COME 2024

COMPUTATIONAL OPTICAL MEASUREMENT AND ITS EDUCATION

第六届计算光学测量及其教育国际研讨会

June 28 - 30, 2024 Chengdu, China

PROGRAM BOOK

会议手册

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ABOUT THE CONFERENCE

Computational Optical Measurement, as a cross-discipline, combining knowledge and techniques from the fields of optics, computer science and engineering, aims to realize high-precision and high-efficiency optical measurements using computational methods. The forum focuses on the in-depth integration of cutting-edge research and postgraduate education, involving research fields including but not limited to optical measurement, optical testing, experimental mechanics, three-dimensional imaging, computational optics, optical instrumentation, artificial intelligence, etc.

To promote academic exchanges and cooperation, technological progress and application innovation, and to provide a platform for young scholars to communicate, scholars in this field have advocated and initiated the International Forum on Computational Optical Measurement and its Education in 2019. The 6th International Forum on Computational Optical Measurement and its Education (COME2024) will be organized by Sichuan University and held from June 28 to June 30, 2024 in Chengdu, China. This forum has invited eight well-known experts in related fields to share their academic achievements and experiences. And a student presentation competition is held to provide a platform for research students to exchange ideas and learn from each other, where 16 Oral Presentations will be awarded.

Welcome you to this global forum to share your ideas and experiences, enjoy the company of new and old friends.

Conference Chairs

Prof. Qican Zhang
Sichuan University

Prof. Xianyu Su
Sichuan University

Prof. Kemao Qian
Nanyang Technological University

Conference Secretary

Zhoujie Wu
Sichuan University

Yuankun Liu
Sichuan University

Organized By

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Yehuan Deng	Yilan Nan	Zhaosheng Chen	Zhengdong Chen

Conference Venue

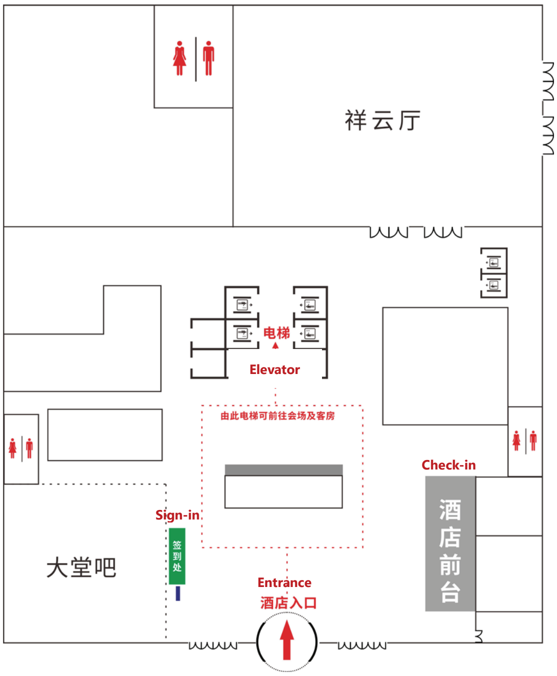
XIANGYU HOTEL

Address: No.103 Xinnan Road, Wuhou District, Chengdu, China.

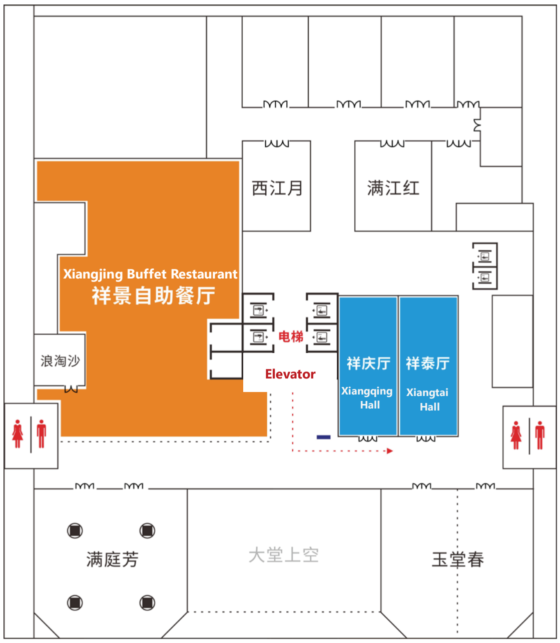
Venue Info:

Level	Meeting Room	June 28	June 29
2F	Xiangqing Hall	✦	
2F	Xiangtai Hall	✦	
3F	Xiangrui Hall		✦

1F

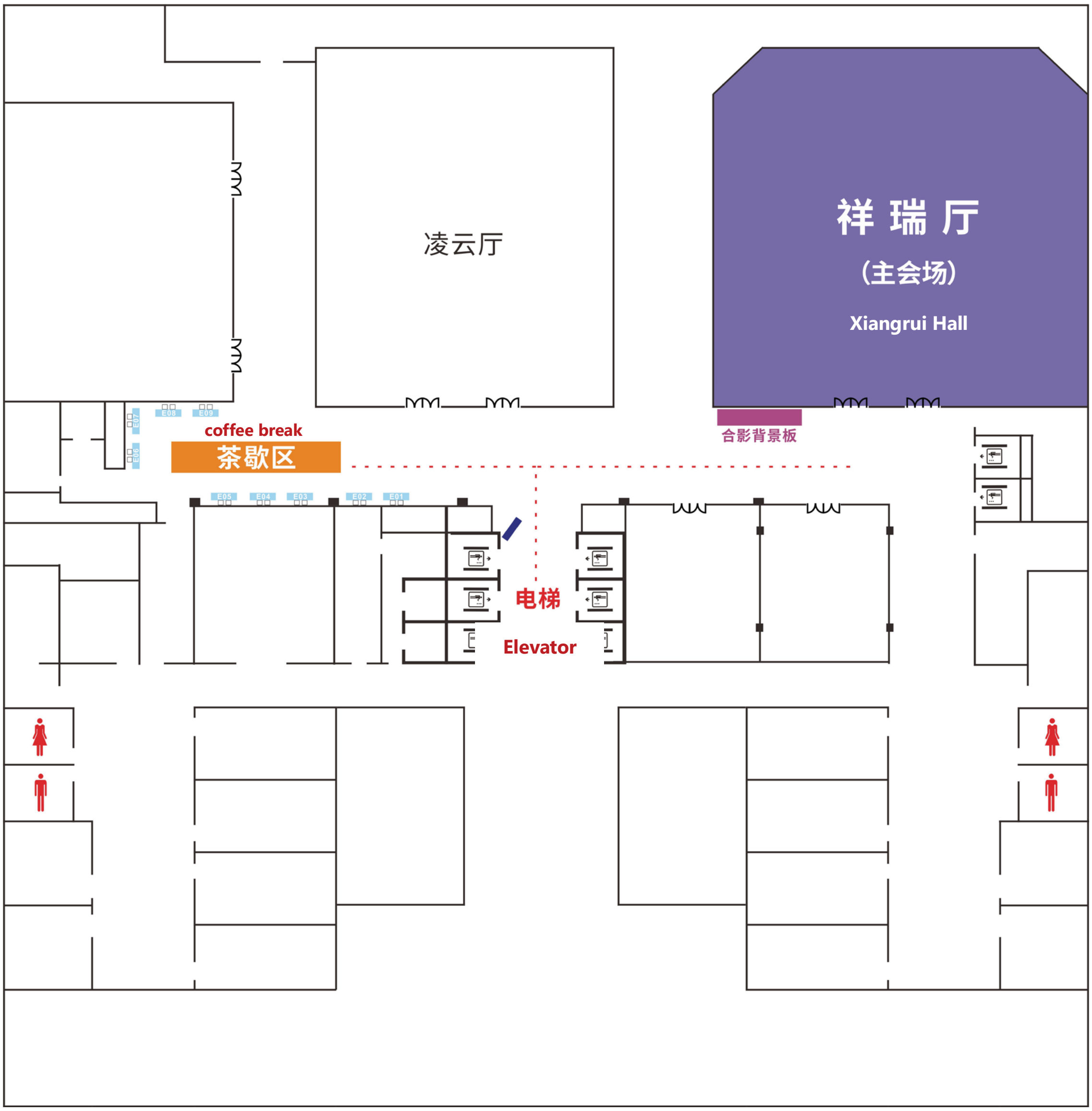


2F



CONFERENCE VENUE

3F



EXHIBITION

E01

光电期刊集群
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E02

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E03

南京理工大学
NANJING UNIVERSITY OF SCIENCE & TECHNOLOGY

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E08

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SICHUAN UNIVERSITY

E09

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TRANSPORTATION

From Chengdu Shuangliu International Airport(recommend)

By Car	Approx. 25 minutes by car/drive, distance approx. 17.3 km
By Metro	About 38 minutes, take the airport line metro **Line 10** (**direction of Taipingyuan**), take **5** stops, change to metro **Line 3** (**direction of Chengdu Medical College**) at **Taipingyuan Station**, take **5** stops, get off at **Moziqiao Station**, and you can directly access the hotel's underground parking lot on the second floor below ground from **Exit A** of the subway station.
By Bus	Take the **Airport Shuttle Bus Line 1** to the Sichuan Gymnasium Station, get off and transfer to **Bus Line 1130**, and get off at **Moziqiao Station**. Walk approximately 313 meters (about 5 minutes) to reach the Xiangyu Hotel.

From Chengdu Tianfu International Airport

By Car	Approx. 52 minutes by car/drive, distance approx. 60 km
By Metro	About 1 hour and 15 minutes, take metro **Line 18 (direction of South Railway Station)**, take **10** stops, change to metro **Line 1 (direction of Weijianian Station)** at South Railway Station, take **3** stops, change to metro **Line 3 (direction of Chengdu Medical College)** at Provincial Gymnasium, take **1** stop, get off at **Moziqiao Station**, and get off at the underground car park of the guesthouse on the negative two floors from Metro **Exit A**.

From Chengdu East Railway Station

By Car	Approx. 25 minutes by car/drive, distance approx. 14.1 km
By Metro	About 29 minutes, take Metro **Line 2 (direction of Xipu Railway Station)** at East Railway Station Metro Station, change to Metro **Line 3 (direction of Shuangliu West Railway Station)** at Chunxi Road Station, take **2** stops, get off at **Moziqiao Station**, and get off at the underground car park of the guesthouse on the negative two floors from Metro **Exit A**.
By Bus	Take bus 49 or 19 and get off at Moziqiao Station.

From South Railway Station

By Car	Approx. 15 minutes by car/drive, distance approx. 5 km
By Metro	About 17 minutes, take **Metro Line 1 (direction of Weijianian Station)** at East Railway Station Metro Station, take **3** stops, change to **Metro Line 3 (direction of Chengdu Medical College)** at Sichuan Gymnasium Station, take **1** stop, get off at **Moziqiao Station**, and get off at the underground car park of the guesthouse on the negative two floors from Metro **Exit A**.
By Bus	Take bus 49 or 19 and get off at Moziqiao Station.

交通指南

成都双流机场（推荐）-成都融通祥宇宾馆

驾车	乘车/驾车约 25 分钟，距离约 17.3 公里
地铁	约 38 分钟，乘坐机场线**地铁 10 号线（太平园方向）**，乘坐 **5** 站，在**太平园站**换乘**地铁 3 号线（成都医学院方向）**，乘坐 **5** 站，至**磨子桥站**下车，从**地铁 A 口**可直接到宾馆地下停车场负二楼
公交	乘坐**机场专线 1 号线**大巴到**省体育馆站**下车换乘 **1130 路公交车**并在**磨子桥站**下车，步行约 313 米（约 5 分钟）可到达成都融通祥宇宾馆。

成都天府国际机场-成都融通祥宇宾馆

驾车	乘车/驾车约 52 分钟，距离约 60.0 公里
地铁	约 1 小时 15 分钟，乘坐**地铁 18 号线（火车南站方向）**，乘坐 **10** 站，在火车南站换乘**地铁 1 号线（韦家碾方向）**，乘坐 **3** 站，在**省体育馆**换乘**地铁 3 号线（成都医学院方向）**，乘坐 **1** 站，**磨子桥站**下车，从**地铁 A 口**可直接到宾馆地下停车场负二楼

成都东站-成都融通祥宇宾馆

驾车	乘车/驾车约 25 分钟，距离约 14.1 公里
地铁	约 29 分钟，在火车东站地铁站乘坐**地铁 2 号线（犀浦方向）**，在**春熙路站**换乘**地铁 3 号线（双流西站方向）**，乘坐 **2** 站，在**磨子桥站**下车，从**地铁 A 口**直接到宾馆地下停车场负二楼。
公交	乘坐 49 路、19 路在磨子桥站下车

成都南站-成都融通祥宇宾馆

驾车	乘车/驾车约 15 分钟，距离约 5 公里
地铁	约 17 分钟，在火车东站地铁站乘坐**地铁 1 号线（韦家碾方向）**，乘坐 **3** 站，在**省体育馆站换乘地铁 3 号线（成都医学院方向）**，乘坐 **1** 站，在**磨子桥站**下车，从**地铁 A 口**直接到宾馆地下停车场负二楼。
公交	乘坐 49 路、19 路在磨子桥站下车

Agenda Overview

Sign-in & Conference Materials Collection	6/28 10:00-19:00 6/29 08:00-17:00 @Lobby of Xiangyu Hotel

Day1 | June 28, 2024

Time	Activity	Chair & Venue
10:00-19:00	Sign-in & Conference Materials Collection	Lobby
	Special Session	
13:30-14:30	Scientific Research and Writing **Kemao Qian**, Nanyang Technological University **Qican Zhang**, Sichuan University	Chair: **Chao Zuo**, Nanjing University of Science and Technology Xiangqing Hall(2F)
14:30-15:00	Corporate Presentation **Sichuan Visensing Technology Co., Ltd** **Sichuan LEAD Industrial Info Tech Co., Ltd** **Opto-Electronic Journals Group**	Chair: **Yuankun Liu**, Sichuan University Xiangqing Hall(2F)
15:00-15:15	Coffee Break	
15:15-17:35	Student Competition-I	Chair: **Shijie Feng**, Nanjing University of Science and Technology Xiangqing Hall(2F)
	Student Competition-II	Chair: **Zhoujie Wu**, Sichuan University Xiangtai Hall(2F)

Day2 | June 29, 2024

Time	Activity	Chair & Venue
	Opening Ceremony	
08:40-08:45	Welcome Address **Chao Liu**, Vice President, Sichuan University	Chair: **Qican Zhang**, Sichuan University Xiangrui Hall(3F)
08:45-08:50	Welcome Address **Yang Yang**, Dean, School of EIE, Sichuan University	
08:50-08:58	Introduction to the Conference **Chenxing Wang**, Southeast University **Haixia Wang,** Zhejiang University of Technology	
08:58-09:00	Group Photo	

Time	Activity	Chair & Venue
Keynote Speeches		
09:00-09:40	*An Introduction to Coherence Scanning Interferometry* **Peter de Groot** President-Elect of SPIE Scientist Emeritus, Zygo Corporation	Chair: **Junfei Shen**, Sichuan University Xiangrui Hall(3F)
09:40-10:20	*Portable Structured-light Metrology System for Form Measurement of Composite Structured Surfaces* **Feng Gao**, Professor of University of Huddersfield	
10:20-10:40	Coffee Break	
10:40-11:20	*Integral Imaging Light Field 3D Display* **Qionghua Wang**, Professor of Beihang University	Chair: **Yuankun Liu**, Sichuan University Xiangrui Hall(3F)
11:20-12:00	*When Optimization Meets Deep Learning* **Liheng Bian**, Professor of Beijing Institute of Technology	
12:00-14:00	Lunch	
14:00-14:40	*Engineered Microsphere and Compound Lens for Optical Nano-Imaging* **Minghui Hong** Academician of the Academy of Engineering, Singapore Professor of Xiamen University	Chair: **Yajun Wang**, Sichuan University Xiangrui Hall(3F)
14:40-15:20	*Full-field Vibration Measurement by LDV-enhanced Imaging Technology* **Yu Fu** Sino-German Humboldt Scholar Researcher at Temasek Singapore Professor of Shenzhen University	
15:20-15:40	Coffee Break	
15:40-16:20	*The Journey of Chasing the Light* **Zhenzhong Xiao** Director, CTO, ORBBEC Inc.	Chair: **Zhongtao Cheng**, Sichuan University Xiangrui Hall(3F)
16:20-17:00	*Exploiting Spatiotemporal Priors for Motion-resolved Holographic Imaging* **Liangcai Cao**, Professor of Tsinghua University	
Awards and Closing Ceremony		
17:00-17:15	Awards Ceremony **Wei Yan**, Sichuan Visensing Technology Co., Ltd **Yingjie Yu**, Shanghai University **Liangcai Cao**, Tsinghua University **Xianyu Su**, Sichuan University	Chair: **Zhoujie Wu**, Sichuan University Xiangrui Hall(3F)
17:15-17:35	Sharing By **Xianyu Su**, Sichuan University	
17:35-17:45	COME 2025 Announcement **Yingjie Yu**, Shanghai University	
17:45-17:50	COME 2024 Summary, Closing **Qican Zhang**, Sichuan University	

KEYNOTE SPEAKERS

JUNE 29, 2024 | 09:00-09:40

Peter de Groot

President-Elect of SPIE
Scientist Emeritus, Zygo Corporation

Prof. Peter de Groot is fascinated by optics and its practical use for measuring things. Educated first in History then in experimental atomic Physics at the Universities of Grenoble, Maine, and Connecticut, he enjoys discovering the hidden links between academic and applied research that fuel inventions and creative solutions in science and industry.

