nocturneAR: An Outdoor AR-Based Musical Interface in Dark Transitional Landscapes

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Figure 1: A participant interacting with luminous objects in a dark forest environment.

Abstract

nocturneAR is a participatory outdoor music installation that explores liminal audio-visual experiences in darkness using Augmented Reality (AR). Although AR systems typically rely on sufficient illumination and thus fail in dark environments, we developed an AR-based musical interface for dimly lit outdoor spaces by utilizing visible light communication through LED flashing as AR markers.

We propose an AR system in which light functions simultaneously as a navigational cue, interaction trigger, and musical interface. Participants walk through dark outdoor environments, such as night forests, guided by multiple luminous objects while holding a smartphone. Directing the smartphone toward a light source activates AR visuals and sound playback. As participants move between lights, sounds accumulate and transform, generating evolving harmonic structures that include chords, dissonance, and undulating textures.

This system frames spatial navigation toward light as an embodied musical interaction, enabling participants to discover sound relationships through movement in an uncertain environment. By engaging with ambiguous visual cues and transitional sound states within darkness, the installation creates a liminal experience that blurs the boundaries between navigation, performance, and listening.

We present the system design and describe an exploratory nighttime forest exhibition, discussing how darkness and visible light-based interaction can support novel forms of spatial musical experience in AR contexts.

Keywords

Augmented Reality, Dark Place, Musical Interface, Visible Light Communication

1 Introduction

Augmented Reality (AR) has become an increasingly popular medium for musical interfaces and sound installations, offering new ways to combine visual information, spatial interaction, and sound. In musical contexts, AR is often used to visualize musical structures, augment instruments, or support interactive composition and performance. However, these systems typically rely on stable visual tracking and sufficient illumination, implicitly assuming bright and visually reliable environments.

As a result, AR-based musical interaction has rarely been explored in dark or visually ambiguous spaces, such as outdoor environments at night. Darkness is generally treated as a technical constraint to be avoided, rather than as a condition that might meaningfully shape the musical experience. In sound art and embodied listening practices, darkness can heighten attention and bodily awareness, and encourage deeper engagement with sound and space.

This paper presents nocturneAR, a participatory outdoor music installation that explores how AR can function as a musical interface in darkness. To enable AR interaction in dimly lit environments, we developed a system that utilizes visible light communication through LED flashing as AR markers. In nocturneAR, light serves simultaneously as a navigational cue, an interaction trigger, and a musical interface. Participants walk through dark outdoor spaces, such as night forests, guided by luminous objects while holding a smartphone. Pointing the smartphone toward a

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light activates AR visuals and sound playback, and sounds evolve as participants move between lights.

Rather than minimizing uncertainty, nocturneAR embraces ambiguity as a core design principle. Limited visibility, unstable visual cues, and transitional sound states encourage exploratory movement and attentive listening, producing a liminal audio-visual experience that blurs boundaries between navigation, performance, and listening.

Through the design and presentation of nocturneAR in an exploratory nighttime forest exhibition, this research investigates how darkness and light-based interaction can support novel forms of spatial musical experience using AR. We discuss the system design and reflect on the experiential qualities that emerge when AR-based musical interaction is situated in dark, ambiguous environments.

2 Related Work

Augmented Reality (AR) has been widely explored for musical interaction. Prior work has investigated AR for performance support and collaboration[11], instrument extension[9], and participatory musical engagement[10]. Systems such as SAGeM[5], which treat real-world objects as instruments through gesture interaction using an HMD, and Luna [1], which enables manipulation of virtual musical objects through AR gestures, demonstrate how AR can augment or extend traditional instrumental paradigms. Smartphone-based systems, including ARLooper[7], further explore mobile AR as a platform for musical interaction. However, many of these systems rely on camera-based SLAM for position estimation and object recognition, limiting their functionality in low-light environments.

AR technologies designed specifically for dark environments include infrared-based approaches[2], yet such systems typically require specialized hardware and are not easily implemented using standard smartphones or consumer HMDs.

Installations situated in dark environments have also explored alternative sensory configurations. Sound Forest[3] presents sound through light and tactile modalities, creating multisensory experiences. Works such as Being With The Waves[8] investigate embodied movement and perception within spatial sound environments, Pharosphones[6] enables participatory music using the light from participants' smartphones. While these works use visual limitation as an experiential device, they do not position light itself as an interactive musical interface.

Building upon our prior work[4], nocturneAR extends AR expression in dim environments toward a musical interface paradigm. Specifically, it reframes light not only as a visual marker but as a navigational and sonic interaction mechanism, enabling spatial sound interaction in conditions of limited visibility.

3 Overview of nocturneAR

nocturneAR is a participatory outdoor music installation designed for dark environments such as night forests. The work invites participants to explore a dimly lit landscape guided by small luminous objects while holding a smartphone. Through interaction with light, participants encounter sound and AR visuals that gradually unfold across space.

The installation consists of multiple LED-based luminous objects distributed throughout the environment. Each object emits a subtle flashing light that serves as a navigational cue and an interaction trigger. Participants freely walk through the space, directing their smartphone cameras toward these light sources. When a light is detected, AR visuals appear on the screen and a corresponding sound is activated.

As participants move between different light sources, sounds accumulate and overlap, forming evolving harmonic and textural structures. The resulting soundscape is not predetermined but emerges through the participant's path, orientation, and duration of engagement. There is no fixed goal or optimal route; instead, the installation encourages exploratory movement and attentive listening in darkness.

