Demonstrating Thermal Flux: Using Mixed Reality to Extend Human Sight by Thermal Vision

Pascal Knierim[1], Albrecht Schmidt[1], Thomas Kosch[2]
[1]LMU Munich, Munich, Germany, {firstname.lastname}@ifi.lmu.de
[2]TU Darmstadt, Darmstadt, Germany, kosch@tk.tu-darmstadt.de

Figure 1: A person uses our prototype to understand thermal flux in a physics lab experiment. Users can either use a smartphone (left) or HMD (right) to extend their sight by thermal vision. Virtual elements are an extension for non-functional setups to simulate a real experiment.

ABSTRACT

Human vision underlies several constraints in its spatial, temporal and spectral resolution. One limitation is the visual sensation of temperatures, which can be a useful addition for human sight in education or work scenarios. This demo presents how mixed reality applications can virtually superimpose objects' thermal properties with the physical world into a coherent environment. We present a prototype that utilizes either a smartphone or a head-mounted display to mediate thermal flux. We show the feasibility of our prototype in the context of a physics lab experiment that fosters the understanding of heat conduction for different materials. We envision thermal vision as an addition to the human sight that can be accomplished with already available technologies. Finally, we discuss how our prototype can be designed as a context-aware in-situ interface that toggles between regular and thermal vision.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; *Ubiquitous and mobile devices.*

KEYWORDS

Mixed Reality, Augmented Sight, Thermal Vision, Education

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1 INTRODUCTION

Human sight is a crucial component to perceive, understand, and interact with the environment. However, visual perception underlies certain spatial [5], spectral [1] and temporal [8] limitations that are a continuous subject for research. One constraint is the spectral limitation, which can be overcome through specialized sensors that show the output on a separate display. Practical educational courses that are common in physics, rely on this approach to teach the thermal conductivity of different materials using thermal cameras [12]. However, past research has shown that the separation of probe and display device strains working memory and elicits a higher number of errors during observational and measurement experiments [10]. Further, research investigated Mixed Reality (MR) as a key technology for overcoming the constraints of human vision by spatially aligning information on objects in real-time [11]. Such information is beneficial in learning scenarios, especially when adding interactive lessons [2, 3]. Both, mobile [7] and stationary [9] MR applications have shown beneficial effects on learning. We envision that MR will extend human vision by various input channels (*e.g.,* thermal vision) to support the understanding of causalities in educational scenarios.

This demo accompanies our paper [6] and presents a mixed reality application that enables physic students to simulate, observe,

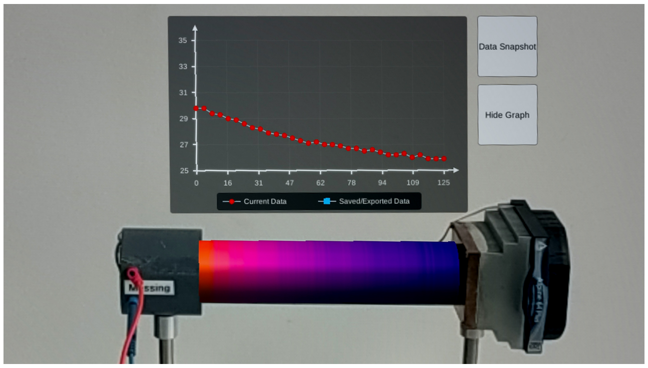

Figure 2: False-color representation of the metallic rod showing the thermal flux. Temperature changes can be observed in real-time using a smartphone or HMD.

and understand the heat flux of a brass rod. The temperatures can be monitored using a smartphone or a head-mounted display (HMD) (see Figure 1). The visualization is spatially anchored and blends with the rod, effectively replacing the user's regular sight trough thermal vision while maintaining the environment's regular appearance. This demo contributes a system that the community can pick up to investigate further modalities that extend or amplify human vision.

2 PROTOTYPE

The presented demo focuses on a common thermal lab experiment in the studies of physics. The experiment itself consists of a metallic rod made of aluminum, copper, or brass. A 24-volt power supply is used to control a cartridge heater on the one end of the metallic rod while a fan controls the temperature of the other end. Together they generate a temperature gradient within the rod. Further, there are insulated rods to generate different thermal flux properties (*i.e.,* to control the temperature distribution). A Optris PiConnect[1] thermal camera with a resolution of 160×120 pixels is placed in front of the metallic rod. The thermal camera is connected to a single board computer and streams wireless the data to the smartphone or HMD. Here, the data stream contains the temperature signature. The temperature signature is then spatially registered on the metal rod. The result is a false-color visualization and a plot representing the changes in real-time on top of the metal rod. Therefore we used the Vuforia framework[2]. We employ a Google Pixel XL 64 GB and a Microsoft HoloLens as an AR display modality. The color temperature is spatially aligned on the metallic rod and displayed on the respective device (*i.e.,* smartphone or HMD). Students can observe the thermal flux of the metallic rod in real-time after starting the experiment (see Figure 2). Figure 3 displays the architecture of our implementation.

3 DISCUSSION

We showcase a prototype that mediates visible thermal properties in a physics experiment. Our demo supports the understanding of temperature distributions in a physics experiment. Instead of separating the probe and display device, we merge both aspects into a coherent environment. Past research emphasized that this can lead to a lower perception of cognitive workload [10] and even to a better learning performance that outperforms real-world learning [4]. However, design implications need to be considered first before substituting real-world experiments with virtual ones.

[1] https://www.optris.global/optris-pix-connect - last access 2020-10-09
[2] https://library.vuforia.com/getting-started/overview.html - last access 2020-10-09

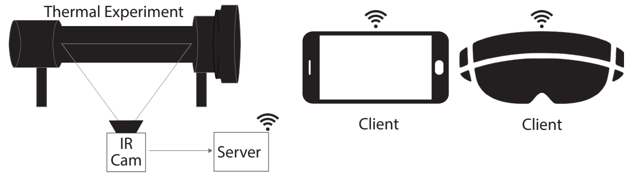

Figure 3: The architecture of the prototype. Thermal data of an experiment is captured using an infrared camera (IR Cam) and streamed via a server to either a smartphone or HMD.

3.1 Future Work

We plan to improve the prototype in an iterative process. First, we plan to integrate the thermal sensing capabilities on the display device itself. Previous research has investigated how mobile thermal vision can be implemented for firefighters [1]. We plan to use this as an inspiration for an in-situ conversion of normally visible objects to a thermal vision. For example, a combination of eye-tracking and gestures can be used to detect objects of interest and overlay the thermal information over the objects of interest.

4 CONCLUSION

Can technology compensate for missing attributes in human sight? In this demo, we showcase how thermal radiation, which is usually not visible to the naked eye, can be visualized on AR displays using infrared cameras. We realized a common physics experiment to showcase the feasibility of our approach. Traditional experiments do not entail real-time visualizations, and data has to be analyzed offline, hence splitting the attention of the user between data recording, measurement, and probe. We envision that our prototype supports student learning, and in a bigger picture, inspires researchers to create iterations that augment human vision beyond the biological limitations of the human eye.

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