Dr. de Groot joined Zygo in 1992, and has been Executive Director of Research, Chief Scientist, and now Scientist Emeritus. His work has led to 141 US patents for optical instruments and 225 technical papers and book chapters. He is a Fellow of numerous international professional societies, and is the 2024 President Elect of SPIE, the international society for optics and photonics.

An experienced educator, Dr. de Groot has taught secondary school science as well as advanced topics at universities, and professional development courses worldwide, as an instructor, adjunct professor, and honorary professor.

Speech Title

An Introduction to Coherence Scanning Interferometry

Abstract: The story of coherence scanning interferometry (CSI) is a journey through the history of optics, beginning with the discovery of interference fringes and leading up to present-day methods of surface structure analysis. For a time, after the invention of the laser, the principles of low-coherence interferometry were forgotten, as researchers raced to develop laser-based distance sensors. The rediscovery of white light methods thirty years ago dramatically advanced applications for high precision measurements using light waves, leading to modern CSI microscopy.

In this lecture, I trace the history of interferometry with incoherent light sources from Newton's colored bands to the current state of the art in optical metrology. We will see how the fundamentals of coherence and fringe formation enable manufacturing metrology for everything from engine parts to virtual reality headsets. Current topics include both practical instrument design as well as scattering theory applied to the interaction of light with surfaces.

KEYNOTE SPEAKERS

JUNE 29, 2024 | 09:40-10:20

Feng Gao

Professor of University of Huddersfield

Dr F. Gao is a Reader at the School of Computing and Engineering, University of Huddersfield, UK. His research interests focus on the study of optical interferometry, 3D fringe projection for surface measurement, metasurfaces and their applications. He studied precision measurement and instrumentation as an undergraduate and postgraduate student at Tianjin University. He was awarded a Ph.D. degree at Coventry University, UK. His research experience includes research and development of dimensional metrology instruments and measurement standards at the National Institute of Metrology of China and PTB, Germany, as well as research in the fields of surface metrology and surface strain measurement at Loughborough University, UK.

Speech Title

Portable Structured-light Metrology System for Form Measurement of Composite Structured Surfaces

Abstract: A portable hybrid structured-light based measurement system is presented for in-situ and embedded form metrology of structured composite surfaces. The proposed technique contains three subsystems: phase measuring deflectometry (PMD) subsystem, fringe projection profilometry (FPP) subsystem, and stereo vision subsystem. PMD subsystem accurately reconstructs the form data of specular surfaces based on the principle of structured-light reflection, while FPP subsystem measures rough surfaces by projecting structured light on the measured surfaces. Then the output data from the subsystems are stitched to reconstruct a complete form of the measured composite surfaces. An embedded measurement experiment in a diamond turning machine demonstrates that the proposed techniques can achieve 24.8 μm form accuracy in rough surface measurement and 400 nm form accuracy in specular surface measurement.

Keynote Speakers

JUNE 29, 2024 | 10:40-11:20

Qiong-Hua Wang

Professor of Beihang University

Qiong-Hua Wang is a professor of optics at Beihang University. She was a professor at Sichuan University from 2004 to 2018. She was a post-doctoral research fellow at School of Optics/CREOL at the University of Central Florida from 2001 to 2004. She was a faculty at the University of Electronic Science and Technology of China (UESTC) from 1995 to 2001. She received B. S., M. S. and Ph. D. degrees from UESTC in 1992, 1995 and 2001, respectively. She published more than 350 papers in peer-review journals and authored 3 books. She holds more than 160 US and Chinese patents. She is a Fellow of SID, OPTICA, SPIE and COS. Her research interests include display and imaging technologies.

Speech Title

Integral Imaging Light Field 3D Display

Abstract: Integral imaging 3D display is one import 3D display technology. In order to improve the performance of the integral imaging 3D display, we proposed and developed a large-viewing angle tabletop integral imaging 3D display and a high-resolution integral imaging 3D display. The structure, principle and performance of the integral imaging 3D displays will be introduced in detail in the talk.

Keynote Speakers

JUNE 29, 2024 | 11:20-12:00

Liheng Bian

Professor of Beijing Institute of Technology

Liheng Bian is a Professor with Beijing Institute of Technology. His research interests include computational imaging and sensing. He has published a monograph of Computational Imaging and Sensing, and over 60 peer-reviewed papers on Nature Communications, Light: Science & Applications, eLight, CVPR, and etc. He has also been granted more than 40 patents. He has been elected to the Outstanding Youth Project of the National Natural Science Foundation of China. He has been awarded the the first prize of the Chinese Institute of Electronics, first prize of the Ministry of Public Security of the People's Republic of China, the first prize in the National Finals of the Third "Yuanchuang Cup" Innovation and Creativity Competition, and the Best Paper Award of SPIE Photonics West Conference. He has served as the guest editor of "Light: Science & Applications" and "Light: Advanced Manufacturing", and joined the young editorial board of "Space: Science & Technology" and "Signal Processing".

Speech Title

When Optimization Meets Deep Learning

Abstract: Computational reconstruction is one of the most important processes of computational imaging, and the performance of reconstruction algorithms directly impacts imaging quality. Conventional reconstruction methods based on convex optimization apply gradient descent to approximate the extremum of the objective function. With the rapid development of computational imaging, modern imaging systems increasingly pursue wide field of view, high resolution, and large spatial bandwidth product reaching up to billions of pixels. The ultra-high computational complexity of the aforementioned optimization-based reconstruction methods poses serious challenge to tackle such large-scale data. As an emerging data-driven reconstruction method, deep learning maintains low computational complexity, high fidelity and high efficiency. However, it exhibits poor generalization, and requires large-scale datasets and retraining for different system configurations or even different parameters. In this context, we explore a hybrid joint optimization reconstruction method integrating both convex optimization and deep learning. This approach leverages the advantages of both model-based and learning-based methods, resulting in high efficiency, strong robustness, and wide generalization. Experiments demonstrates its capability to achieve large-scale high-dimensional computational imaging in both real and complex domains.

KEYNOTE SPEAKERS

JUNE 29, 2024 | 14:00-14:40

Minghui Hong

Academician of the Academy of Engineering, Singapore
Professor of Xiamen University

Prof. Hong Minghui is the Tan Kah Kee Chair Professor, Xiamen University, China. He is also the Engineering Technology Division Chairman and Dean of Pen-Tung Sah Institute of Micro-Nano Science and Technology of Xiamen University. Prof. Hong specializes in laser microprocessing & nanofabrication. He has co-authored 15 book chapters, 42 patents granted, and ~600 scientific papers and 100+ plenary/keynote/invited talks in international conferences. He is a member of organizing committees for Laser Precision Micromachining International Conference (2001~2024), International Symposium of Functional Materials (2005, 2007 and 2014), Chair of International Workshop of Plasmonics and Applications in Nanotechnologies (2006), Chair of Conference on Laser Ablation (2009) and Chair of Asia-Pacific Near-field Optics Conference (2013 and 2019). Prof. Hong is invited to serve as an Editor of Light: Science and Applications, Engineering, Science China G, Laser Micro/nanoengineering, and Executive Editor-in-chief of Opto-Electronic Advances and Opto-Electronic Science. Prof. Hong is Fellow of Academy of Engineering, Singapore (FSEng), Fellow of Optical Society of America (OPTICA), Fellow of International Society for Optics and Photonics (SPIE), Fellow of International Academy of Photonics and Laser Engineering (IAPLE) and Fellow of Institution of Engineers, Singapore (IES). As an active tech entrepreneur, he is also the leading founder of Phaos Technology Pte. Ltd., Opto Science Pte. Ltd. and Xiamen Light Technology Integration Pte. Ltd.

Speech Title

Engineered Microsphere and Compound Lens for Optical Nano-Imaging

Abstract: Microsphere optical nanoscope, as a competitive nano-imaging technique, has extensive applications in the semiconductor industry and biology due to its real-time imaging ability, label-free characteristics, and good compatibility with conventional microscopes. After years of rapid development, the microsphere optical nanoscope still faces restrictions on imaging resolution, contrast, magnification, and field-of-view. To further promote the imaging performance of the microsphere optical nanoscope, two new technical modification routes are developed. At single component level, engineered microspheres with enhanced nano-imaging ability, such as hyper-hemi-microsphere and bilayer-film-decorated microsphere, are put forward and realized through diverse nanofabrication techniques. At device level, substituting single microsphere with microsphere compound lens can improve imaging performance in multiple aspects, such as customized magnification and large field-of-view. Effectiveness of these modifications has been proved in semiconductor chip inspection and microfluidic dynamic nano-imaging. Furthermore, these technical advances pave way for a miniaturized all-microspheres nanoscope with an ultra-compact system configuration, which makes low-cost and portable optical nanoscopes feasible..

KEYNOTE SPEAKERS

JUNE 29, 2024 | 14:40-15:20

Yu Fu

Sino-German Humboldt Scholar
Researcher at Temasek Singapore
Professor of Shenzhen University

Dr. Yu Fu received his bachelor 's degree in Mechanical Engineering from Shanghai Jiao Tong University and his master's and doctoral degrees in Mechanical Engineering from the National University of Singapore.

In 1997, Dr. Fu joined the Department of Mechanical Engineering at the National University of Singapore as a Professional Officer, pursuing research on optical measurement and image processing techniques. He has published more than 100 papers in leading international journals and conference proceedings. In 2006, he was awarded the prestigious Alexander von Humboldt research fellowship and worked with the renowned Institute of Technical Optics (ITO), the University of Stuttgart, on optical dynamic measurement. He joined Temasek Laboratories at Nanyang Technological University in 2009. In July 2011, Dr. Fu received the prestigious Temasek Fellowship from Singapore's Ministry of Defence and Nanyang Technological University to serve as a Principal Investigator in Temasek Laboratories. In 2018, he joined Shenzhen University as a Professor in the College of Physics and Optoelectronic Engineering. Currently, Dr. Fu's research focuses on optical dynamic measurement and structural health diagnostics. Dr. Fu is also a Fellow member of SPIE.

Speech Title

Full-field Vibration Measurement by LDV-enhanced Imaging Technology

Abstract: Vibration measurement, particularly the measurement of mode shapes, is crucial for structural dynamic analysis and defect localization because it helps validate finite element or analytical vibration models. Laser Doppler Vibrometry (LDV) and high-speed Digital Image Correlation (DIC) are the leading methods for experimental mode shape measurement. Unfortunately, the resolution of DIC is insufficient for detecting vibrations in normal structures. Similarly, the spatial sampling provided by LDV is limited. We have proposed a new full-field vibration measurement method that utilizes LDV-enhanced imaging technology with standard-rate cameras. This imaging technique could involve DIC or fringe/speckle projection. Our experiments demonstrate that the LDV spectrum can guide the removal of camera noise and significantly enhance the resolution of vibration measurements using imaging technology. The results of data fusion indicate that this method can effectively localize defects in various structures through vibration measurement.

KEYNOTE SPEAKERS

JUNE 29, 2024 | 15:40-16:20

Zhenzhong Xiao

Director, CTO, ORBBEC Inc.

Dr. Zhenzhong Xiao, professor level senior engineer, co-founder of ORBBEC Inc., received his Bachelor's degree, Master's degree and PhD degree from Xi'an Jiaotong University, and went to Nanyang Technological University, Singapore for postdoctoral research in 2010, and then he was appointed as a doctoral lecturer in the School of Mechanical Engineering of Xi'an Jiaotong University, mainly engaged in the research of machine vision and 3D sensing technology, and he has been co-founded ORBBEC Inc. as the Chief Technology Officer since 2013. He is committed to the research and industrialisation of structured light, active/passive binocular vision and other mainstream optical measurement technologies based on scattered speckle and stripe projection. He has participated in more than 10 research projects at national, provincial and municipal levels, and has applied for 328 patents and granted 129 patents.

Speech Title

The Journey of Chasing the Light

Abstract: With the optical measurement has been twenty years, read the master's degree and doctoral degree to stay in school and then leave school to start a business, academics have the good fortune to meet three or five friends, entrepreneurial road to make people grow more. What hasn't changed over the years is to keep learning and pursuing light.

KEYNOTE SPEAKERS

JUNE 29, 2024 | 16:20-17:00

Liangcai Cao

Professor of Tsinghua University

Liangcai Cao received his BS/MS and PhD degrees from Harbin Institute of Technology and Tsinghua University, in 1999/2001 and 2005, respectively. The n he became an assistant professor at the Department of Precision Instruments, Tsinghua University. He is now tenured professor and director of the Institute of Opto-electronic Engineering, Tsinghua University. He was a visiting scholar at UC Santa Cruz and MIT in 2009 and 2014, respectively. His research interests are holographic imaging and holographic display. He is a Fellow of the Optica and the SPIE.

Speech Title

Exploiting Spatiotemporal Priors for Motion-resolved Holographic Imaging

Abstract: Reference-free holographic imaging techniques have been long pursued because they obviate the high experimental requirements of conventional interferometric methods, but they are faced with an inherent trade-off between phase imaging fidelity and temporal resolution. Here, we propose a general algorithmic framework, termed spatiotemporally regularized inversion (STRIVER), for motion-resolved holographic reconstruction by exploiting spatiotemporal priors. Specifically, total variation with respect to the complex spatio-temporal datacube is introduced as a sparsity-promoting regularizer.

We experimentally demonstrate the use of spatiotemporal sparsity and implicit priors to obtain time-resolved holographic video of living organisms at a framerate-limited speed of over 100 Hz. STRIVER can also be potentially extended to other measurement schemes, spectral regimes, and imaging modalities, pushing the temporal resolution of computational imaging toward higher limits.

