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附件1

浙江工程师学院（浙江大学工程师学院）
同行专家业内评价意见书

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申报工程师职称专业类别（领域）：电子信息

浙江工程师学院（浙江大学工程师学院）制

2025年03月21日

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一、个人申报

（一）基本情况【围绕《浙江工程师学院（浙江大学工程师学院）工程类专业学位研究生工程师职称评审参考指标》，结合该专业类别(领域)工程师职称评审相关标准，举例说明】

1.对本专业基础理论知识和专业技术知识掌握情况(不少于200字)

在电子信息（控制工程）专业领域，我对本专业的基础理论知识和专业技术知识有着扎实的掌握。在本科和硕士阶段，我系统学习了控制理论、信号处理等基础知识，这些知识为我后续的专业学习和实践提供了坚实的支撑。

在专业技术方面，我通过参与多个前沿项目，积累了丰富的实践经验。例如，在基于扩散模型的扫描电子显微镜图像增强研究中，我深入探索了扩散模型应用于图像处理的研究，开发了创新的两阶段图像增强流程，并设计了高效的去噪网络架构。在高温合金原位热机械测试辅助系统的开发中，我熟练运用增强现实技术和实时数据交互功能，解决了测试过程中的复杂问题。这些项目不仅让我掌握了先进的技术手段，还培养了我解决复杂工程问题的能力。

2.工程实践的经历(不少于200字)

在基于SEM图像增强项目中，我针对扫描电子显微镜图像采集过程中效率与质量难以平衡的难题，开发了一种基于扩散模型的图像增强算法。我采用DDPM实现创新的两阶段图像增强流程，第一阶段利用SwinIR网络进行图像去噪，第二阶段则利用去噪后的图像数据提升分辨率。为解决传统Conditional DDPM方法中训练计算量大与推理速度慢的问题，我设计了包含交叉注意力机制的Encoder-Decoder架构去噪网络。经过优化，两阶段方案显著提升了生成图像质量，PSNR指标提高10%以上，同时轻量化模型结合DDIM采样方法有效缩短了推理时间，提高了图像处理的实时性。这一项目不仅锻炼了我的算法设计与优化能力，还让我深刻体会到将理论知识应用于实际问题解决的重要性，为我在工程实践中积累了宝贵经验。

3.在实际工作中综合运用所学知识解决复杂工程问题的案例（不少于1000字）

案例：基于扩散模型的原位SEM图像增强与AR交互系统

主要内容：

基于扫描电子显微镜开展原位高温实验能够同步模拟服役工况并监测材料微观组织结构的动态演变，可以应用于航空发动机核心部件的耐高温性能、抗疲劳强度及可靠性研究，这对于提升国家工业和科技水平具有重要意义。目前的扫描电镜原位实验主要具有操作复杂、数据分析不够直观以及难以平衡成像速度与图像质量等局限性。现有的图像增强技术以基于扩散模型的生成式方法表现最为突出，但由于未考虑扫描电镜成像原理和模型复杂性，仍存在推理效率低、细节恢复差等问题。本文结合电子显微镜成像机制设计了基于扩散模型的高效两阶段轻量化扫描电镜图像增强方法，并基于增强现实技术构建了面向原位实验的可视化交互平台开发。论文主要工作如下：

1. 设计基于注意力机制和扩散模型的轻量化扫描电镜图像超分辨率模型。根据目前基于扩散模型的图像超分辨率方法存在计算量大、推理效率低等局限性，设计了一种包含交叉注意力机制的端到端编码器-解码器架构替换条件扩散模型中的大型去噪网络，同时结合确定性采样有效降低了推理时间。在具体实验例中将推理耗时从 25 秒降低到 1 秒内。

2. 基于扫描电镜成像原理改进图像增强流程实现更优异的图像生成质量。通过进一步分析扫描

电镜成像过程中影响图像质量的原因，提出高效两阶段扫描电镜图像增强方案，在第一阶段中将低分辨率图像进行预去噪后输入第二阶段的轻量化扫描电镜图像超分辨率模型中作为条件输入图像，以避免直接上采样带来的噪声扩散问题。实验证明基于两阶段的图像增强在峰值信噪比、学习感知图像块相似度等指标上存在明显提升（分别提升 4.6%与 17.9%），同时在具体微观结构细节的视觉效果更加优异。

