

Demonstration of Flashpoint: A Thermally-Charged Arcade Experience

Daniel Honrales*
University of Texas at Dallas

Mason Liu†
University of Texas at Dallas

Jason Cheon‡
University of Texas at Dallas

Jin Ryong Kim§
University of Texas at Dallas



Figure 1: Flashpoint is a multisensory experience, rendering dynamically expressive thermal-tactile sensations in a perceptually-driven gauntlet interface with engaging XR content.

ABSTRACT

We introduce Flashpoint, a multisensory system combining vibrotactile and thermal actuation to deliver spatiotemporally dynamic, contextually driven feedback. By leveraging perceptual mechanisms over dense actuator arrays, our gauntlet interface renders expressive feedback patterns—across vibration, impact, heat, and cold—while maintaining compact and minimal hardware. We also demonstrate portability and deployability by pairing the interface with a competitive multiplayer AR game, interweaving multisensory feedback with virtual and physical interactions. Through Flashpoint, we showcase a practical approach towards deep multi-modal integration with XR applications, pointing towards new opportunities for multisensory interaction in future systems.

Index Terms: Thermal-tactile Interface, 2D Thermal Motion, Augmented Reality, Thermal Masking

1 INTRODUCTION

Immersive technology research has increasingly turned toward non-conventional sensory modalities, with thermal stimulation emerging as a promising direction. Temperature is fundamental to everyday perception, conveying both environmental cues and affective meaning. How thermal feedback is experienced depends heavily on its context and quality. A warm campfire or cool breeze can feel comforting, while a raging wildfire or biting blizzard signals danger. Unlocking the full potential of thermal rendering therefore requires fine-grained control over intensity, spatial localization, and temporal responsiveness.

However, the thermal modality poses inherent challenges. Thermal perception is slow to respond and spatially diffuse—where vibrotactile signals can localize to precise points within milliseconds, thermal sensations spread across broad areas and take seconds to register [3, 9]. Actuation technology mirrors these constraints: thermal actuators tend to be bulkier, more power-intensive, and costlier than standardized vibrotactile actuators [8, 5], which makes dense thermal actuator arrays impractical and complicates multimodal

control schemes [4]. In response, researchers have pursued alternative integration strategies, including mid-air delivery [13, 14, 20], environmental systems [17, 1], wearable displays [16, 7, 21], and perceptually-driven effects [12].

Among these, perceptual approaches show notable promise. Composite illusions that perceptually merge thermal and tactile feedback [6] can bypass certain hardware constraints altogether. In particular, the thermal masking illusion [15, 19] allows thermal sensation to be precisely localized at vibrotactile actuation sites, even without conscious perception of the underlying thermal source. This mechanism has since been extended to thermal-tactile gloves [18] and expressive thermal motion [11, 10]. However, these techniques remain largely unvalidated in real-world settings, and it is still unclear how well thermal-tactile integration holds up in physically active, dynamic contexts.

We investigate this design space with Flashpoint, a multisensory interface and immersive experience built on dynamically rich thermal feedback. Flashpoint draws on the thermal masking [19] and apparent motion [2, 10] illusions to render vivid and active thermal-tactile sensations across the forearm using a minimal set of vibrotactile and thermal actuators. To address the responsiveness and adaptability limitations of prior systems, we refine the interface design by introducing multiple independently controlled thermal actuators alongside additional LRA motors. We further embed this interface directly into immersive content through physical play in a multiplayer AR game (see Fig. 1). Together, the Flashpoint interface and experience point toward novel opportunities for multisensory interaction and engagement by illustrating how thermal feedback can be accessibly integrated into consumer-facing applications.

2 HARDWARE

The Flashpoint gauntlet houses a multisensory rendering array within an adjustable sleeve form factor (see Fig. 2), with actuators distributed around the forearm to render fused thermal and vibrotactile feedback. Building on techniques introduced by HeatFlow [10], we expand the actuator array to achieve greater spatial range while maintaining precision and fluidity. We also introduce independent thermal control schemes to enhance temporal readiness. The gauntlet is further designed for portability, with Velcro sleeves and 3D-printed structures enabling a wearable, mobile interface.

Thermal Actuator Two flexible Peltier-based thermal actuators (TEGWAY S043A030040) provide thermal stimulation. Each achieves a 64°C differential at 2.2 V/6.0 A, reaching target temperature in 1 s and returning to baseline in 10 s. We position each Peltier at the ventral or dorsal midline of the forearm. Tempera-

*e-mail: daniel.honrales@utdallas.edu

†e-mail: mason.liu@utdallas.edu

‡e-mail: jason.cheon@utdallas.edu

§e-mail: jin.kim@utdallas.edu

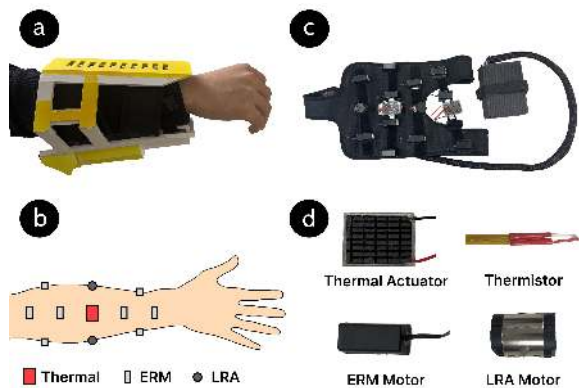


Figure 2: The (a) Flashpoint gauntlet with diagrams of (b) the actuator distribution, (c) the inner sleeve, and (d) the individual components.

ture is PID-controlled via thermistors (TEWA TT6-10KC8-9-50) and regulated with heatsinks. The actuators operate independently and alternate utilization, allowing rapid switching or simultaneous hot/cold presentation.