STUDENT COMPITITION-I

JUNE 28, 2024 | 15:15-17:35 | Xiangqing Hall | 2F

Session Chair: **Shijie Feng**, Nanjing University of Science and Technology

Student Chairs: **Cui Huang**, Sichuan University; **Junjie She**, Sichuan University

TABLE OF TIME

Time	Speaker/Title
15:15-15:25	**Wenfeng Fu**, Southwest University of Science and Technology **Title:** Enhancing the Overall Performance of Perovskite Solar Cells Using Nano-pyramid Anti-reflective Layer
15:25-15:35	**Bin Shen**, Shanghai University **Title:** Ultra-precision Planar Optics Measurement Based on Wavelength Tuning
15:35-15:45	**Wenwu Chen**, Nanjing University of Science and Technology **Title:** Deep-learning-enabled Temporally Super-resolved Multiplexed Fringe Projection Profilometry: High-speed kHz 3D Imaging with Low-speed Camera
15:45-15:55	**Wei Li**, Zhejiang University of Technology **Title:** Anti-spoofing Study on Palm Biometric Features
15:55-16:05	**Xiang Wei**, Nanjing University of Science and Technology **Title:** 3D Computational Modeling of Multispectral Photoacoustic Dermoscopy: Simulations Aiding Systematic Optimization and Data Acquisition
16:05-16:15	**Jiayi Qin**, Sichuan University **Title:** Deep Learning-based Single-shot Fringe Projection Profilometry Using Spatial Composite Pattern
16:15-16:25	**Yu Cai**, University of Science and Technology of China **Title:** Motion Perception Using a Bionic Single Pixel Compound Eye
16:25-16:35	**Chuxuan Huang**, Shanghai Jiao Tong University **Title:** Quantitative Complex Wavefront Retrieval Based on Phase Modulations and Deep Learning
16:35-16:45	**Feifei Chen**, Sichuan University **Title:** Dynamic 3D Reconstruction Under Complex Reflection and Transmission Conditions Using Multi-scale Parallel Single-pixel Imaging
16:45-16:55	**Yanzhao Liu**, Beihang University **Title:** RAFT-DIC: A Task-optimized Neural Network for User-independent, Accurate and Dense Displacement Field Measurements
16:55-17:05	**Wenjun Jiang**, Guangdong University of Technology **Title:** Reinforcement Learning Boosts Coherent Beam Combination Phase Control
17:05-17:15	**Zhihao Li**, Shanghai University **Title:** MEMS Morphology Recovery and Deformation Detection Based on Digital Holography
17:15-17:25	**Jiafa Chen**, University of Shanghai for Science and Technology **Title:** Research on Near-infrared and EEG Dual Modality Imaging Methods for Children with Attention Deficit Hyperactivity Disorder
17:25-17:35	**Kang Wei**, Southeast University **Title:** Deformation and Vibration Measurement of Large-scale Thin-film Structures Based on Stereo-DIC

Enhancing the Overall Performance of Perovskite Solar Cells Using Nano-pyramid Anti-reflective Layer

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ABSTRACT

Perovskite solar cells (PSCs) still suffer from varying degrees of optical and electrical losses. This article provides a new design scheme for ultra-thin perovskite solar cells with high energy conversion efficiency.To enhance the light decoupling and capture ability of Planar PSCs, a PSCs with Al_2O_3 pyramid anti-reflection layer structure (Al_2O_3 PARLs) is proposed. This study investigates the solar absorption characteristics of Al_2O_3 pyramid anti-reflection layer perovskite solar cells (Al_2O_3 pyramid PSCs) using the finite difference time domain method (FDTD). The effect of the structure of Al_2O_3 PARLs on the photoelectric performance of PSCs was investigated by changing various parameters. Under the AM1.5 solar spectrum (300-800 nm), the average light absorption rate and average quantum efficiency (QE) of PSCs containing pyramid array textured rear layers (PARLs) were significantly higher than those of planar PSCs. The Al_2O_3 PARL-based PSCs achieved a light absorption rate 96.05%. Additionally, electrical simulations were performed using the finite element method (FEM) to calculate the short-circuit current density (J_{SC}), open-circuit voltage (V_{OC}), and maximum power (Pmax). Based on the maximum value of the average light absorbance, the geometric structure of Al_2O_3 pyramid PSCs is optimized. And the optimization results coincide with J_{SC} and QE results The results of the electrical simulation indicate that the maximum J_{SC} is 23.54 mA/cm^2. Additionally, the J_{SC} of Al_2O_3 pyramid PSCs is 22.73% higher than that of planar PSCs, resulting in a PCE of 24.34%. As a result, the photoelectric conversion rate of the battery is increased from 14.01% to 17.19%. These findings suggest that the presence of Al_2O_3 PARLs enhances photon absorption, leading to an increase in electron-hole pairs and ultimately improving the photocurrent of the cell.

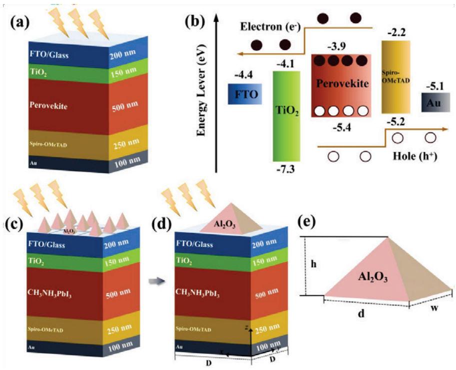

Figure 1. (a) Diagram of Planar PSCs; (b) Energy band diagram of carrier transport in the designed PSCs; (c) Diagram of Al_2O_3 pyramid PSCs; (d) A cycle of the structure; (e) The dimensional details of one cell of Al_2O_3 PARLs (d:w= 1:1).

Keywords: perovskite solar cells, pyramid structure, photoelectric conversion efficiency, Solar energy absorption.

Ultra-precision Planar Optics Measurement Based on Wavelength Tuning

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ABSTRACT

Optical measurement technology has a wide range of applications in the fields of semiconductors, defense and military, additive manufacturing, heritage conservation and underwater morphometry.

Aiming at the problem of high-precision measurement of various optical components that determine the performance level of equipment in large science and large devices, this group has carried out a series of research on precision optical measurement technology and equipment. Taking interferometry of flat optical elements with multiple parallel surfaces as an example, the conventional method suffers from two main problems: On the one hand, the measurement beam will interfere with the reference beam after reflection on the front and rear surfaces of the parallel plate as well as inside, resulting in the surface shape information of the front and rear surfaces being overlapped and not effectively separated; On the other hand, the requirement of a certain multiplicative relationship between the thickness of the measured parallel plate and the length of the interferometric cavity is difficult to meet in the practical measurement environment, which is not conducive to flexible application in the engineering inspection environment. Therefore, this group has proposed a high-precision separation and reconstruction algorithm of multi-surface information under free cavity length based on wavelength-tuned phase shift technique to address the typical problems of current parallel flat plate optical interferometry. By analyzing the relationship model between cavity length multiplication and sampling frequency, combined with the discrete Fourier window transform, this group has established a variety of interferometric harmonic sampling and matching methods. The exact solution of the frequency and phase of multi-surface superimposed interferometric signals with free cavity length has been achieved, which avoids the measurement failure caused by signal overlapping and inaccurate estimation of a priori information and improves the engineering application capability of the algorithm.

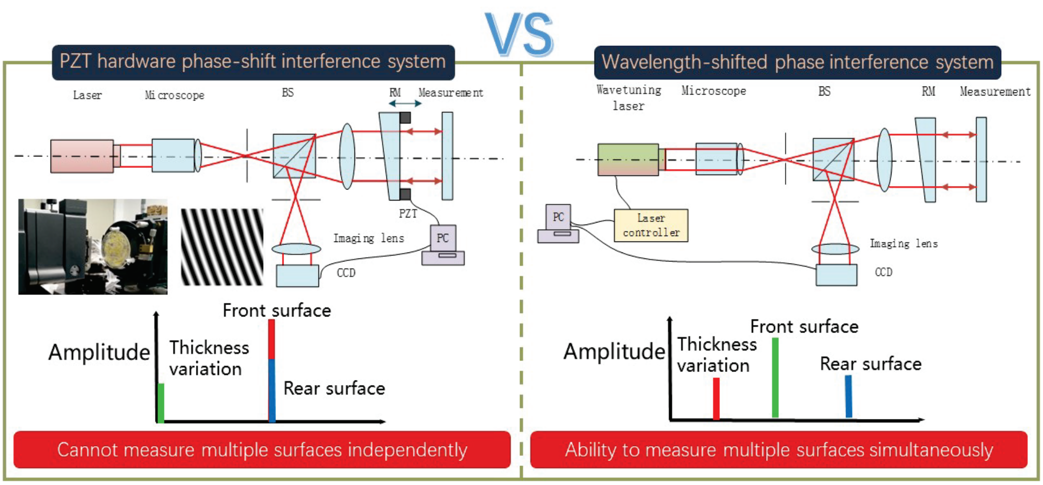

Figure 1. Comparison of phase-shift interference (a) traditional PZT system and (b) Wavelength-shifted system.

Keywords: Optical interferometry, Wavelength tuning, Phase shifting

Deep-learning-enabled Temporally Super-resolved Multiplexed Fringe Projection Profilometry: High-speed kHz 3D Imaging with Low-speed Camera

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ABSTRACT

Recent advances in imaging sensors and digital light projection technology have facilitated rapid progress in 3D optical sensing, enabling 3D surfaces of complex-shaped objects to be captured with high resolution and accuracy. Nevertheless, due to the inherent synchronous pattern projection and image acquisition mechanism, the temporal resolution of conventional structured light or fringe projection profilometry (FPP) based 3D imaging methods is still limited to the native detector frame rates. In this work, we demonstrate a new 3D imaging method, termed deep-learning-enabled multiplexed FPP (DLMFPP), that allows to achieve high-resolution and high-speed 3D imaging at near-one-order of magnitude-higher 3D frame rate with conventional low-speed cameras. By embedding temporal information in one multiplexed fringe pattern, DLMFPP uses deep neural networks to decompose the pattern and analyze separate fringes, furnishing a high signal-to-noise ratio (SNR) and ready implementation solution over conventional computational imaging techniques. We demonstrate this method by measuring different types of transient scenes, including rotating fan blades and bullet fired from a toy gun, at kHz using cameras of around 100 Hz. Experiential results establish that DLMFPP allows slow-scan cameras with their known advantages in terms of cost and spatial resolution to be used for high-speed 3D imaging tasks.

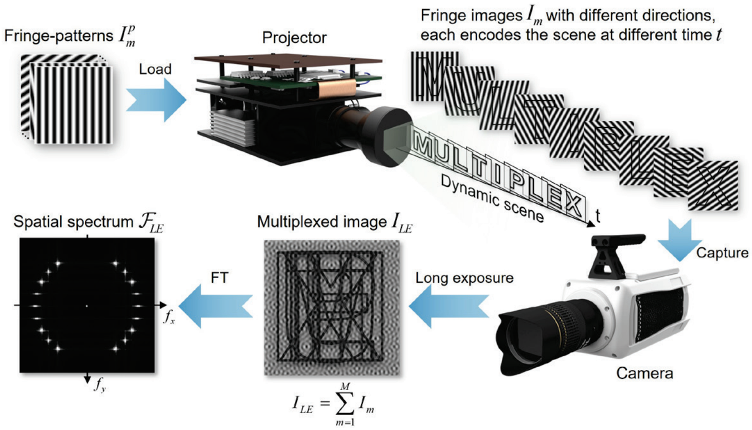

Figure. Schematic of DLMFPP: The projector sequentially projects fringe patterns I_m^p onto the dynamic scene, allowing the corresponding modulated fringe images I_m to encode the scene at different time t. Then the camera captures a multiplexed image I_{LE} with a long exposure time, and the spatial spectrum F_{LE} (multiple fundamental components corresponding to I_m are circularly distributed) can be obtained by Fourier transform (fringe pattern index m=1,2,3,...,M, M is the total number of the patterns). A synthetic scene composed of letters, “MULTIPLEX”, is used to illustrate the principle.

Keywords: 3D imaging, fringe projection profilometry, multiplex, deep learning, temporal super-resolution.

Anti-Spoofing Study on Palm Biometric Features

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ABSTRACT

Spoofing attacks severely threaten the security of biometric recognition systems. Two concerns are raised regarding palm biometrics. Firstly, the anti-spoofing ability of the palm vein as a subcutaneous feature needs further exploration, in-depth research is in need. Secondly, the capability of the palmprint and palm vein in liveness detection has been underestimated. So, extracting extra liveness information for spoofing detection is urgently needed. This study proposes a dual-wavelength synchronous acquisition system for palm biometrics, Static biometrics of palmprint and palm vein and dynamic biometrics of SpO2 and pulse are captured and extracted. The proposed system maintains the recognition ability of the palm biometric system and achieves high anti-spoofing ability without additional hardware requirements. And under the proposed scheme, most hand feature measurement systems can be upgraded to obtain liveness information with minimal adjustment. We used palmprints and veins for recognition and PPG, SpO2, and pulse for anti-spoofing. Based on the dynamic features, this study proposes a three-layer anti deception strategy to evaluate the activity of PPG, SpO2, and pulses. In the first and second layers, SpO2 and pulse are used to determine the authenticity of the measured object, while in the third layer, the PPG signal after zero phase filtering is used to determine. Based on the analysis of the human skin, various artificial palmprints and palm veins are fabricated using a variety of materials. Experiments investigated the anti-spoofing capabilities of palm biometrics. The results show that the proposed system can accurately extract SpO2 and pulse from palmprint and palm vein images, and SpO2 and pulse can significantly increase the anti-spoofing capability of palm biometrics.

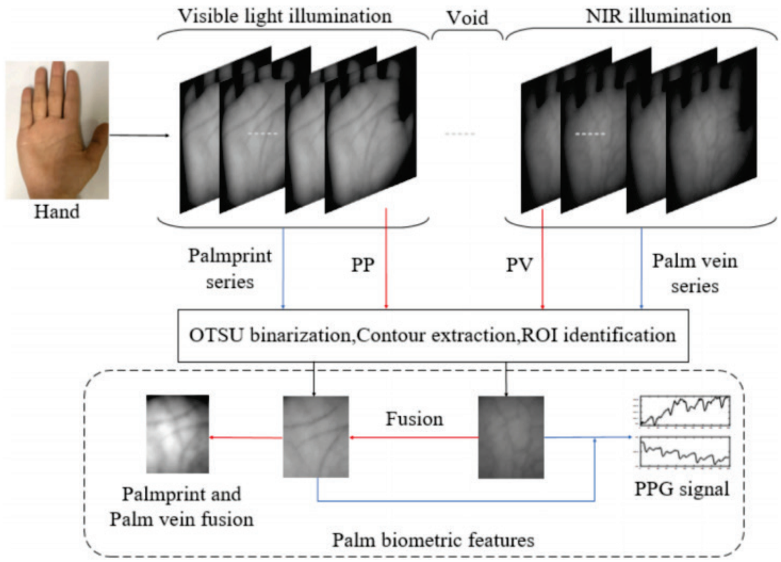

Figure 1. The data processing flow.

Keywords: Anti-spoofing, Dynamic biometrics, SpO2, Pulse, Palm.

3D Computational Modeling of Multispectral Photoacoustic Dermoscopy: Simulations Aiding Systematic Optimization and Data Acquisition

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ABSTRACT

As one of most human diseases, skin diseases are mainly manifested by structural and functional changes of tissues, photoacoustic dermoscopy (PAD) is an emerging non-invasive imaging technology that can help in the diagnosis and assessment of dermatological conditions by directly obtaining optical absorption information of skin tissues, and then providing high-contrast and high-resolution medical image as well as functional and pathobiological information. Despite advances in photoacoustic dermoscopy, it is still not clear how to obtain quantitative accuracy of the reconstructed PAD images according to optical absorption property of skin, distribution and wavelength and excitation light, and acoustic performance of ultrasound transducer. In this work, a hybrid simulation computational model of three-dimensional skin for quantitative PAD by integrating optical (MCmatlab) and ultrasound (k-Wave) propagation simulations is developed, which can be used to correct the optical and acoustic distribution, and provide accurate imging solutions of PAD for dense vessel networks and multilayer skin tissues. And, a series of simulation experiments have been performed on those three-dimensional PAD computational models of skin with three-layer and seven-layer structures to prove that the method could provide a theoretical foundation for the application of quantitative PAD in skin diagnosis, and assist in the development and optimization of PAD equipment, as well as provide assistance for deep learning dataset acquisition.

