

Flashpoint: A Thermally-Charged Arcade Experience

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Figure 1: Flashpoint is a multisensory interface and experience, leveraging perceptual mechanisms to render dynamically expressive thermal-tactile sensations with engaging XR content.

Abstract

We present Flashpoint, a multisensory experience realized through a wearable interface and multiplayer AR game. Our demo employs vibrotactile and thermal actuators in a gauntlet form factor, leveraging perceptual mechanisms to deliver thermal-tactile feedback that is spatiotemporally dynamic and contextually rich. This approach accomplishes diverse feedback modalities while reducing standard hardware requirements. Experiencing vibration, impact, heat, cold, and visual stimulation, users draw on the gauntlet interactions and rendering to competitively engage within an AR environment, dueling opponents through thermally-charged attacks. Precise feedback pattern design and real-time responsiveness to game events foster immersion and engagement, while the interplay of physical and virtual interactions unifies game actions with sensory stimulation. Flashpoint demonstrates opportunities for accessible multisensory interfaces and applied perception-driven design in future research.

CCS Concepts

• **Human-centered computing** → **Interaction techniques**; **Haptic devices**; **Virtual reality**.

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Keywords

Thermal-tactile Interface, 2D Thermal Motion, 2D Tactile Motion, Thermal Referral

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1 Introduction

Research on immersive technology has increasingly expanded towards non-conventional sensory modalities, including thermal stimulation. Temperature plays a vital role in everyday sensing, providing both environmental information and empathetic sensation. The effect and experience of thermal feedback depends heavily on context and quality. For example, warm campfires and cool breezes can offer comforting respite, but blazing wildfires and chilling blizzards invoke danger and alarm. To fully utilize the potential of thermal rendering, designers require fine-grained control over thermal intensity, spatial localization, and temporal responsiveness.

However, the thermal modality itself presents inherent challenges. Thermal perception is slow and spatially diffuse by nature. Where vibrotactile signals localize to precise positions within milliseconds, thermal sensations spread over wider areas and take seconds to detect [3, 9]. Rendering technology reflects these issues—thermal actuators are more bulky, power-hungry, and expensive compared to standardized vibrotactile actuators [5, 8], making dense arrays of thermal actuators impractical and multimodal control

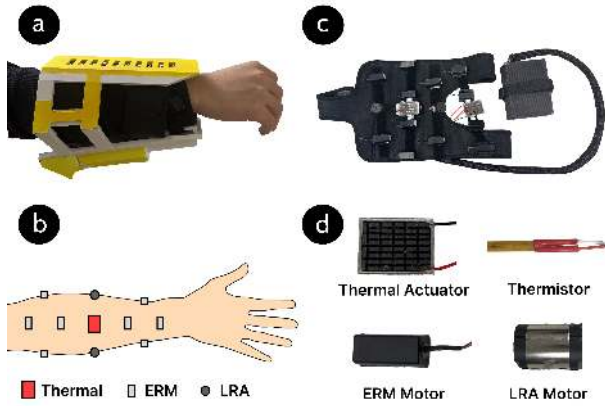


Figure 2: The (a) Flashpoint gauntlet with (b) a diagram of the actuator distribution, (c) the inner sleeve, and (d) the individual components.

schemes more complex [4]. Recent research has thus explored alternative integration methods, including mid-air delivery [13, 14, 20], environmental systems [1, 17], wearable displays [7, 16, 21], and perceptual effects [12].

The perceptual approach has proven to offer tangible and experiential benefits. Composite illusions have been perceptually combine thermal and tactile feedback [6], bypassing hardware limitations in certain cases. Notably, the thermal masking illusion [15, 19] enables precise localization of thermal sensation at vibrotactile sites, even without perception of the original thermal source. This mechanism has since been extended to thermal-tactile gloves [18] and expressive thermal movements [10, 11]. Still, real-world application of these techniques remains limited, and the integrity of thermal-tactile integration in physically active contexts remains unknown.

We explore this design space with Flashpoint, a multisensory interface and immersive experience powered by dynamically rich and responsive thermal feedback. The Flashpoint interface leverages the thermal masking [19] and apparent motion illusions [2, 10] to render vibrant and active thermal-tactile sensations across the forearm with minimal vibrotactile and thermal actuators. We address prior limitations in thermal responsivity and feedback adaptability of prior work by refining the interface design, introducing multiple individually controlled thermal actuators and additional LRA motors. We also directly integrate the interface with immersive content and physical play in a multiplayer AR game (see Fig. 1). With the Flashpoint interface and game, we envision a truly interactive and engaging user experience, exploring how thermal feedback can accessible integrate into consumer-facing applications and delight users with novel multisensory opportunities.