3.
基于增强现实技术开发扫描电镜原位实验可视化交互平台。针对原位实验操作复杂、数据缺乏直观的可视化交互与分析手段等问题，结合增强现实技术开发可视化交互平台并设计操作指南、远程专家指导、三维模型交互等应用，显著提升了实验效率、安全性、数据分析效率和准确性。

项目的主要创新：

扫描电子显微镜开展原位高温实验，旨在为航空发动机关键部件的材料研发与优化提供有力支撑。针对扫描电镜原位实验现存的成像速度与图像质量难以兼顾、操作复杂、数据分析不直观等问题，我开展了一系列创新性工作，取得了一定成果，其创新点主要如下：

1. 轻量化超分辨率模型设计：结合扫描电镜二次电子成像原理，深入剖析现有深度学习技术在图像超分辨率任务中的局限，创新性地引入注意力机制，设计端到端编码器 - 解码器架构替换大型去噪网络，结合确定性采样，成功在保证图像质量基本稳定的前提下，将推理耗时大幅缩减，从 25 秒骤降至 1 秒内，极大提升了实验效率，为原位高温实验的实时监测提供了有力技术支撑。

2. 两阶段图像增强流程优化：进一步探究扫描电镜成像影响因素，提出高效两阶段图像增强方案。首阶段预去噪结合第二阶段轻量化超分辨率模型，有效避免噪声扩散，开发便捷应用界面便于操作人员快速部署与对比。经消融实验确定最优参数，所提方法在多项指标上显著超越其他方法，峰值信噪比提升 4.6%，学习感知图像块相似度提升 17.9%，微观结构细节呈现更为优异，为材料微观组织结构精准分析奠定基础。

3. 可视化交互平台构建：针对原位实验操作复杂、数据分析不直观的困境，借助增强现实技术，开发扫描电镜原位实验可视化交互平台。详细阐述平台架构、交互方式及基于增强现实的实验操作说明、远程专家指导等多元应用，切实提升实验效率、安全性及数据分析准确性，为原位实验开辟全新交互模式。

（二）取得的业绩（代表作）【限填3项，须提交证明原件（包括发表的论文、出版的著作、专利证书、获奖证书、科技项目立项文件或合同、企业证明等）供核实，并提供复印件一份】

1. 公开成果代表作【论文发表、专利成果、软件著作权、标准规范与行业工法制定、著作编写、科技成果获奖、学位论文等】

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AR-assisted In-situ Thermomechanical Testing System for Superalloys	会议论文	2024年12月15日	IEEE International Conference on Data Science and Systems	1/6	

2. 其他代表作【主持或参与的课题研究项目、科技成果应用转化推广、企业技术难题解决方案、自主研发设计的产品或样机、技术报告、设计图纸、软课题研究报告、可行性研究报告、规划设计方案、施工或调试报告、工程实验、技术培训教材、推动行业发展中发挥的作用及取得的经济社会效益等】

（三）在校期间课程、专业实践训练及学位论文相关情况	
课程成绩情况	按课程学分核算的平均成绩： 90 分
专业实践训练时间及考核情况(具有三年及以上工作经历的不作要求)	累计时间： 1.1 年（要求1年及以上） 考核成绩： 83 分
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22260202

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日常表现考核评价	非定向生由德育导师考核评价、定向生由所在工作单位考核评价： ☑优秀　　☐良好　　☐合格　　☐不合格 德育导师/定向生所在工作单位分管领导签字（公章）：罗阮 2025年 3月21日
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浙 江 大 学 研 究 生 院

攻读硕士学位研究生成绩表

学号：22260202	姓名：李子欣	性别：女	学院：工程师学院	专业：电子信息	学制：2.5年
毕业时最低应获：24.0学分		已获得：27.0学分		入学年月：2022-09	毕业年月：
学位证书号：			毕业证书号：		授予学位：