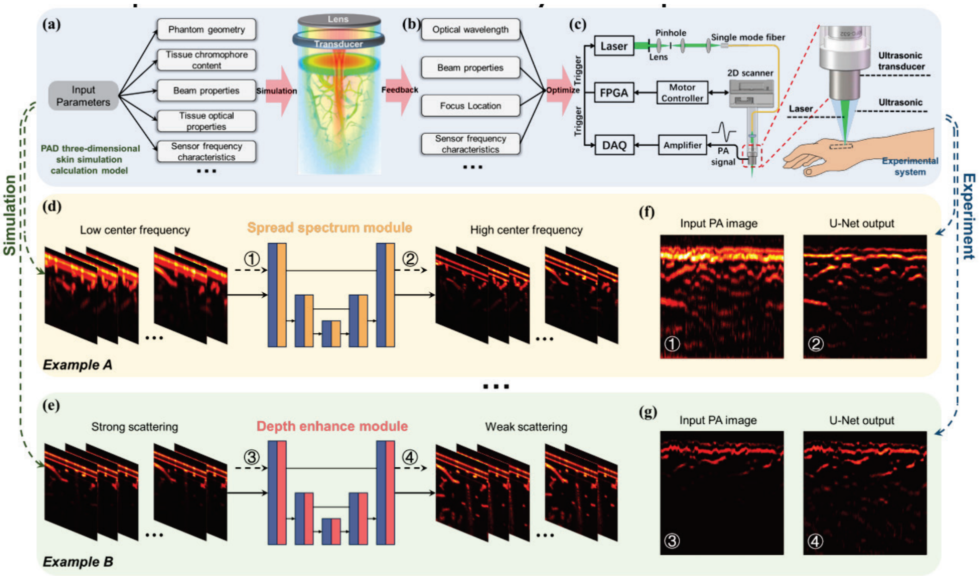

Figure 1. The process of using the 4D spectral-spatial computational PAD combined with experiments for dataset acquisition (a-c) and system optimization for deep learning (d-g).

Keywords: Photoacoustic simulation, skin model, photoacoustic dermoscopy, multispectral, 3D modeling

Deep Learning-based Single-shot Fringe Projection Profilometry Using Spatial Composite Pattern

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ABSTRACT

Single-shot fringe projection profilometry (FPP) is crucial for real-time or dynamic 3D measurement scenarios. In this regard, we propose a spatial composite fringe pattern projection profilometry (SCFPP), which creatively fuses the spatial feature in different frequency fringe patterns. Inspired by image inpainting techniques in computer vision, SCFPP employs a novel adaptive space-division encoding strategy (ASES) to divide fringe patterns into several basic blocks and re-aggregate partial basic blocks in the spatial domain to form a spatial composite fringe pattern. In the demodulation stage, we develop a deep learning network model, the phase inpainting network (PIN), to restore the spatial composite fringe pattern to complete phase information. The absolute phase map is then obtained with high accuracy by applying the conventional three-frequency heterodyne phase unwrapping (CTHPU) algorithm with three known wrapped phase maps. To our knowledge, SCFPP is the first successful use of spatial multiplexing strategy in FPP. Additionally, SCFPP can be seen as an application of image inpainting techniques in the fringe projection field, introducing new ideas for applying computer vision methods in fringe analysis.

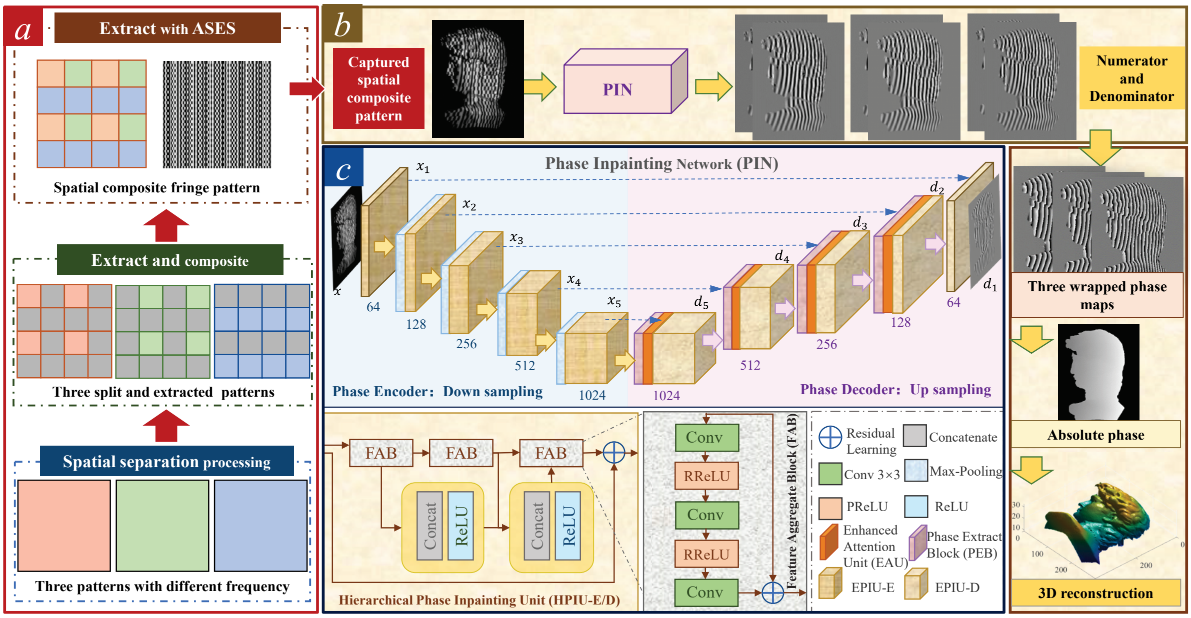

Figure 1. Principle of deep learning-based single-shot fringe projection profilometry using spatial composite pattern: (a) Flow chart of encoding three fringe patterns with different frequencies using adaptive space-division encoding strategy (ASES); (b) 3D measurement process based on deep learning; (c) The phase inpainting network (PIN).

Keywords: Fringe projection, 3D measurement, Single shot, Deep learning, Image inpainting.

Motion Perception Using a Bionic Single Pixel Compound Eye

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ABSTRACT

The insect-inspired artificial compound eye system has many unique advantages, such as a larger field of view, lower aberration, and higher sensitivity to moving object, compared to that of single-aperture vision system. However, most artificial compound eyes utilize CCD or CMOS as image sensor, which limits the information acquisition speed at 30-60 fps. To increase the temporal resolution of artificial compound eye, we design a bionic artificial compound eye system based on multiple single-pixel photodetectors instead of the image sensor. Due to the high bandwidth of the single-pixel photodetector, the maximum value of temporal resolution can reach 3570 [signals (ss)/second (s)], while the maximum value of natural insects is approximately 300 [ss/s]. Our artificial compound eye system shows the unique advantages of multi-channel structure compared to single-aperture camera. In the locating experiment, the locating accuracy has been maximally improved about 64.2% from 7-channel to single channel. In the collision experiment, we can make a simple and rapid judgment of the collision path of the object. The proposed visual system has broad application for the avoidance of obstacles in autonomous mobile robots.

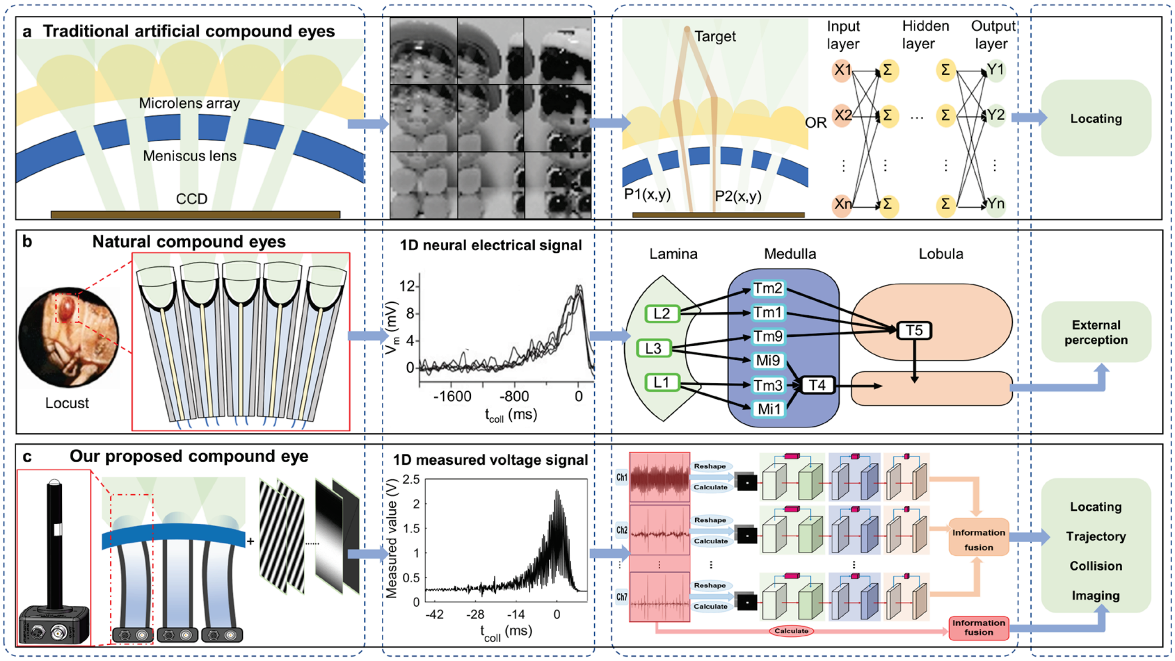

Figure 1. Information processing diagram of three types compound eye system. (a) Artificial apposition compound eye system with a CCD. (b) Vision system of a nature insect. (c) Our proposed bionic apposition compound eye visual system.

Keywords: Single pixel imaging, Compound eye, Motion perception.

Quantitative Complex Wavefront Retrieval Based on Phase Modulations and Deep Learning

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ABSTRACT

Complex wavefront retrieval (CWR) refers to retrieving the complex wavefront (CW), which consists of amplitude and phase distributions of a light field from the intensity-only measurements. CW contains information about reflectivity and surface shape of an object, to retrieve it is essential to various applications including 3D shape measurement. Traditionally, digital holography (DH) is recognized as the benchmark due to its quantitative CWR capability with high accuracy. However, the interferometric structure of DH suffers high complexity of system and high sensitivity to external disturbances. Although many non-interferometric techniques including Shack-Hartmann wavefront sensor (SHWS) and Gerchberg-Saxton algorithm (GS) offer simpler system and higher robustness to external disturbance, there does not exist a technique that has high-accuracy quantitative capability for complex-valued objects comparable to DH. To breakthrough this bottleneck, we propose a technique for quantitative CWR based on phase modulations and deep learning. In the optical system, we utilize a spatial light modulator (SLM) to modulate the target CW with random phase patterns. Such modulations enforce more efficient constraints than pure diffractions, thereby alleviating the ill-posedness of CWR problem. As for algorithm, we design a physics-driven deep learning-based framework. The deep neural network (DNN) in this framework performs the inversion of the measurement formation, it directly predicts the CW in an unsupervised manner. Experimental results demonstrate that our technique enables (1) quantitative CWR with high accuracy at the same level with DH, (2) effective CWR with faster retrieval speed and fewer measurements than non-learning techniques based on phase modulations, (3) CWR with higher spatial bandwidth product (SBP) than other deep learning-based techniques. We believe this paradigm of codesign efficient optical arrangement with powerful computation tool inspires better solvability for CWR problem in the future research.

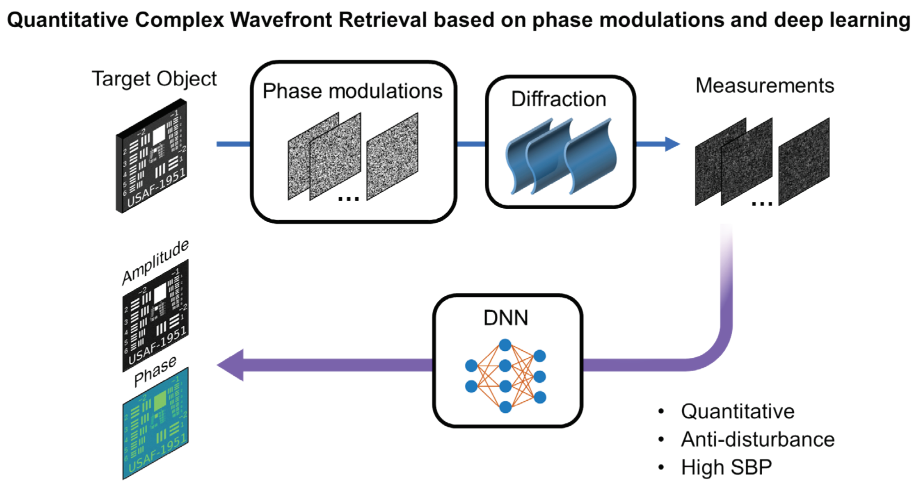

Figure 1. quantitative complex wavefront retrieval based on phase modulations and deep learning.

Keywords: Complex wavefront retrieval, Coherent modulation imaging, Deep Learning.

Dynamic 3D Reconstruction Under Complex Reflection and Transmission Conditions Using Multi-scale Parallel Single-pixel Imaging

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ABSTRACT

Depth measurement and three-dimensional (3D) imaging under complex reflection and transmission conditions is challenging and even impossible for traditional structured light technique, due to its precondition of point-to-point triangulation. Despite recent progress in addressing this problem, there is still no efficient and general solution. In this work, a multi-scale parallel single-pixel imaging technique is proposed for dynamic 3D shape measurement under complex reflection and transmission conditions. Firstly, optimal Fourier dual-slice projection is developed to efficiently separate and utilize different illumination and reflection components, which can significantly decrease the number of projecting patterns in each sequence from thousands to 15. Secondly, multi-scale parallel single-pixel imaging (MS-PSI) is proposed based on the established and proved position invariant theorem, which breaks local regional assumption and enables dynamic 3D reconstruction. And finally, FPP-constrained localization is presented to enable large-depth-range measurement. Our methodology successfully unveils unseen-before capabilities such as (1) accurately depth measurement of the time-varying high-dynamic-range scene under complex reflection condition; (2) dynamic measurement through thin volumetric scattering media at a rate of 333 frames per second; (3) dynamic two-layer 3D imaging of the semitransparent surface and the object hidden behind it, as shown in Fig. 1.

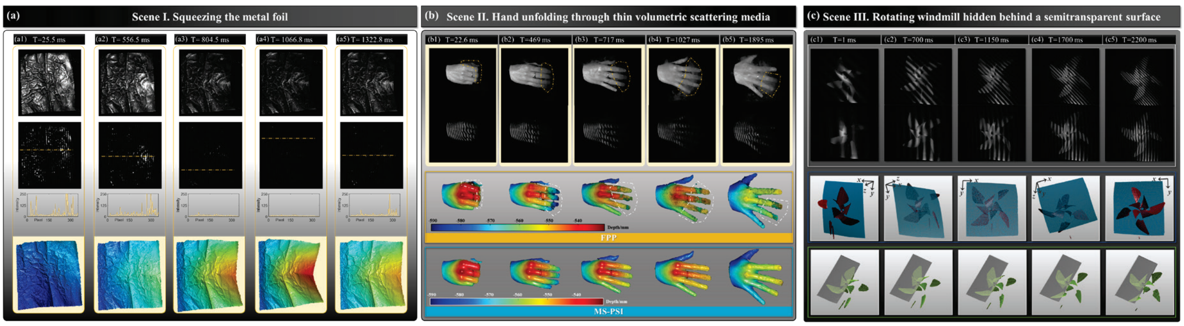

Figure 1. Experimental results on three dynamic scenes under complex reflection and transmission conditions. (a) Scene I. Squeezing the metal foil. (b) Scene II. Hand unfolding through thin volumetric scattering media. (c) Scene III. Rotating windmill hidden behind a semitransparent surface.

Experimental results confirm that the proposed method owns fast illumination separation and localization ability, which paves the way for dynamic 3D reconstruction under complex optical field reflection and transmission conditions, benefiting the imaging and sensing applications in advanced manufacturing, autonomous driving, biomedical imaging, etc.