2 System

The Flashpoint gauntlet features a multisensory rendering array embedded into an adjustable sleeve form factor (see Fig. 2). The various actuators render thermal, vibrotactile, and visual feedback around the arm. Spatial precision and fluidity is accomplished with expanded hardware and techniques demonstrated by HeatFlow

[10], while temporal readiness is enhanced with improved control schemes. We also present the gauntlet as a portable interface, wearable and mobile via Velcro sleeves and 3D-printed structures.

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. Temperature 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. 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.

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.

2.1 Experience

The Flashpoint experience directly integrates the gauntlet interface with a multiplayer AR context. Users duel against one-on-one, using thermally-charged attacks to deplete the health of their opponent. Both physical and virtual interactions are available, with users directly inflicting or receiving dynamic, real-time multisensory feedback in response (see Fig. 3). The gamified experience features active movement, diverse feedback, and thorough integration of the real and virtual worlds for full sensory engagement.

AR Environment The Flashpoint AR application seamlessly blends real and virtual elements. The virtual environment presents spatial transformation with engaging visual effects while AR preserves visibility of the gauntlets, surroundings, and other users. Built in Unity and deployed on Meta Quest 3 HMDs, the application hosts multiplayer functionality via Photon Fusion. Its sci-fi scenery and obstacles use Meta's Depth API to realistically align and occlude virtual objects within the real play space, while appealing visual and audio effects foster engagement across game events.

Game Actions and Feedback The competitive game context lets users strategize and adapt in an exhilarating battle. Inspired by popular games and arcade machines, the Flashpoint gauntlet equips users with various tools, actions, feedback patterns, including:

- **Heat Laser:** A red laser beams outward from the user's palm, felt as warm strokes travelling 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.

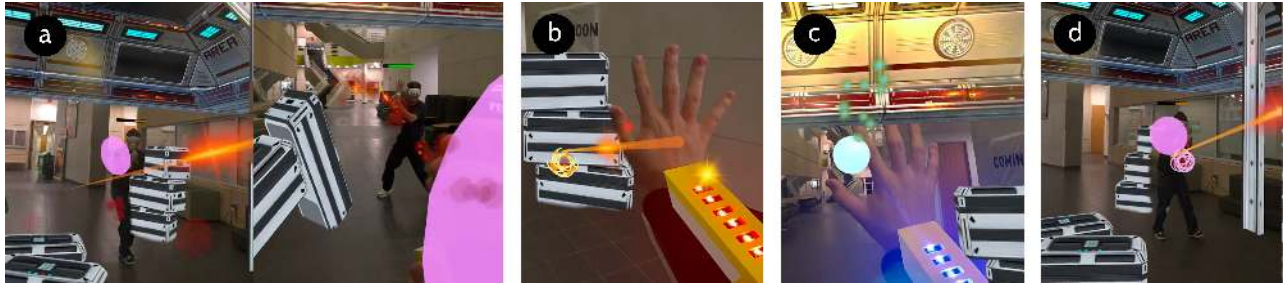


Figure 3: The (a) AR multiplayer game experience, where players can (b) beam hot lasers, (c) launch ice bombs, and (d) shield from incoming attacks. The Flashpoint gauntlet renders multisensory feedback for each game action.

- **Weapon Switch:** Users physically pump the gauntlet grip to switch between heat laser and frost bomb, felt as congruent warm or cool strokes spiraling 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.

Users continue the duel until one user reaches zero health. By pairing multisensory feedback with game events, we enhance the presence of virtual entities and perceptual impact of user actions.

3 Demo Experience

At UIST 2026, our demo presents a thrilling arcade experience with dynamic multisensory feedback rendered through the Flashpoint interface. Attendees will engage with each other through the gamified AR context, moving around real space and trading thermal-tactile effects in real-time. Attendees will be instructed on how to interact with the Flashpoint system and AR environment, including possible actions and goals. Demonstrators will help attendees put on the Flashpoint gauntlets and XR equipment, and will provide guidance throughout the demo. The entire demo, including setup and briefing, will take approximately 7 minutes per attendee.

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