学习时间	课程名称	备注	学分	成绩	课程性质	学习时间	课程名称	备注	学分	成绩	课程性质
2022-2023学年秋季学期	工程技术创新前沿		1.5	87	专业学位课	2022-2023学年冬季学期	产业技术发展前沿		1.5	94	专业学位课
2022-2023学年秋季学期	新时代中国特色社会主义理论与实践		2.0	94	公共学位课	2022-2023学年冬季学期	工程中的有限元方法		2.0	100	专业选修课
2022-2023学年秋季学期	金属学原理与先进合金材料		2.0	85	专业学位课	2022-2023学年春季学期	研究生英语基础技能		1.0	69	公共学位课
2022-2023学年秋冬学期	高阶工程认知实践		3.0	92	专业学位课	2022-2023学年春季学期	传感器网络信息处理技术		2.0	93	跨专业课
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说明：1. 研究生课程按三种方法计分：百分制，两级制（通过、不通过），五级制（优、良、中、及格、不及格）。

2. 备注中“*”表示重修课程。

学院成绩校核章：

浙江大学研究生（60）成绩校核章

成绩校核人：张梦依

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Data Science Track #/A

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Data Applications Track #/C

AR-assisted In-situ Thermomechanical Testing System for Superalloys

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***Abstract*—In-situ thermomechanical experiments of superalloys can precisely control experimental conditions and achieve real-time observation, which is conducive to establishing the connection between the evolution of material microstructure and changes in performance. However, the complexity of the experimental operation process and the lack of intuitiveness in the subsequent analysis process still limit the study of in-situ experimental research of materials. To this end, in this paper, we incorporate augmented reality (AR) and propose an AR-assisted thermomechanical system for superalloy testing to help experimental personnel complete experiments and subsequent analyses better. To standardize laboratory personnel's operational behavior and avoid equipment damage caused by errors during the experimental process, we provide operation instructions and real-time remote expert guidance. The innovative observation methods and rich interaction methods included in the system provide researchers with a new perspective, significantly improving the efficiency and accuracy of data analysis. The proposed system is expected to enhance experimental efficiency and promote knowledge sharing and collaborative research, thereby helping researchers gain a deeper understanding of material deformation phenomena.**

***Index Terms*—augmented reality, in-situ testing, user interaction, operating guidance**

I. Introduction

The aerospace industry's rapid expansion has necessitated stricter standards for aero-engines, the pivotal power systems of aircraft, particularly in terms of their thrust-to-weight ratios and performance in extreme conditions [1], [2]. Superalloys and high-performance aluminum alloys are extensively utilized in fabricating aero-engines and sophisticated transport vehicles. These superalloy components are deployed in challenging environments characterized by high temperatures and stresses, underscoring the critical importance of their engineering structures' safety and reliability [3], [4]. In practice, the alloy materials' microstructure must be meticulously controlled through superior manufacturing processes to guarantee exceptional overall performance.

In superalloy research, microstructure evolution and deformation mechanisms are predominantly studied through ex-situ post-mortem analyses, which do not provide insights into the dynamic processes under actual service conditions. Rapid advancements in in-situ characterization techniques and equipment have been made to bridge this gap [5], [6]. These developments aim to forge a robust correlation between the microstructural evolution and the consequent alterations in material performance.

In-situ experiments of alloys based on Scanning Electron Microscopy (SEM) are an advanced material characterization technique capable of real-time observation of the microstructural changes of alloys under various external conditions such as temperature, stress, and chemical environments. Despite the numerous advantages of in-situ experiments, their operation is typically complex, necessitating that experimental personnel possess a solid background in materials science and comprehensive operational training. During the experimental process, a large amount of image time-series data regarding the sample's microstructure is generated, which is crucial for understanding the micromechanisms of materials. Post-processing of the data often involves image preprocessing, feature extraction, quantitative analysis, machine learning and pattern recognition, and three-dimensional reconstruction. These methods provide rich information but require deep expertise. Moreover, the inherently three-dimensional nature of the microstructure of metallic materials is a key consideration. While current methods focus on quantitative analysis, there's a need for more intuitive ways to present the extensive image data. The two-dimensional images obtained from SEM in-situ experiments are limited, highlighting the importance of acquiring three-dimensional models through advanced characterization techniques [7], [8]. The integration of two-dimensional images with three-dimensional models for subsequent analysis is a