Keywords: Computational imaging, 3D shape reconstruction, 3D imaging, Single-pixel imaging, Light transport coefficient

RAFT-DIC: A Task-optimized Neural Network for User-independent, Accurate and Dense Displacement Field Measurements

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ABSTRACT

Being an image-based optical technique for full-field deformation measurements, the ultimate purpose of digital image correlation (DIC) is to realize accurate, precise and pixel-wise displacement/strain measurements in a full-automatic manner without users' inputs. In this work, we propose a task-optimized neural network, called RAFT-DIC, to achieve user-independent, accurate and pixel-wise displacement field measurements. RAFT-DIC is based on the state-of-the-art optical flow architecture: RAFT. The proposed RAFT-DIC architecture consists of three key components: (1) the feature encoder that extracts the features of input images, (2) the correlation layer that constructs a 4D correlation volume between all pairs, and (3) the iterative update operator that recurrently updates the estimated displacement field based on a convolutional gated recurrent unit (Conv-GRU), its main overall architecture is Fig. 1(a). Particularly, we make two targeted improvements that fundamentally enhanced its measurement accuracy and generalization performance. Firstly, we remove all the down-sampling operations in the encode module to improve the perception of spatial information, and reduce the number of pyramid levels of the correlation layer to increase the small displacement accuracy. By building the correlation layer to compute the similarity of pixel pairs, and iteratively updating the displacement field through a recurrent unit, RAFT-DIC introduces the prior information of DIC measurement to guide the displacement estimation with high accuracy. Secondly, we develop a novel dataset generation method to synthesize customized speckle patterns and diverse displacement fields, which facilitate the construction of a robust and adaptable dataset to improve the network generalization. Both simulated and real experimental results (Fig. 1(b)) demonstrate that the accuracy of the proposed method is approximately an order of magnitude higher than pervious deep learning-based DIC (DL-DIC). The proposed RAFT-DIC shows higher accuracy as well as stronger practicality and cross-dataset generalization performance over existing DL-DIC, and is expected to be a new standard architecture for DL-DIC.

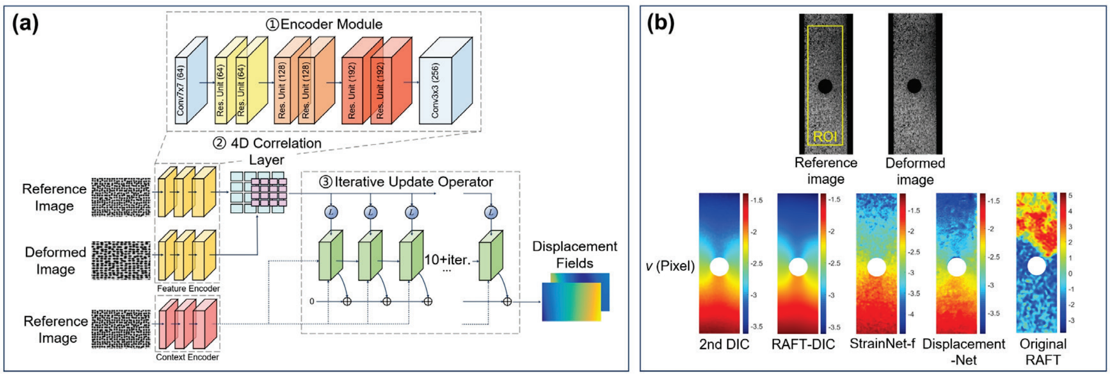

Figure 1. (a) Main overall architecture of RAFT-DIC; (b) measured v displacements corresponding to subset-based DIC, RAFT-DIC, StrainNet-f, DisplacementNet and original RAFT for a uniaxial tensile test.

Keywords: Digital Image Correlation, Deep Learning, Convolutional Neural Network.

Reinforcement Learning Boosts Coherent Beam Combination Phase Control

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ABSTRACT

CBC technology uses multiple channels of low-power amplification instead of a single channel of high-power amplification, and ultimately achieve high-power output and the key to this technology is the fast and efficient adjustment of the phase of each laser beam. Traditional phase control methods include the heterodyne method, the dithering method, and SPGD, all of which can effectively correct the phase of each beam. These methods have been applied to practical CBC systems and are well developed and well established. However, these algorithms have some shortcomings, such as great sensitivity to external noise and over-complexity of the whole system.

In recent years, the research heat of machine learning has gradually increased, and some studies have proved the feasibility of the application of deep learning in CBC technology. It is often necessary to create a dataset containing a large number of labels. A set of samples and labels are composed of diffraction patterns and phases. However, accurate phase labels are difficult to be obtained in experiments because the system is affected by environmental vibrations, etc., and it changes constantly.

Only if the feedback from the real system is obtained in real time and the network evolves accordingly, the algorithm can play a better role in real CBC systems. In particular, reinforcement learning algorithms can interact with the environment in real time, get feedback from the environment and update themselves to get evolved. Based on this, we have combined reinforcement learning with laser coherent combination and completed a lot of work. We not only confirmed its feasibility from simulation systems, but also achieved good results in real experimental systems, providing another new solution for coherent beam combination. Moreover, reinforcement learning is worthy of attention and application in other optical systems containing control problems.

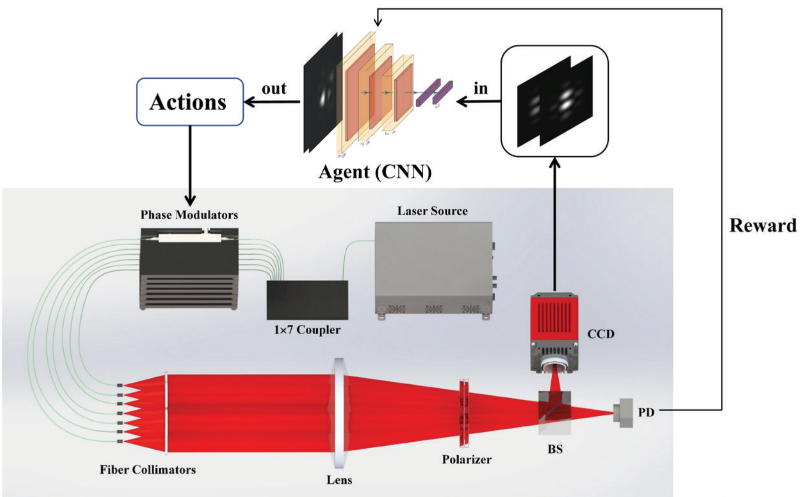

Figure 1. Coherent beam combination system combining reinforcement learning.

Keywords: Coherent beam combination, phase control, reinforcement learning, feedback, environment.

MEMS Morphology Recovery and Deformation Detection Based on Digital Holography

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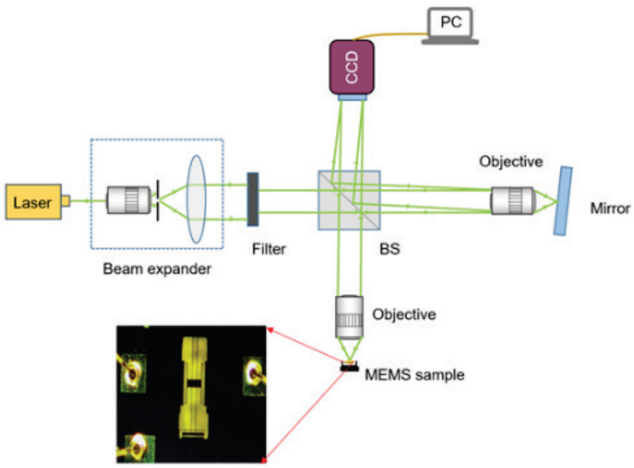
ABSTRACT

A microelectromechanical system (MEMS) is a system device with micro-structure, which is widely used in aerospace, medical equipment, automobile, and other fields. Because MEMS itself has a small size structure, its deformation cannot be directly observed, so it is necessary to use effective technical means. The traditional contact measurement method will cause damage to the surface of the device, and the accuracy is low. As a non-contact and high-precision technology, digital holography can realize nanometer-scale displacement measurement, so it can be applied in the fields of MEMS morphology, deformation, defect, and dynamic detection. In this study, MEMS is used as the detection object, and digital holographic technology is used to obtain the microstructure of MEMS and the tiny deformation under the state of energization. In the experiment, firstly, the MEMS samples are pre-amplified by the microscopic objective lens, and the magnification is calibrated by the standard resolution plate to determine the actual magnification, and the magnification calibration is realized. Secondly, due to the introduction of quadratic spherical error in the objective lens amplification, and because different materials on the MEMS surface have different optical reflection characteristics, some areas will produce phase disorder. Therefore, the effects of quadratic error and disordered phase in the phase diagram are eliminated by the iterative method and mask setting, and the morphology of the comb-shaped structure on the MEMS surface is restored. Finally, by reconstructing the phase of the MEMS before and after electrification, the deformation values before and after electrification were successfully measured. The results show that there is a nanoscale out-of-plane displacement on the MEMS surface. This method can realize defect detection, vibration masurement, and motion analysis of MEMS, and provides a feasible solution for MEMS detection problems.



Schematic of digital holographic MEMS detection optical path

Keywords: Digital holography, Morphology recovery, Deformation detection

Research on Near-infrared and EEG Dual Modality Imaging Methods for Children with Attention Deficit Hyperactivity Disorder

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ABSTRACT

The brain function assessment of children with attention deficit hyperactivity disorder (ADHD) aids in the precise diagnosis, treatment, and rehabilitation of these children. Near-infrared spectroscopy (NIRS) and electroencephalography (EEG) dual-modality detection hold significant value in the evaluation of children with ADHD. The current screening of children with ADHD mainly relies on subjective evaluations, such as rating scales, for determining the severity of the disorder, lacking comprehensive physiological data assessment bases. Therefore, identifying objective biomarker information is an urgent and critical issue to be addressed. This project explores three levels of research: the study of combined EEG and functional near-infrared spectroscopy (fNIRS) detection methods, the development of an integrated detection system, and the establishment of application research for ADHD in children. In terms of hardware, a wireless and portable system for the synchronous acquisition of EEG and fNIRS data is achieved. In terms of software, effective feature capture of EEG and brain tissue light absorption spectra is achieved through human-computer interaction. For the assessment model, a mathematical model correlating spectral data with electrophysiological parameters is established using a collaborative coupling metric learning method, with research on deep learning-based identification and classification of ADHD in children. By addressing these scientific issues and key technologies, a dual-modality imaging research method suitable for ADHD studies using EEG and fNIRS is developed, which is applied in early diagnostic and assessment research for ADHD.

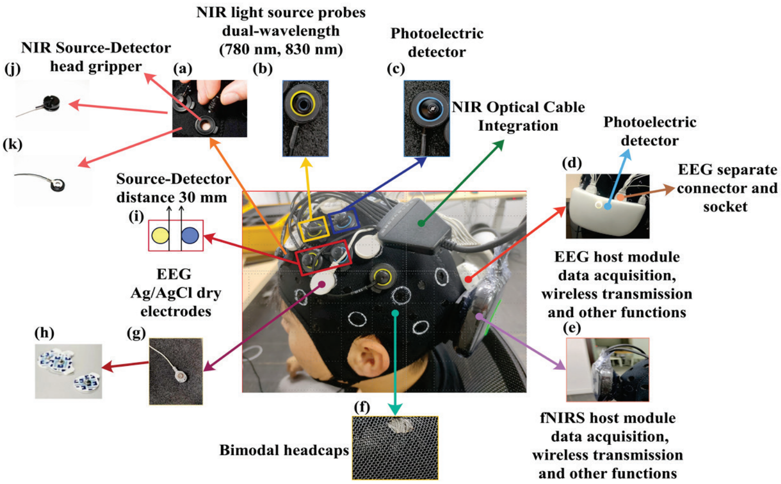

Figure 1. Wearable portable fNIRS-EEG bimodal system (a) NIR source-detector head gripper (b) NIR light source probes (c) Photoelectric detector (d) EEG host module (e) fNIRS host module(f) bimodal headcaps (g) Ag/AgCl dry electrodes (h) Chip electrodes (i) source-detector distance 30 mm (j) Upper part of the optical pole holder (k) Lower part of the optical pole holder.

Keywords: fNIRS, EEG, ADHD, Functional brain imaging, Dual modality.

Deformation and Vibration Measurement of Large-scale Thin-film Structures Based on Stereo-DIC

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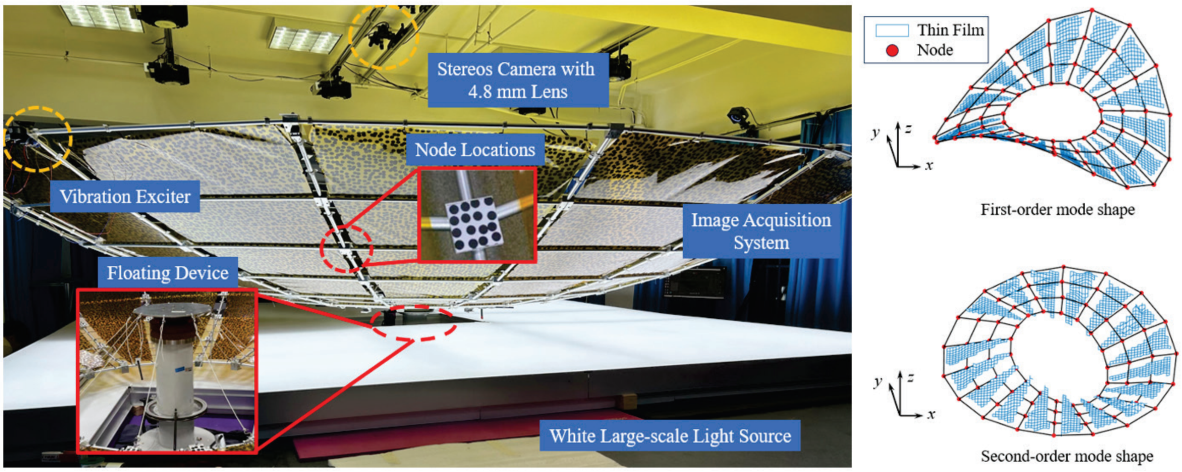
ABSTRACT

Due to their flexible configuration and lightweight characteristics, film structures have gained significant attention in the field of aerospace engineering. Stereo-digital image correlation (stereo-DIC) methods offer distinct advantages for obtaining full-field measurement results. However, challenges persist in fabricating high-quality speckle patterns and addressing problem of imaging reflections for large-scale transparent film structures. This paper focuses on fabricating high-quality digital speckle patterns without altering the vibration characteristics of thin film, as well as addressing the problem of imaging reflections. A combined large-scale backlighting system and transmission imaging are introduced to solve the problem of reflections. To avoid altering the characteristics of the thin film, the single-particle transfer printing technique is developed. The effectiveness of the experimental method is demonstrated through rotational and vibration tests conducted on the large umbrella thin-film structure with a diameter of 6 meters. This method provides a powerful means for studying the mechanical behavior and vibration characteristics of large-scale thin-film structures.



Keywords: Thin-film structure, Large-scale measurement, Stereo-digital image correlation, digital speckle patterns, Vibration test.

