifying the required high-frequency information.

This research work, by combining liquid lens technology and computational imaging technology, provides an economical and efficient technical solution for achieving large field of view, high resolution, fast, and highly adaptable imaging compatible with compound eye cameras. The research results are expected to be applied in various fields such as machine vision, urban traffic, and security monitoring. This work, titled "Fast-zoom and high-resolution sparse compound-eye camera based on dual-end collaborative optimization," has been published in Opto-Electronic Advance early view section.

Research Team
Prof. Qiong-Hua Wang is a Changjiang Scholar Distinguished Professor in the Ministry of Education, a recipient of the National Science Fund for Distinguished Young Scholars, a top talent in the National "Ten Thousand Talents Plan" for scientific and technological innovation, a fellow of the Chinese Optical Society, the International Society for Optical Engineering, the Society for Information Display, the Optical Society of America, and the Optical Engineering Society, and the project leader of the National Key Research and Development Program. The focus of the research is on imaging and display technologies. She has published over 350 papers indexed by SCI, authored three books with Science Press, granted nearly 200 invention patents in the United States and China, and received the 2023 National Technology Invention Award (Second Class) as the primary contributor, among other scientific and technological achievements. From 2001 to 2004, she served as a Research Scientist at the College of Optics, University of Central Florida, USA. From 2004 to 2018, she was a professor and doctoral advisor at Sichuan University. Since 2018, she has been a professor and doctoral advisor at Beihang University. Currently, Prof. Qiong-Hua Wang leads a research team of 42 members, including 6 faculty members, 1 postdoctoral researcher, 1 assistant, 23 doctoral students, and 11 master's students. The team's main research work focuses on 3D display technology, liquid crystal technology, liquid photonic devices, and imaging technology.

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