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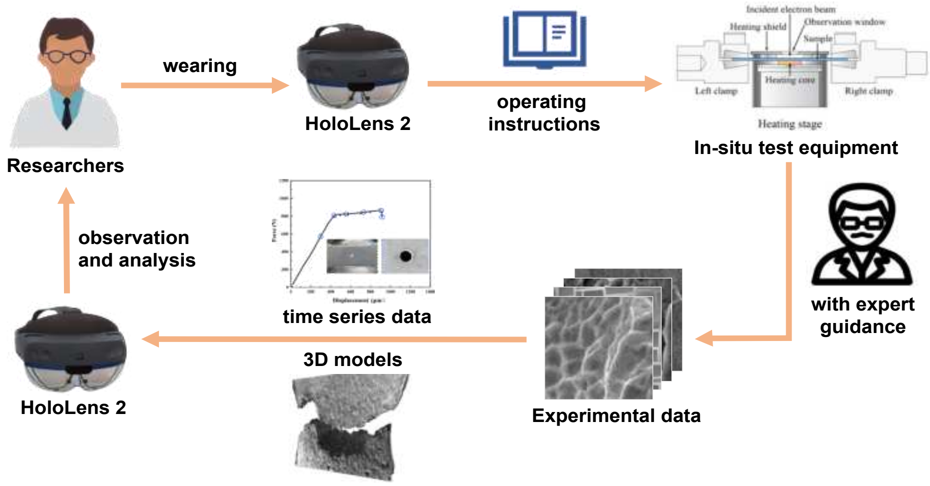

Fig. 1. System architecture

significant challenge that researchers are actively working to overcome.

Augmented Reality (AR) seamlessly integrates virtual elements like images, videos, and 3D models into the user's real-world view [9]. By superimposing digital information onto the actual environment, AR deepens the user's immersion and enriches their experience, significantly boosting efficiency and engagement across manufacturing [10], healthcare [11], and education [12] sectors. AR has transformed everyday activities, from shopping and traveling to social interactions, offering more personalized and enriched user experiences. As AR converges with other advanced technologies like artificial intelligence, its applications are anticipated to expand, propelling digital transformation and fostering innovation. Integrating AR into the in-situ experimentation and analysis of superalloys promises to enhance experimental efficiency and safety while facilitating knowledge sharing and collaborative research, thus aiding a more profound comprehension of experimental phenomena.

In this work, we investigate the potential of employing an AR head-mounted display, specifically the Microsoft HoloLens 2, to facilitate the in-situ experimental process and subsequent analysis. This proposed system aims to bridge the gap for experimenters by delivering enhanced professional operational instructions and guidance and offering an intuitive, convenient, immersive, and real-time observational and interactive environment. The system's architecture is depicted in Fig. 1. For example, the system provides the relevant applications, as shown in Fig. 2. Researchers can obtain real-time operational guidance during experiments and more intuitive and convenient data analysis methods after the experiments. To the best of our knowledge, we are the first to achieve AR in in-situ SEM operation instructions and data analysis.

The rest of this paper is organized as follows. Section II reviews related work. Section III presents the architecture, construction, and development of the proposed system. Section IV introduces the implementation and evaluation results. Section V concludes this work.

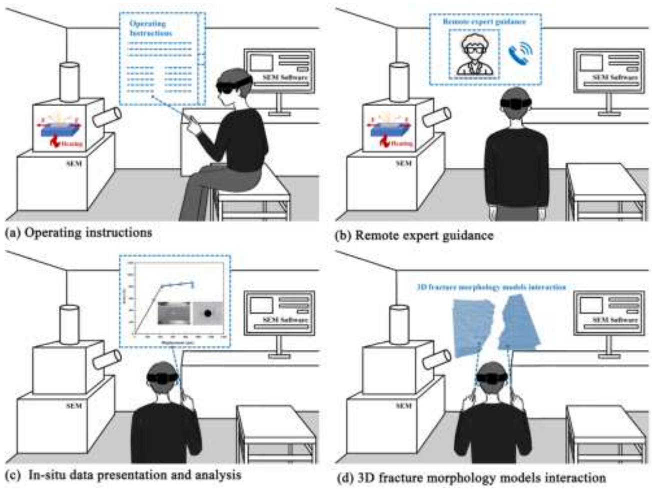

Fig. 2. Applications of the proposed system

II. Related Work

AR technology enhances users' perception and interaction with the natural world by superimposing computer-generated images onto the user's field of view, characterized by real-time, interactivity, and three-dimensionality. The term "AR" was first introduced in 1992 by Boeing engineers T.P. Caudell and D.W. Mizell [13], who developed a simple see-through headset to assist aircraft engineers in completing complex wiring diagrams, thereby reducing costs and increasing efficiency. However, the concept can be traced back to the head-mounted display designed by Ivan Sutherland, the father of computer graphics at Harvard University, in 1968 [14]. Although it was pretty primitive regarding user interface and realism, it was the first experiment where digital reality replaced the real world, laying the foundation for AR technology.