STUDENT COMPITITION-II

JUNE 28, 2024 | 15:15-17:35 | Xiangtai Hall | 2F

Session Chair: **Zhoujie Wu**, Sichuan University

Student Chairs: **Mingke Lei**, Sichuan University; **Tianyue He**, Sichuan University

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15:25-15:35	**Qingran Miao**, Zhejiang University of Technology **Title:** Sweat Gland Enhancement Method for Fingertip OCT Images Based on Generative Adversarial Network
15:35-15:45	**Yong Tang**, Beihang University **Title:** Reconfigurable Large-scale Fringe Projection System
15:45-15:55	**Yunuo Chen**, Fudan University **Title:** Enhancing the Efficiency and Robustness of Monoscopic Deflectometry by Bayesian Approach
15:55-16:05	**Delong Yang**, Beijing Institute of Technology **Title:** Enhancing Non-interferometric 3D Refractive Index Tomography with Beam Propagation Networks: A Novel Algorithm to Overcoming Reconstruction Challenges
16:05-16:15	**Fuqian Li**, Sichuan University **Title:** Single-exposure High-dynamic-range 3D Measurement via Untrained Neural Network
16:15-16:25	**Jie Wang**, University of Electronic Science and Technology of China **Title:** µPMD for Dynamic Three-dimensional Sensing of Specular Surfaces
16:25-16:35	**Yihao Xue**, University of Science and Technology of China **Title:** Adaptive Foveated Single-Pixel Imaging Inspired by the Diversity of Pupils
16:35-16:45	**Liuling Gu**, Southeast University **Title:** Three-dimensional Camera Array for Deep-water Measurement with Short Working Distance and Large Field of View
16:45-16:55	**Xiaowen Li**, Nanjing University of Aeronautics and Astronautics **Title:** Multiple-view 3D Profile and Deformation Measurement Based on Pseudo-overlapped Imaging
16:55-17:05	**Nenqing Lyu**, Nanjing University of Science and Technology **Title:** Structured Light 3-D Sensing for Complex Scenes
17:05-17:15	**Haotian Chen**, Shanghai University **Title:** Study on the Method of Cylindrical Interference Splicing Measurement
17:15-17:25	**Huiling Zhang**, Shanghai University **Title:** Digital Holographic Detection and 3D Characterization of Mural Microcracks
17:25-17:35	**Zekun Zhang**, Sichuan University **Title:** Refractive Index Measurement Deflectometry for Measuring Gradient Refractive Index Lens

Hardware-induced Error Compensation for Large-step Phase-shifting Patterns on DLP4500

Speaker: Jiancheng Qiu Supervisor: Gaoxu Wu

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ABSTRACT

DLP4500 is a widely applied digital light procession (DLP) for fringe projection profilometry (FPP). However, due to limited buffer amount, it works usually unstable when the pattern sequence exceeds six, causing undesired periodical error on extracted phase especially when large-step phase-shifting algorithm is chosen. To address the problem, this work proposes to compensate hardware-induce phase error by calibrating error to phase look-up-table (LUT). Especially, to build the LUT, the phase error map is obtained by re-projecting the 3D deviation of a flat with quasi-ideal surface to phase domain. The results of comprehensive experiments demonstrate that this method can effectively reduce periodic phase errors induced by hardware defect of DLP4500, thereby greatly guarantee the performance of large-step phase-shifting algorithms in high-accuracy phase extraction.

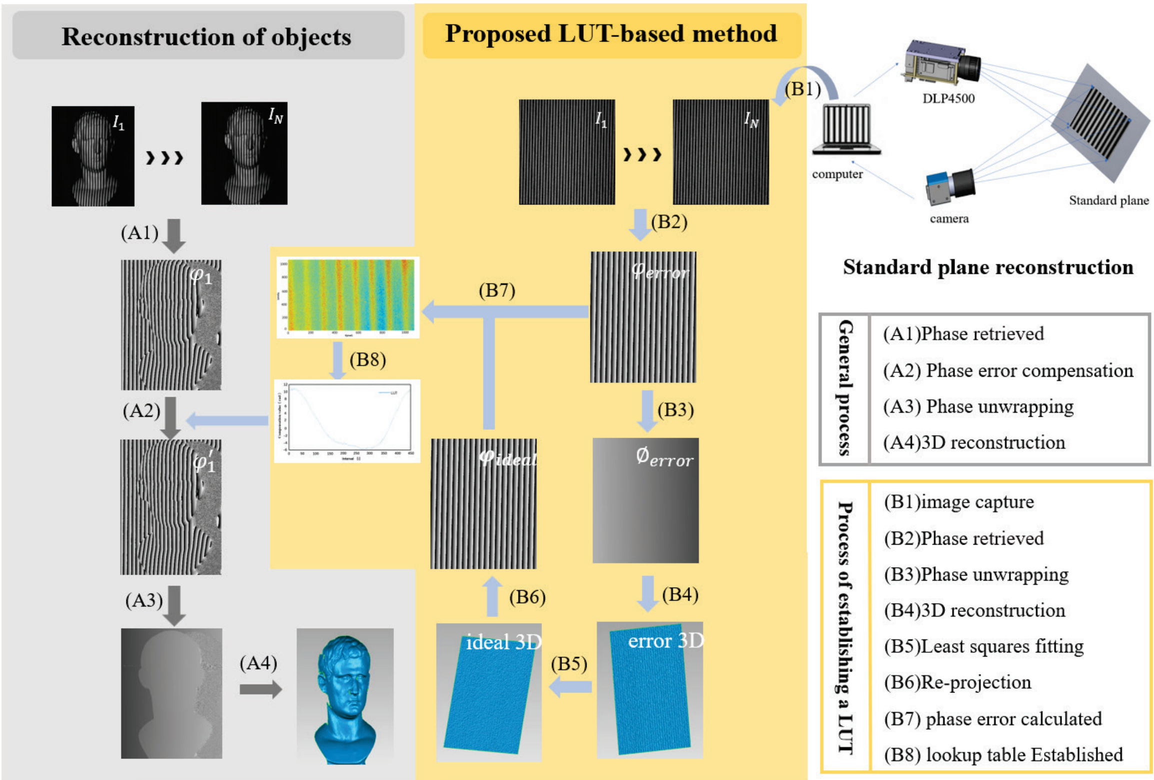

Figure 1. Hardware-induced error compensation flow chart.

Keywords: large-step phase-shifting, Hardware-induced, Re-projection, LUT

Sweat Gland Enhancement Method for Fingertip OCT Images Based on Generative Adversarial Network

Speaker: Qingran Miao Supervisor: Haixia Wang

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ABSTRACT

Sweat pores are gaining recognition as a secure, reliable, and identifiable third-level fingerprint feature. Challenges arise in collecting sweat pores when fingers are contaminated, dry, or damaged, leading to unclear or vanished surface sweat pores. Optical Coherence Tomography (OCT) has been applied in the collection of fingertip biometric features. The sweat pores mapped from the subcutaneous sweat glands collected by OCT possess higher security and stability. However, speckle noise in OCT images can blur sweat glands making segmentation and extraction difficult. Traditional denoising methods cause unclear sweat gland contours and structural loss due to smearing and excessive smoothing. Deep learning-based methods have not achieved good results due to the lack of clean images as ground-truth. This paper proposes a sweat gland enhancement method for fingertip OCT images based on Generative Adversarial Network (GAN). It can effectively remove speckle noise while eliminating irrelevant structures and repairing the lost structure of sweat glands, ultimately improving the accuracy of sweat gland segmentation and extraction. To the best knowledge, it is the first time that sweat gland enhancement is investigated and proposed. In this method, a paired dataset generation strategy is proposed, which can extend few manually enhanced ground-truth into a high-quality paired dataset. An improved Pix2Pix for sweat gland enhancement is proposed, with the addition of a perceptual loss to mitigate structural distortions during the image translation process. It's worth noting that after obtaining the paired dataset, any advanced supervised image-to-image translation network can be adapted into our framework for enhancement. Experiments are carried out to verify the effectiveness of the proposed method.

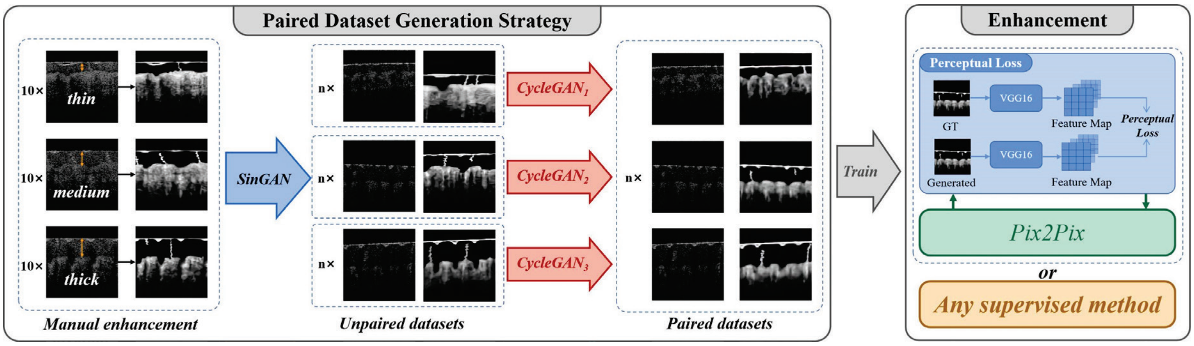

Figure 1. Overall flow of the sweat gland enhancement method for OCT images.

Keywords: Optical coherence tomography (OCT), sweat gland, enhancement, generative adversarial network (GAN), paired dataset generation strategy.

Reconfigurable Large-scale Fringe Projection System

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ABSTRACT

Fringe projection (FP) systems are increasingly used in industrial applications, particularly for the measurement of customized large components. However, the variability in dimension and placement of different products for in-situ measurement presents challenges to the flexibility of current large-scale FP paradigms. The fixed multi-sensor setups require precise calibration, and the movable single-view sensors with tracking systems face limitations in registration, such as reliance on auxiliary devices or markers. In this paper, a reconfigurable large-scale fringe projection (RLS-FP) system is developed, which consists of a regional fringe projection (rFP) system for high-accuracy single-view measurement and a global tracking network (GTN) constituted by several tracking fringe projection (tFP) systems for registration. Due to the merits of phase-based registration, this system enables marker-free and coating-free measurement, and is easy to calibrate after reconfiguration according to specific application. By utilizing the cameras from GTN and tracking optimization, the RLS-FP system can achieve high accuracy in a meter-scale measurement volume. Two metal vehicle door panels are completely measured with high density to prove the potential application in large complex form measurement.

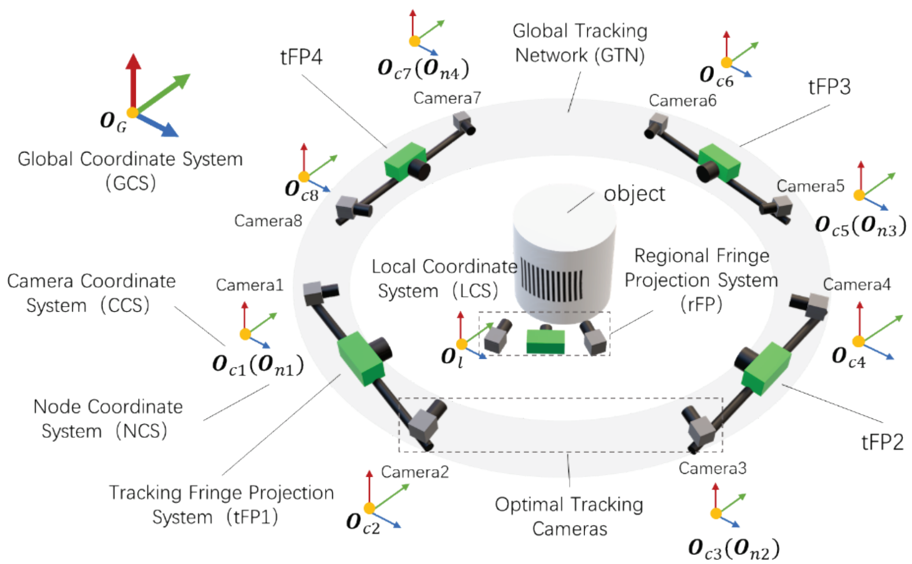

Figure 1. The system schema of reconfigurable large-scale fringe projection system (RLS-FP), composed of one regional fringe projection system (rFP) and a global tracking network (GTN) that consists of 4 tracking fringe projection (tFP) systems.

Keywords: Fringe projection, Reconfigurable system, Large-scale measurement, Global calibration

Enhancing the Efficiency and Robustness of Monoscopic Deflectometry by Bayesian Approach

Speaker: Yunuo Chen Supervisor: Xiangchao Zhang

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ABSTRACT

The increasingly widespread application of optical components with complex forms has led to higher demands for measurement techniques. Recently, monoscopic deflectometry has demonstrated strong competitiveness in form measurements requiring sub-micron accuracy due to its advantages such as a large dynamic range, simple system structure, and low hardware cost. However, in the practical application, there remain challenges including cumbersome calibration, dependency on third-party instruments for workpiece positioning, instability in the parameter calculation, and poor interpretability. These significantly impact the efficiency and robustness, especially when adjustments are made to the measurement system or there are errors in the nominal form of the surface under test.

To address these issues, an automatic camera calibration method is developed based on a mixed regression model. Hence the need for cumbersome manual operations is obviated. The co-planarity constraint of spherical mirror reflections is introduced to enhance the stability of geometrical calibration, while allowing for the calibration with only one shot. Additionally, a self-positioning method of workpieces is proposed by combining ray-tracing and Gaussian process regression, eliminating the reliance on additional precision instruments. Starting from the camera's intrinsic parameters, a complete uncertainty propagation chain is constructed based on the uncertainty propagation theory, and all the parameters are estimated in terms of probability distributions rather than single values. Then the reliability of the measurement result can also be estimated. Experimental results demonstrate that the proposed methods effectively enhance the efficiency and robustness of monoscopic deflectometry, achieving measurement accuracy in the order of hundred-nanometers, thereby improving its practicability in various application scenarios.

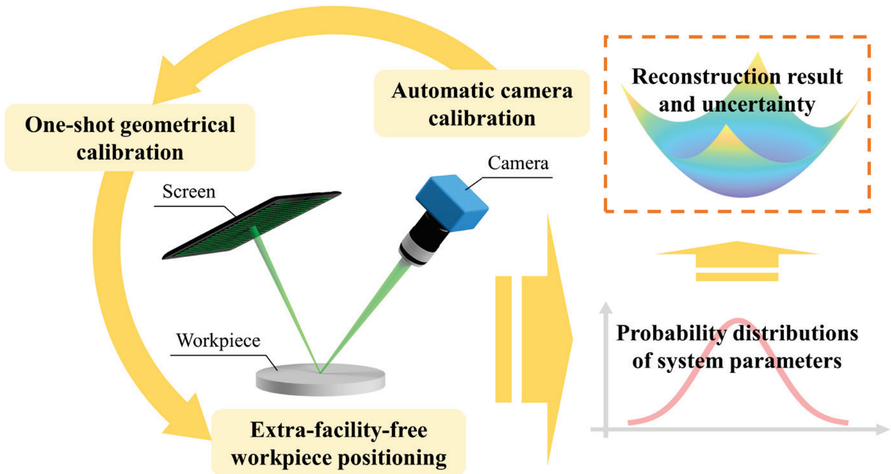

Figure 1. Schematic diagram of monoscopic deflectometry enhanced by Bayesian approach.

Keywords: Monoscopic deflectometry, Calibration, Uncertainty propagation, Bayesian approach.

Enhancing Non-interferometric 3D Refractive Index Tomography with Beam Propagation Networks: A Novel Algorithm to Overcoming Reconstruction Challenges

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ABSTRACT

Non-interferometric 3D refractive index tomography has garnered significant attention in the life sciences due to its straightforward system implementation and exceptional imaging performance. However, when the study sample deviates from the weak scattering approximation, the complexity of the physical propagation process poses substantial reconstruction challenges. Traditional algorithms struggle to achieve global optimization in such scenarios, resulting in time-consuming and potentially ineffective reconstructions. To overcome these limitations, we propose a Beam Propagation Network (BPN) that requires no pre-training. Each layer of this network is based on the beam propagation model, ensuring clear physical significance. BPN demonstrates robust generalization capabilities and reconstructs the 3D refractive index distribution of the sample by optimizing a set of intensity images. Additionally, BPN calibrates intensity fluctuations between different illuminations through learnable intensity correction parameters.

Considering the multiple backward scattering effects, we integrate "scattering attenuation layers" between adjacent layers in the BPN. By incorporating physical priors of the sample and leveraging the classic dropout training method from deep learning, BPN effectively addresses background and axial artifacts in the tomography reconstruction process. Through simulations and experimental validations, we demonstrate the effectiveness and feasibility of this method. Experimental results show that BPN enhances clarity and significantly eliminates axial artifacts in refractive index tomography. The implementation of BPN offers a new paradigm for non-interferometric tomography, holding substantial potential for practical applications.