Vibrotactile Actuators Vibrotactile stimulation is provided by ERM and LRA actuators. The ERM motors (Tatoko B07PXZSP7J; $3 \times 1.8 \times 1.2$ cm) are GPIO/PWM-controlled, delivering up to 1.5 N at 3 V peak. Four ERM motors are equidistantly spaced along the forearm on the ventral and dorsal sides. Two additional ERM motors are positioned on each lateral side of the forearm for full coverage. Timed activation across motors generates strokes of movement along the arm. The LRA motors (Vibronics VL32158H-L25; 22 mm diameter $\times$ 30 mm length; 70 Hz resonance) deliver 3 g RMS acceleration in under 0.1 s, providing near-instant impact feedback and supporting vibrotactile movement patterns. Each LRA motor is placed on the lateral side of the forearm between ERM motors, serving as a central vibrotactile unit.

System Control A Raspberry Pi 4 Model B controls the gauntlet system, orchestrating predefined activation patterns triggered by event signals. The Pi communicates event signals with its paired HMD via BLE. An H-bridge controls thermal actuator polarity and intensity; ERMs are driven via GPIO/PWM, and LRAs via a Class-D amplifier (HiLetgo PAM8610). Portable battery packs power the system, and a programmable LED strip indicates system state.

3 SOFTWARE

We directly integrate the gauntlet interface with a multiplayer AR context to create an immersive multimodal experience. In the Flashpoint game, users duel one-on-one, unleashing thermally-charged attacks. We also interweave virtual and physical interactions, enhancing immersion and embodiment as users directly inflict or receive dynamic, real-time multisensory feedback responses (see Fig. 3). The resulting gamified experience combines active movement, diverse feedback modalities, and thorough integration of the real and virtual worlds to deliver full sensory engagement.

AR Environment The Flashpoint AR application seamlessly blends real and virtual elements, transforming physical space with engaging visual effects while preserving visibility of the gauntlets, surroundings, and other players. Built in Unity and deployed on Meta Quest 3 HMDs, the application supports multiplayer functionality via Photon Fusion. Its sci-fi scenery and obstacles leverage Meta Depth API to realistically align with and occlude virtual objects within the physical play space, while immersive visual and audio effects heighten engagement across in-game events.

Game Actions and Feedback We implemented various game actions to enable strategy and adaptation during the active and com-

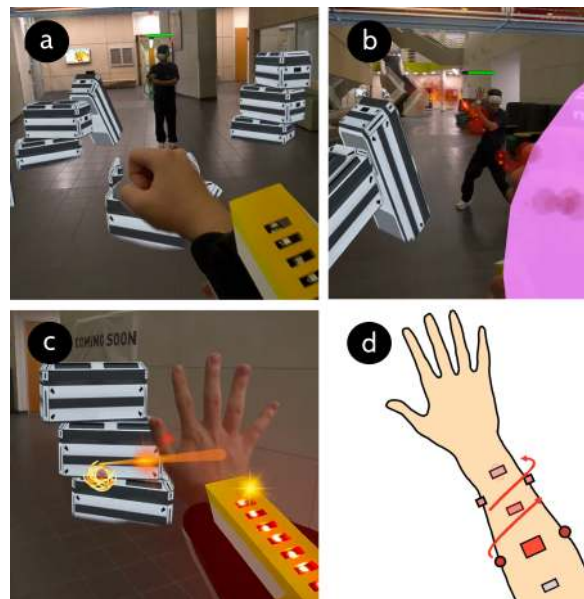


Figure 3: The (a) multiplayer AR environment with (b) a gamified context. Game actions are synchronized with multisensory feedback, such as (c) the gesture-activated heat beam and (d) hot rising swirls.

petitive context of the game. Drawing inspiration from popular games and arcade experiences, such as laser tag, the Flashpoint gauntlet equips users with a range of tools, actions, and feedback patterns, including:

- **Heat Laser:** A red laser beams outward from the user’s palm, felt as warm strokes spiraling from elbow to wrist.
- **Frost Bomb:** A blue projectile launches from the user’s hand and explodes on impact, felt as quick, punctuated pulses of coolness spreading outward from forearm center.
- **Weapon Switch:** Users physically pump the gauntlet grip to switch between heat laser and frost bomb, felt as congruent warm or cool strokes traveling from wrist to elbow.
- **Shield:** A fist gesture raises a purple disc to block incoming projectiles, felt as muted impact vibrations fused with the appropriate temperature upon collision.
- **Getting Hit:** A projectile hit is felt as the incoming temperature, amplified by strong impact LRA vibrations and reverberating ERM microvibrations.

The duel continues until one user reaches zero health. By synchronizing multisensory feedback with game events, we heighten presence of virtual entities and amplify perceptual impact of user actions, fusing the real and virtual worlds into a unified experience.

4 DEMO EXPERIENCE

At ISMAR 2026, our demo offers attendees a thrilling arcade experience with dynamic multisensory feedback delivered through the Flashpoint interface. Paired attendees will engage one another within the gamified AR context, moving through physical space and trading thermal-tactile effects in real time. Before playing, attendees will be briefed on how to interact with the Flashpoint system and AR environment, including the available actions and goals. Demonstrators will assist attendees in putting on the Flashpoint gauntlets and XR equipment, and will provide guidance throughout the demo. The entire experience, including setup and briefing, will take approximately 7 minutes per attendee.

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