In recent years, AR has shown tremendous potential in education and maintenance, especially in applications such as teaching, experimental assistance, and remote expert guidance. By providing more intuitive learning experiences and operational advice, integrating virtual images with the natural world can help users better understand abstract concepts and complex processes.

Many different fields have adopted AR devices to accomplish educational tasks. Lv et al. [15] designed a mixed reality environment for spatial analysis of digital elevation models, integrating rich knowledge points through an intelligent geographical sandbox, enhancing the analysis effect and immersive teaching experience. Cai et al. [16] proposed a neurosurgical training and education system, improving surgical trainees' understanding of tumor characteristics in pituitary tumor resection. Khajarian et al. [17] presented a real-time markerless tracking and registration system for AR-guided liver surgery using HoloLens 2, which streamed RGBD data, employed deep learning for segmentation, and evaluated the impact of liver section visibility and device movement on the registration process. Feith et al. [18] developed a mixed reality user interface for Microsoft HoloLens 2 that utilized dual quaternions to enhance interactive robot learning, allowing users to intuitively observe, control, and refine robotic movements in a 3D space.

In addition to its application in education, AR technology can more conveniently complete complex tasks while ensuring safety due to its unique interactivity and virtuality. Zhao [19] developed an AR-based auxiliary system for turbine maintenance, superimposing virtual models of maintenance process knowledge on actual operating equipment, simplifying the process of turbine maintenance. Song et al. [20] developed HoloCV, a head-mounted mixed reality system that enabled contactless vital signs monitoring and real-time pre-diagnostic results presentation, facilitating medical emergency responses. Smith et al. [21] developed an AR handwashing tool for children with ASD, enhancing hand hygiene practices through an engaging and personalized learning experience.

In summary, the application prospects of AR technology in fields such as education, operations, and maintenance are vast. Specific experimental teaching and remote guidance cases demonstrate the potential for further application in other areas. However, relevant progress has yet to be made in using AR technology for teaching superalloy materials, especially in in-situ experimental teaching and analysis.

III. Design of the AR-assisted in-situ thermomechanical testing system

A. System architecture

For the application scenario mentioned above, we propose an AR-assisted in-situ thermomechanical testing system for superalloys, as shown in Fig. 1. Researchers wearing HoloLens 2 glasses during the in-situ experiment can see virtual electron microscope equipment information and operation manuals. In emergencies or difficulties, they can obtain guidance and suggestions from remote experts through a real-time audio and video communication mechanism. After the experiment, the complex time-series data generated during the in-situ process (including mechanical curves and microstructural images at different moments), the data processed after analysis (such as Digital Image Correlation results), and the models obtained from the three-dimensional reconstruction of the microstructures in the specimen [22] can all be imported into HoloLens 2 for visualization. Researchers can utilize this platform to conduct a more in-depth data analysis through innovative observation perspectives and rich interactive methods.

B. System construction and development

The system selects the Microsoft HoloLens 2 headset as the display terminal. This wireless wearable holographic computer can communicate bidirectionally with multiple remote users through video, voice, and mixed reality. It can register an accurate environmental map in the system through spatial mapping functions to achieve visual picking, allowing holograms to blend seamlessly with the natural environment and providing users with a more realistic experience. On this basis, HoloLens 2 offers users an enriched mixed reality experience by integrating a multitude of interaction technologies. These technologies include precise hand tracking, which allows users to interact with virtual objects through natural gestures; eye tracking, enabling the device to respond to the user's gaze; and voice control, which lets users operate the device with commands. Additionally, HoloLens 2 supports hand-controlled beams and air tapping, enabling users to interact with distant holograms without the need for physical contact.

The system was developed using the Unity engine (version 2021.3.40f1) to create an AR application, which includes virtual image rendering and UI interface design. The Mixed Reality Toolkit (MRTK) and Vuforia Engine were utilized for auxiliary development. MRTK facilitates the rendering of AR projects, significantly enhancing the construction of AR experiences. Vuforia Engine, on the other hand, can place virtual objects and trigger corresponding virtual user interfaces in response to image markers based on the spatial configuration of the HoloLens 2 device when it detects pre-configured electron microscope images. Local and remote audio and video communication was implemented using MixedReality-WebRTC, and finally, the program was deployed to the HoloLens 2 device through Visual Studio 2019.