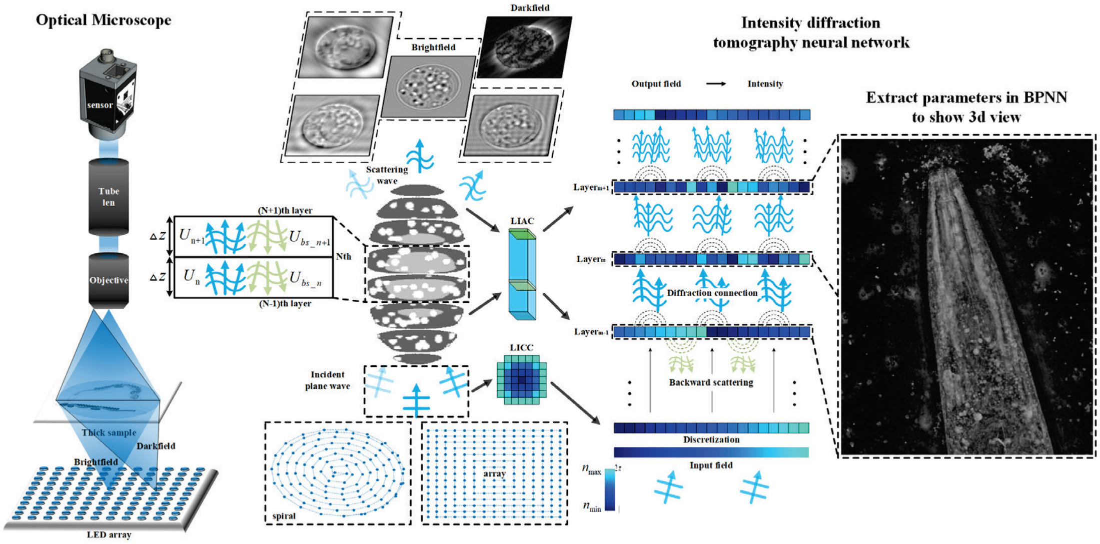

Figure 1. The principle of beam propagation network (BPN) and dropout in BPN

Keywords: Non-interferometric Tomography, Beam Propagation Network (BPN), Deep Learning

Single-exposure High-dynamic-range 3D Measurement via Untrained Neural Network

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ABSTRACT

Three-dimensional measurement for high-dynamic-range (HDR) surfaces is one of challenge issues in industry manufacturing. However, current HDR methods, including conventional methods and supervised-learning-based methods, generally make compromise in either the efficiency or the accuracy. To alleviate this compromise, we propose a generalized fringe enhancement method based on the untrained neural network (UNN) to achieve HDR measurement from only a single exposure. There are two important contributions in our work. First, to the best of our knowledge, we propose the first generalized UNN-based framework to solve the underexposure–overexposure hybrid issue. Without pretraining on any dataset, our framework can simultaneously achieve fringe denoising in the underexposure issue, and fringe inpainting in the overexposure issue. Second, we propose a sine regularization term to improve the inpainting quality in overexposed areas. Unlike existing methods that merely inpaint the corrupted areas based on their reliable adjacent areas, we utilize the unique sinusoid character of fringe to constrain the inpainting. Consequently, the robustness of our method can be effectively enhanced. Experiments for poorly illuminated scenes, high-reflection scenes, and their hybrid scenes demonstrate the proposed single-exposure method can substantially eliminate the measurement error (0.0603 versus 4.1775 mm) compared with the direct measurement.

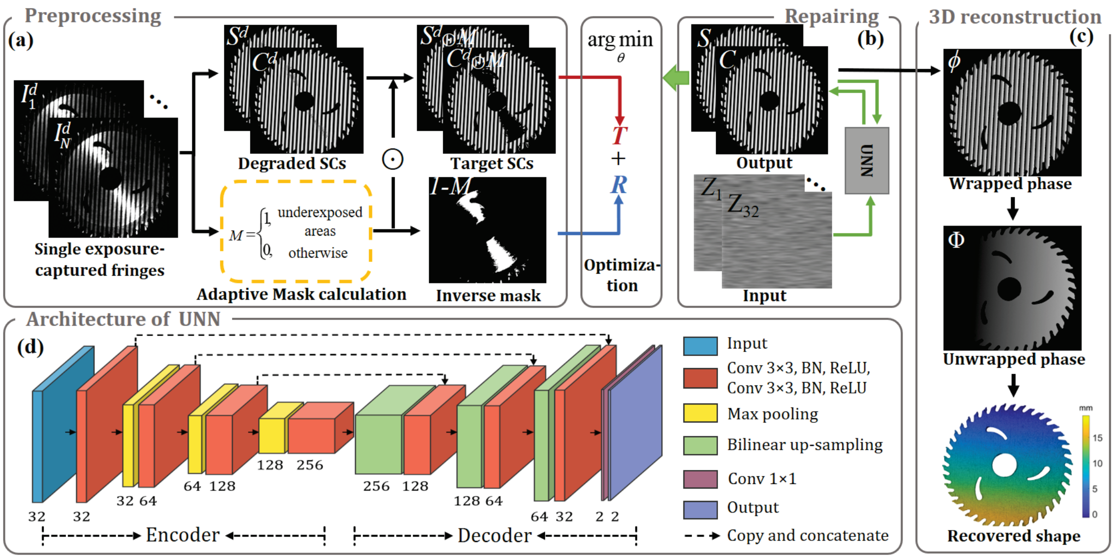

Figure 1. Flowchart of the proposed method. (a) Preprocessing: capturing phase-shift fringe patterns under single exposure, then retrieving inverse mask and target sinusoidal components (SCs) with the adaptive mask calculation algorithm; (b) Repairing: repairing degraded SCs via the untrained neural network (UNN); (c) 3D reconstruction: recovering wrapped phase from generated SCs, unwrapping phase, and reconstructing 3D shape; (d) Architecture of the UNN.

Keywords: 3D measurement, fringe enhancement, high dynamic range, structured light, underexposure–overexposure hybrid issue, untrained neural network

μPMD for Dynamic Three-dimensional Sensing of Specular Surfaces

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ABSTRACT

Phase Measuring Deflectometry (PMD) has been widely applied in the measurement of specular surfaces due to its non-contact, high-precision, full-field measurement capabilities. However, the response time of liquid crystal molecules limits the frame rate of the commercial liquid crystal display (LCD) screen which is the most common structured light source in PMD to 100 frames per second (fps), which can hardly meet the requirement for dynamic scenes. Therefore, it is quite difficult and even impossible for traditional PMD to measure rapidly moving surfaces. In this work, micro-PMD (μPMD) based on the high-speed LED sinusoidal fringe display method is proposed, the fringe acquisition rate of which is supposed to be above 1kfps. The proposed fringe display method utilizes the high-speed switching characteristic of LED sources and the filtering effect of the light diffuser to allow a superfast display rate (potentially up to 100kfps) and superior sinusoidal property. To the best of our knowledge, the proposed μPMD , for the first time, achieved a superfast fringe acquisition rate of 4000fps with consistently high accuracy. Experimental results have demonstrated that the proposed method can significantly suppress motion errors in dynamic scenes and achieve sub-micrometer precision in three-dimensional (3D) reconstruction for specular surfaces. We envision this proposal to be broadly implemented for real-time monitoring in manufacturing.

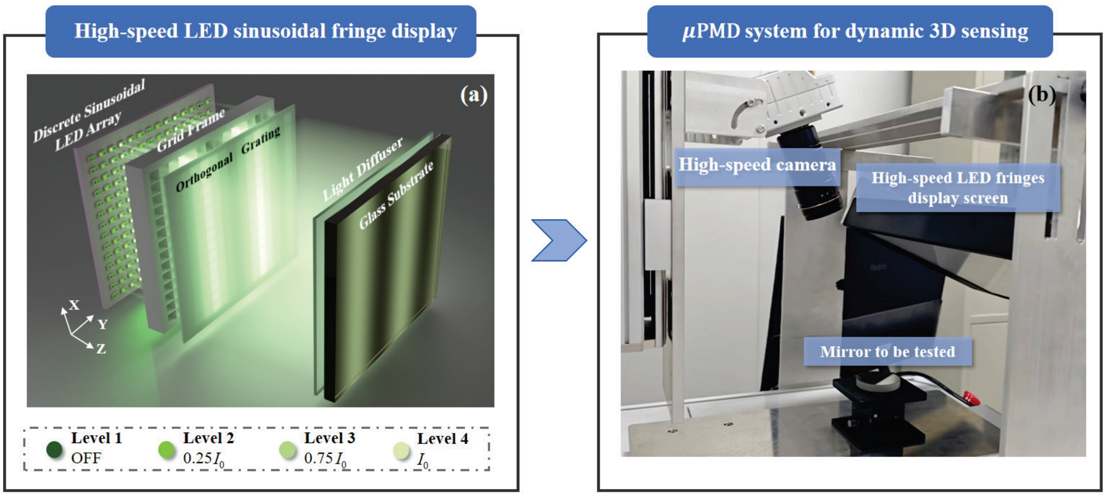

Figure 1. μPMD system based on the high-speed LED sinusoidal fringe display method. (a) Diagram of the proposed high-speed LED sinusoidal fringe display method. (b) μPMD system for dynamic 3D sensing

Keywords: Phase measuring deflectometry (PMD), High-speed fringe display, Dynamic 3D sensing.

Adaptive Foveated Single-pixel Imaging Inspired by the Diversity of Pupils

Speaker: Yihao Xue Supervisor: Huaxia Deng

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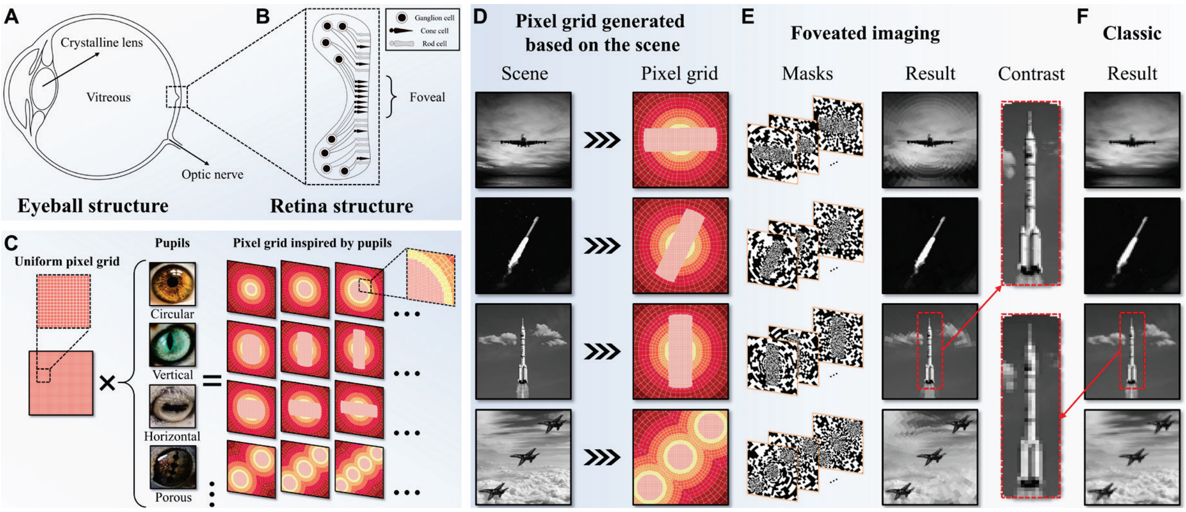
ABSTRACT

As a promising method to realize foveated imaging, foveated single-pixel imaging (FSPI) achieves an adaptive trade-off between resolution and frame rate to suit the dynamic scene under investigation by algorithm optimization. However, we note that the sampling of the scene occurs in the polar coordinate system with the use of FSPI, which leads to the circular fovea. This circular shape limits the complete reconstruction of the regions of interest (ROIs). To address this issue, we propose an FSPI method with arbitrarily shaped regions of high resolution inspired by the diversity of pupils. Our work extends the foveal sampling to the Cartesian coordinate system based on the shape of the ROIs in the scene. Using this strategy, we identify the ROIs by prior scene measurements and establish the fovea of the corresponding shape in the Cartesian coordinate system. Meanwhile, the position of the fovea within the field of view is obtained by prior information calculation. Outside the foveal region, the surrounding area of lower resolution is sampled in the polar coordinate system. The presented pupil-diversity-inspired FSPI method with precise positioning and high relevance between the ROIs and the foveal provides a reliable approach for adaptive foveated scene illumination, thereby enhancing the performance of the foveated computational imaging system.



(**A** to **B**) Human eye. (A) Eyeball structure. (B) Model of ganglion, cone, and rod cell distributions in the retina fovea area. (**C**) Spatially variant pixel grid inspired by pupils, converted from the uniform pixel grid. (**D** to **F**) Comparison between spatially variant resolution and uniform resolution. In the central region of the result shown in (E), the linear resolution is twice that of the result shown in (F). (D) Pixel grid generated based on the scene, containing N = 4096 pixels of varying area. (E) Examples of the 4096 Hadamard patterns reformatted onto the spatially variant grid shown in (D) and the images reconstructed from correlations with the 4096 spatially variant masks. (F) The images reconstructed from correlations with the 4096 uniform masks.

Keywords: Foveated single-pixel imaging, The diversity of pupils, Arbitrarily-shaped fovea, Precise positioning.

Three-dimensional Camera Array for Deep-water Measurement with Short Working Distance and Large Field of View

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ABSTRACT

Underwater vision-based three-dimensional(3D) measurement is commonly confronted with complex environments such as deep water pressure, refraction distortion, light absorption and scattering, which makes it challenging for underwater vision-based methods to achieve high measurement accuracy and efficiency. In this paper, a novel method based on underwater 3D camera array is proposed, enabling close-range, large-scale and high-precision 3D reconstruction in deep-water environment. The camera array is designed with multiple binocular camera subsystems, and a method for unifying the extrinsic parameters of the subsystems is proposed to ensure the continuity of measurement results. A refractive camera model and calibration method for refractive parameters are adopted to eliminate refraction-introduced errors in underwater 3D reconstruction. Near-infrared random speckle is used to assist dense image matching in underwater environments. Experimental validation is conducted to verify the accuracy and reliability of the proposed method. The results show that the average reconstruction error is less than 1.1 mm for underwater binocular camera subsystem. The maximum relative error in the depth direction between tow subsystems is 2.61mm with a measurement field of 700mm by 700mm. The camera array is mounted on an underwater robot and applied successfully to underwater structural damage detection.

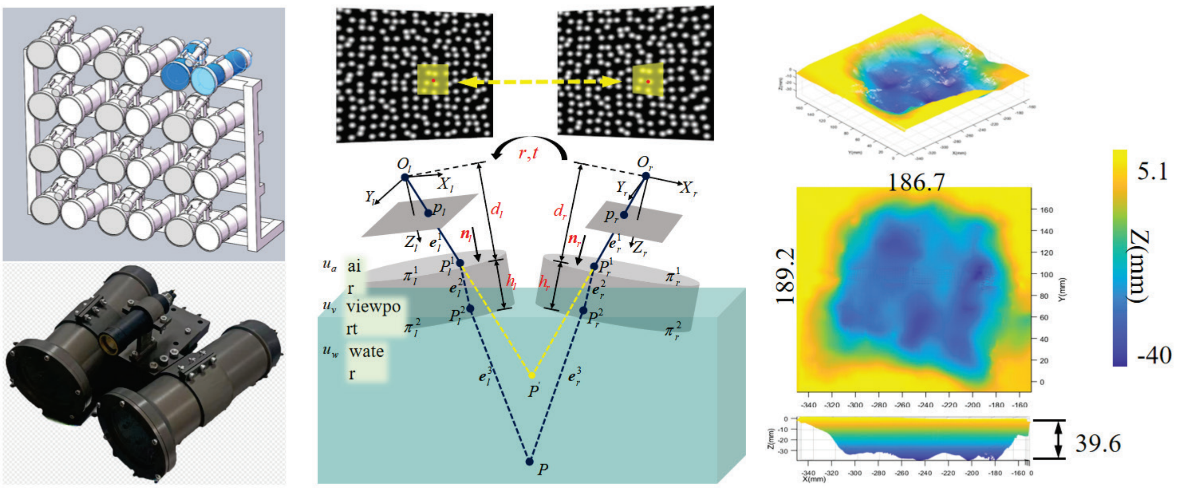

Figure 1. Three-dimensional underwater camera array: design schematic, measurement principles and results.