IV. System functional implementation

A. Operating instructions and remote expert guidance

Laboratory personnel must undergo detailed training and strictly follow the operational procedures during in-situ experiments to efficiently complete them and prevent instrument damage. We have prepared SEM operating instructions and an in-situ experiment guide for this process. Laboratory personnel can wear the HoloLens 2 headset to detect the identification images on the experimental bench. By utilizing the Vuforia Engine, the detected specific pre-configured images are matched

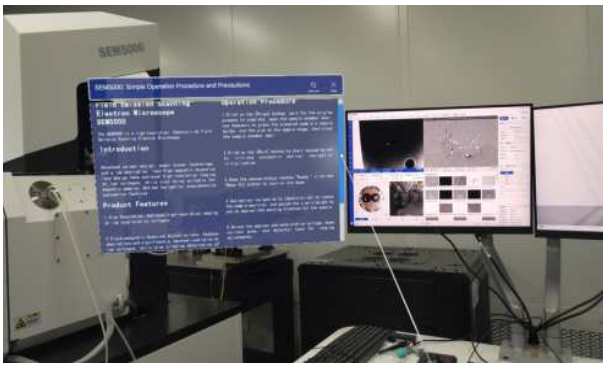

Fig. 3. Operating instruction of SEM5000

with AR models, thereby obtaining corresponding real-time virtual operation instructions. It can complete operations such as zooming, page scrolling, and page tracking through gesture interaction, as shown in Fig. 3, which is the operation manual for the SEM5000, bringing a more intuitive and convenient operational experience.

However, predefined teaching content always makes it challenging to cope with operational issues encountered in experiments, emergencies, or other urgent troubles that must be resolved. Therefore, obtaining expert guidance in real-time through audio and video communication is very important. MixedReality-WebRTC integrates end-to-end audio, video, and data real-time communication into the application and improves collaborative methods and interactive experiences. Fig. 4 shows the architecture of WebRTC.

To establish communication among various users and devices, WebRTC requires a signaling mechanism or protocol support [23]. Signaling is the core of the peer discovery mechanism, which discovers any existing peers and then coordinates communication between browsers. Initially, two clients (A & B) who want to create a connection need a server accessible to both to help them exchange the information required. WebRTC developers can use The Internet Communications Engine (ICE), which simplifies the complexity of the Internet addressing system [24]. The WebRTC access process mainly includes the following steps:

1) Client A and Client B are connected to the signaling server to exchange messages.
2) Client A creates a Peer Connection to obtain the local media stream.
3) Client A creates an Offer, describing the communication parameters, and saves it as the local description.
4) Client A forwards the Offer to Client B through the signaling server.
5) Upon receiving the Offer, Client B creates an Answer and sets it as the local description.
6) Client B forwards the Answer to Client A through the signaling server, setting it as the remote description.
7) Clients A and B exchange ICE candidates forwarded through the signaling server.

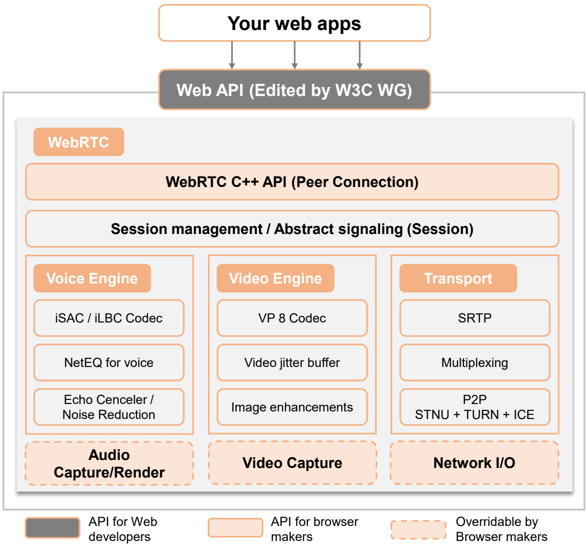

Fig. 4. WebRTC architecture

8) Using ICE candidates, Clients A and B establish a powerful P2P connection, enabling NAT traversal, media data transmission, and the establishment of WebRTC communication.