Keywords: Underwater 3D measurement, Camera array, Refraction correction, Random speckles and Damage detection

Multiple-view 3D Profile and Deformation Measurement Based on Pseudo-overlapped Imaging

Speaker: Xiaowen Li Supervisor: Zhenning Chen

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ABSTRACT

Field of view (FOV) enlargement and spatial resolution increase are mutually constrained in conventional vison-based techniques. A single camera with one sensor can only capture a fixed FOV. To solve this problem, scholars have conducted extensive research and proposed many methods. And there are two common methods to expand FOV, i.e., increasing the number of cameras or reducing the spatial resolution of the image. However, these methods may face the problem of difficult synchronization control of multiple cameras, or lead to low imaging resolution. In this paper, a multiple-view 3D digital image correlation (3D-DIC) method based on pseudo-overlapped imaging is proposed. In this technique, a single 3D-DIC system, with two color splitting prisms and four plannar mirrors, is adopted. As shown in Figure 1, by adjusting the angles of the prisms and mirrors, two adjacent FOVs can be completely imaged onto the whole sensor of each camera with stereo angles θ1 and θ2. Thus, a sensor, e.g., Camera1, with a resolution of M × N pixels, is imaged and overlapped with FOV1 and FOV2 simultaneously. The overlapped imaging of Camera 1 can be separated very clearly into two virtual sensors (Sensors 1-M1 and 1-M2), and each virtual sensor has a full resolution of M × N pixels. As FOV1 captures red light and FOV2 captures blue light, the overlapped images on Camera1's sensor can be separated into two independent images. Therefore, compared with the conventional 3D-DIC system, the proposed method simultaneously enlarges FOVs and increases spatial resolutions by two times. And multiple-view 3D profile and deformation measurement was performed successfully using the proposed method.

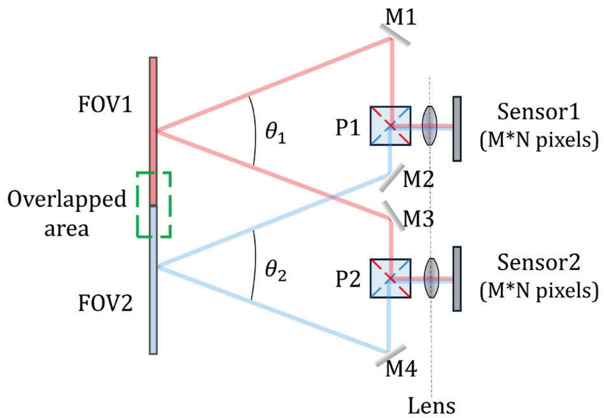

Figure 1. Experimental setup of mulitple-view 3D digital image correlation based on pseudo-overlapped imaging.

Keywords: Multiple-view digital image correlation, pseudo-overlapped imaging, profile and deformation measurement.

Structured Light 3-D Sensing for Complex Scenes

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ABSTRACT

Structured light-based 3-D sensing technique reconstructs the 3-D shape from the disparity given by pixel correspondence of two sensors. However, for scenes under turbid water condition, scenes containing discontinuous reflectivity (DR), and scenes with large depth-of-field (DoF), the captured images are influenced, thus generating 3-D measurement error. First, we construct the error model of fringe projection profilometry (FPP) for scenes under turbid water condition, scenes containing DR error, and scene with large DoF. From the constructed error models, it can be concluded that the DR error is related to both the camera PSF and the scene reflectivity, the error of large DoF is related to the camera PSF, and the scattering error is related to the scattering effect. These error of FPP is hard to be alleviated because of the unknown influencing factors. Single-pixel imaging (SI) can calculate the object surface reflectivity captured by each camera pixel by treating it as a single-pixel detector. Thus, SI is introduced to improve the 3-D measurement for these three complex scenes. In turbid water condition, SI is used to alleviate the scattering caused errors thus improve the measurement accuracy. For scenes containing DR, SI is used to reconstruct the scene reflectivity and normalize the scene reflectivity. From the normalized scene reflectivity, pixel correspondence with error opposite to the original reflectivity is calculated for the DR error removal. For scenes with large DoF, SI is used to calculate the spatial-varying PSF in a large DoF thus recovering the desired fringe patterns. The experiments demonstrate that the proposed methods can improve the measurement accuracy in these scenes.

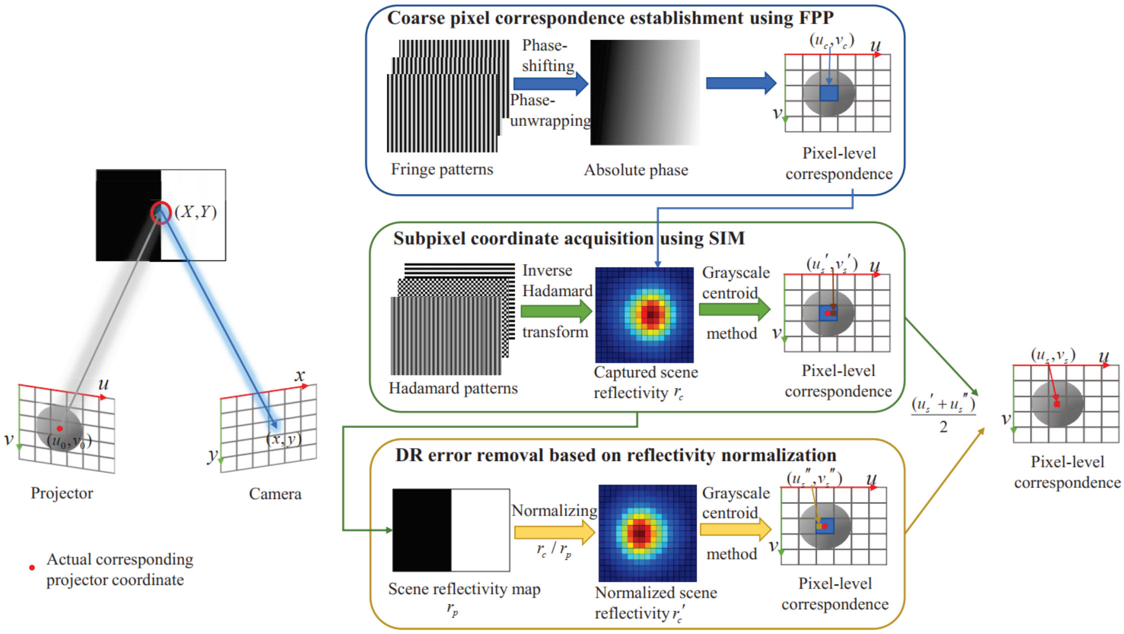

Figure 1. Schematic of the structured light based 3-D measurement method for scenes containing reflectivity discontinuity.

Keywords: Structured light, underwater 3-D measurement, reflectivity discontinuity.

Study on the Method of Cylindrical Interference Splicing Measurement

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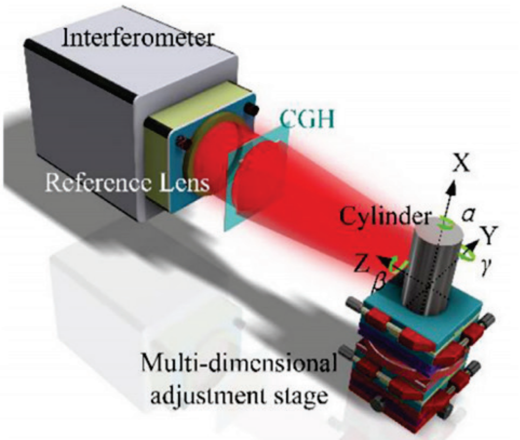
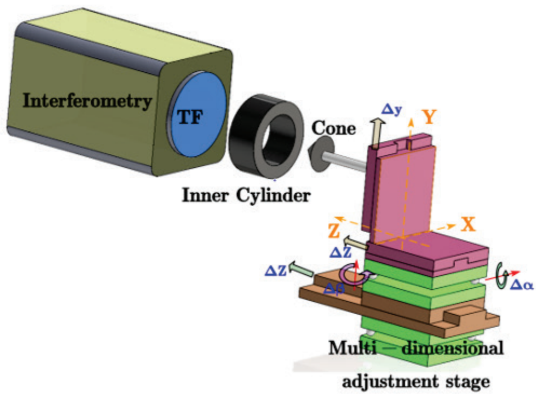
ABSTRACT

Cylindrical parts represented by precision shaft systems play an important role in aerospace, CNC machine tools, precision instruments and other types of engineering fields. Cylindrical surface topography measurement method can be divided into cylindrical outer surface and cylindrical inner surface measurement according to the structure, both of them are cylindrical measurement but the measurement methods are very different. The measurement of the outer surface of the cylinder adopts CGH as the wave front converter to realise the interference between the plane wave and the cylindrical wave to obtain the topographic information of the outer surface of the cylinder, which only obtains the surface information of part of the cylindrical area, and then through the measurement of the cylindrical sub-aperture diameter in turn, the splicing method can complete the complete topographic measurement of the outer surface of the cylinder. The measurement of the inner surface of the cylinder adopts a 90° conical mirror as the optical path converter to achieve the interferometric measurement of the inner surface of the cylinder, which can only obtain part of the topographic information of the inner cylinder, and then by moving the conical mirror, it can obtain the topographic information of the inner cylindrical sub-aperture in turn, and finally through the splicing algorithm to achieve a complete topographic inspection of the inner surface of the cylinder. The proposed method completes the closure of the surface topography measurement method of the cylinder, and by comparing the results with those of the roundness instrument, the results show that the two have good consistency.



(a)



(b)

Figure 1. (a)Cylindrical external surface interferometry system and(b) Cylindrical internal surface interferometry system.

Keywords: Cylindrical measurement, Sub-aperture splicing,interferometry, conical mirror.

Digital Holographic Detection and 3D Characterization of Mural Microcracks

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ABSTRACT

The structure of shallow microcracks in mural paintings is complex and has strong concealment. We develop a portable digital holographic deformation detection system, which combines the principle of diffuse reflection surface hologram recording and the sound wave sweeping excitation. In order to segment and eliminate the background phase introduced by acoustic vibrations, a Gaussian 1σ-based criterion and histogram are used. The stripping of defects from the background information is realized. The local deformation information of microcracks in hologram reconstructed images is extracted, and a mapping relationship between the phase information and the key geometric parameters of microcracks is constructed. This enables the characterization of geometric features of microcrack shape, aspect ratio, and depth-to-diameter ratio. The results demonstrate that acoustic excitation can effectively stimulate shallow microscopic defects to form abnormal interference fringes. Based on the proposed background phase elimination algorithm, it is possible to extract the location and contour features of the defects and to detect shallow microscopic cracks and reproduce the geometric features of the tested frescoes. This provides a quantifiable reference basis for the health diagnosis, restoration and conservation of the mural paintings.

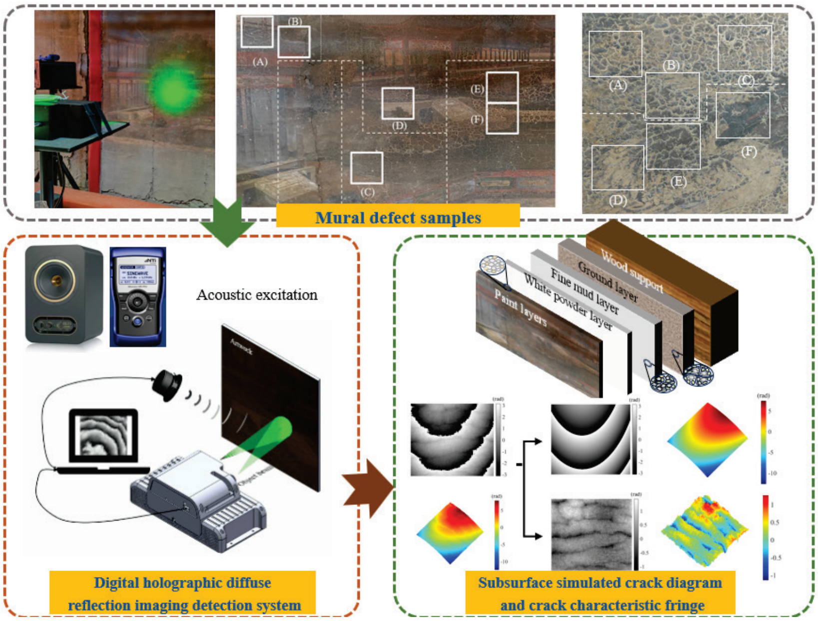

Figure 1. Figure 1. Microcrack detection process and characterization of mural paintings. (a) In-situ detection scenario and detection area (b) Digital holographic deformation detection system (c) Holographic phase diagram and 3D characterization of shallow microcracks

Keywords: Mural shallow microcracks, Digital holographic detection, Acoustic excitation, Phase separation method, 3D characterization.

Refractive Index Measurement Deflectometry for Measuring Gradient Refractive Index Lens

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ABSTRACT

A method based on deflectometry to measure the refractive index distribution of radial gradient refractive index (GRIN) lens is proposed in this paper. The method establishes the relationship between the refractive index distribution and the direction of light ray by deriving the propagation equation of light in a non-uniform medium. By measuring the deflection angle using the principle of deflectometry and the assumption of central refraction, the refractive index distribution of the radial GRIN lens is determined. The specific principle of refractive index measurement deflectometry (RIMD) is described in detail (Fig.1(a)), and the correctness and accuracy of the method are verified through numerical simulations. Furthermore, the effects of calibration error, lens surface shape on the accuracy of the measurement results are analyzed. In the experimental section, the proposed method is applied to measure a radial GRIN lens, and the results are compared with the nominal parameters in terms of shape distribution and numerical values (Fig.1(b), 1(c), and 1(d)), demonstrating good consistency. The measurement error is controlled within the order of 10^(-3) . This method enables rapid and convenient acquisition of full-field information of GRIN lens and holds promising potential for playing an important role in lens manufacturing and production.

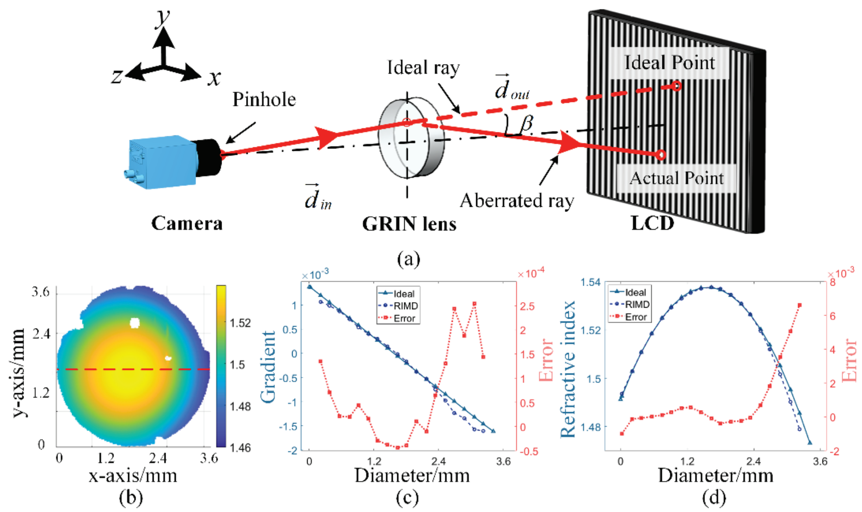

Figure 1. (a) The diagram of the measurement setup for RIMD; (b) Measurement results; (c) Comparison between the reconstructed data and the ideal refractive index gradient; (d) Comparison between the reconstructed data and the ideal refractive index.

Keywords: Deflectometry; Refractive Index; Non-uniform medium

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