The final implementation achieved audio and video communication between the local experimental personnel and the remote experts.

B. Full temporal in-situ data presentation and analysis

In-situ experiments of superalloys have yielded a wealth of mechanical property data and time-series images of microstructure. These data provide detailed insights into the material's behavior at various deformation stages. However, we must present this complex information intuitively and understandably to researchers. To address this issue, we have employed AR technology to integrate experimental data with the HoloLens 2 device, enabling the visualization and interactive analysis of the data.

Here, we take the room-temperature in-situ tensile test of a group of ZG4 nickel-based single-crystal superalloy samples with a film cooling hole as an example. First, we preprocess the experimental data, including the organization of mechanical property curves and the categorization of time-series images. The mechanical property curves will display the stress-strain relationship of the samples at various deformation stages, and critical time points for image acquisition will be marked on the curves. We integrate these data into the HoloLens 2 device, as shown in Fig. 5. This provides researchers with a macroscopic perspective, helping them understand the material's overall performance changes.

Subsequently, researchers can interact with the system through gesture control, selecting the time points of interest, and the system will immediately display the microstructural images and other relevant data at that moment (Fig. 6).

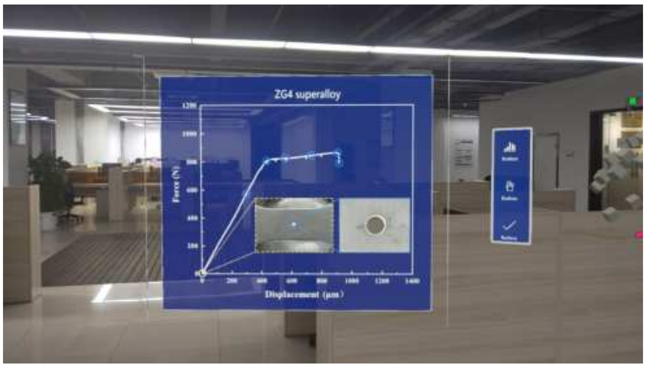

Fig. 5. Tensile stress-strain curve of the in-situ tensile test with SEM images of the initial state of the film cooling hole

Fig. 6(a) shows the SEM image of the gas film holes at that moment and the results of Digital Image Correlation (DIC) analysis with the initial SEM image, allowing for the calculation and observation of the global strain distribution of the specimen. Fig. 6(b) shows the surface morphology characteristics after the sample's tensile fracture failure.

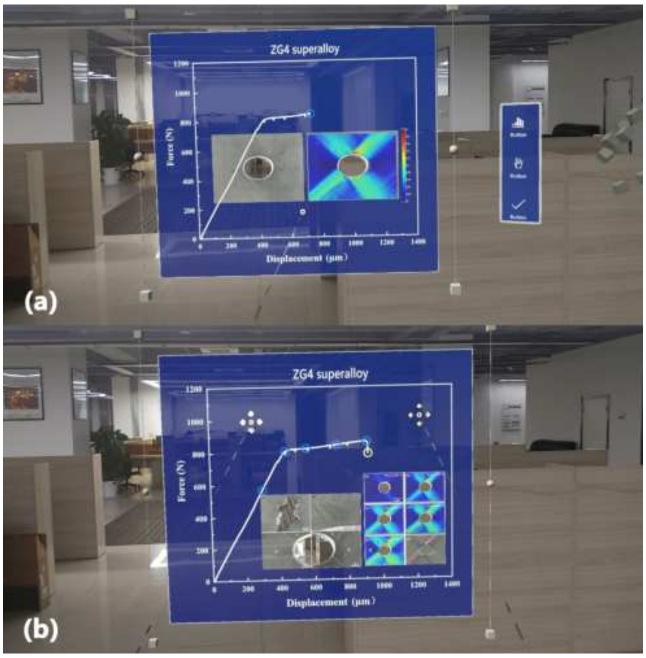

Fig. 6. SEM images and DIC strain distribution images of the film cooling hole at the intermediate and final fracture states

The visualization and interactivity of these data will enable researchers to observe the material's microstructure from different angles and depths, thereby gaining a deeper understanding of the material's deformation mechanisms and microstructural evolution. This provides a new perspective for the study of superalloys, promotes the development of materials science, and provides vital data support for future material design and application.

In our forthcoming research endeavors, we aim to develop a user-friendly interface that will enable researchers to navigate back to previous data points after analyzing a specific time point. This interactive data presentation method will enhance research efficiency and deepen the researchers' comprehension of material behavior.

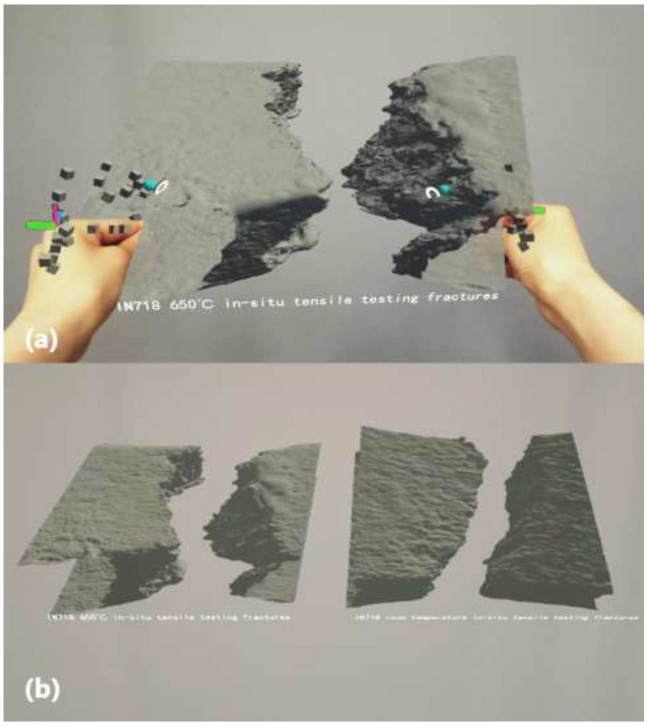

Fig. 7. Interaction and observation of 3D fracture morphology models

C. 3D fracture morphology models interaction

The microstructure of superalloys possesses a complex 3D morphology. Although SEM images offer a substantial depth of field and a certain degree of three-dimensionality, they still have limitations in reflecting height information [25]. Particularly in the critical field of alloy fracture analysis, the complex and undulating morphology of the fracture surface makes it difficult for traditional 2D images to capture its subtle characteristics fully. Therefore, 3D reconstruction technology becomes particularly crucial, as it can provide us with more accurate information on fracture morphology.

We have developed an advanced 3D reconstruction method that acquires multi-angle SEM images by rotating the sample stage, thereby reconstructing the 3D model of the fracture and performing precise scale calibration [22]. However, in the actual observation and analysis process, we have found that existing technological methods still need to be improved in intuitively matching and synergistically observing the 3D model with 2D images and between different 3D models.

To address this issue, we plan to integrate the 3D fracture model into AR technology. Researchers can observe and interact with multiple 3D models simultaneously in virtual space through AR, performing actions such as scaling, rotating, and moving, thereby more intuitively establishing the connection and matching mechanism between 2D images and 3D models. Here, we take the 3D model of the high-temperature tensile fracture of a group of IN718 nickel-based polycrystalline superalloy samples as an example, as shown in Fig. 7. This innovative observation method provides researchers with a new perspective and greatly improves the efficiency and accuracy of data analysis.

V. Conclusion

This paper presents an AR-assisted in-situ thermomechanical testing System for Superalloys, which can help researchers more conveniently obtain operational guidance, experimental information, and result analysis, thereby providing deeper scientific insights into the design and application of superalloys. The proposed material experimental assistance system has more significant advantages than traditional ways of obtaining experimental information: (1) It frees the hands of experimental personnel, conveniently obtaining information on the operation of experimental instruments and real-time remote expert guidance, improving the efficiency and safety of experiments. (2) It provides visualization for the time-series data of materials at different deformation stages in the in-situ experiment of superalloys, presenting complex information more intuitively and understandably to researchers. (3) The system's rich interactive methods and innovative observation methods provide researchers with a new perspective, significantly improving the efficiency and accuracy of data analysis. The system is efficient and can meet the different teaching and training needs. In future work, we will explore the 3D surface morphology reconstruction methodology during the in-situ experiment. We plan to apply AR methods to expand our observation and analysis methods. Through this method, we expect to achieve real-time, dynamic observation and quantitative analysis of materials' deformation and fracture process under actual use conditions.

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