By situating musical interaction within a dark and ambiguous environment, nocturneAR creates a liminal experience at night in nature. The work frames light as both a perceptual guide and a musical interface, allowing participants to experience sound generation as a process of discovery shaped by movement and uncertainty.

4 System Design

4.1 System Overview

The system employs LED-based visible light communication adapted from DarkAR[4]. System configuration is shown in Figure 2.

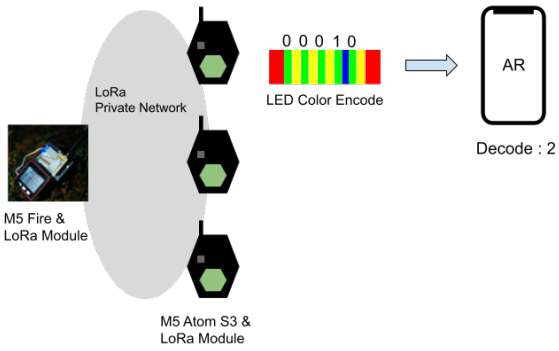

Figure 2: System Configuration

The system consists of multiple LED-based luminous objects, a controller that manages the objects, and the participant's smartphone. The luminous objects are composed of an M5 Atom, LEDs, and a LoRa module, emitting light that encodes IDs. The controller synchronizes luminous objects and assigns IDs via a LoRa private network. Participants hold smartphones such as iPhones and point their cameras at the lights to trigger AR displays and sound playback. The smartphone app is implemented using iOS Swift frameworks. However, the smartphone itself does not perform any network communication; the experience is accessible simply by installing and launching the application.

LED flashing patterns encode object IDs using a scheme adapted from DarkAR[4]. The smartphone decodes the color sequence into a unique ID. The illumination times for each color are 200ms for red:separator, 120ms for green/yellow/blue:0 or 1 and 50ms gap for each color, resulting in a total of 1,900ms for the 5 bits.

4.2 Sound and Visual Design

In nocturneAR, AR activation is directly coupled with sound playback. When a participant directs their smartphone toward a luminous object, the system simultaneously displays AR visuals

and triggers a sound associated with that object. Each object corresponds to a specific sonic element, such as a pitch or harmonic component.

The sound design evolves through the layering of sustained tones triggered by participants' movements. Sounds corresponding to each object overlap to generate chords, dissonances, and emergent rhythmic interactions. These elements function not as complete musical expressions on their own, but as fragments that acquire meaning through spatial combination.

The pitch materials consist of 18 discrete MIDI note values, distributed across multiple registers. Up to four simultaneous tones may overlap, occasionally accompanied by bell-like accents that emphasize harmonic shifts.

Rather than defining fixed harmonic progressions, the system provides an open harmonic field in which musical form emerges through spatial interaction. Situated in dark natural environments, this design reinforces attention to movement, listening, and spatial orientation, supporting the liminal and exploratory qualities of the installation. This design emphasizes harmonic emergence over direct control.

The AR video design is conceived as an abstract composition based on black and white. It consists of geometric and organic forms while concrete representations are intentionally excluded. The reason for keeping the visual presentation minimal and non-representational is to avoid competing with the auditory experience. In a dark environment, strong colors or figurative imagery risk diverting participants' attention away from the sound and spatial dimensions. The high-contrast black-and-white abstract imagery functions as a "punctuation mark" that allows for the perceptual confirmation of the light sources' activation, blending into the experience without imposing a dominant visual language.

5 Exhibition and Deployment

nocturneAR was presented as an outdoor exploratory installation in a forest environment at night on February 11, 2026. The deployment was designed to investigate how participants experience AR-based musical interaction in darkness, and how light-oriented navigation and sound generation function in a natural, low-visibility setting.

Multiple luminous objects were distributed throughout the forest at varying distances. The installation was intentionally minimal, with no explicit instructions regarding optimal routes or expected behaviors. During the exhibition, participants engaged with the installation at their own pace, often moving slowly and deliberately between light sources. The distributed luminous objects formed a visually distinct configuration within the forest environment, creating localized points of attention in an otherwise dark landscape.

Participants navigated the terrain while orienting toward light and sound. Many explored experimentally, pausing at specific light sources or revisiting them in different sequences to experience changes in sound layering. The limited visibility beyond the illuminated areas, combined with shifting harmonic relationships, appeared to direct attention toward auditory and spatial perception. In multi-participant situations, overlapping sounds blended with ambient environmental noise.

Observations suggested that the ambiguity of the interaction played a significant role in shaping participants' behavior. Rather than attempting to optimize control, participants tended to explore experimentally, pausing near specific light sources or revisiting sounds they had previously activated. The lack of clear visual dominance directed attention toward auditory and spatial cues, reinforcing the physicality of the musical interaction.

Participants informally reported experiences such as: "I felt myself drawn toward the light", "I found the mysterious sensation created by overlapping sounds pleasant", "It was fun to feel like I was performing by layering sounds". These comments generally aligned with the insights derived from the observations.

This deployment functioned as an exploratory investigation into how darkness, light-based AR interaction, and spatial sound generation could be integrated. Rather than evaluating performance metrics, the exhibition provided insight into how environmental instability and perceptual ambiguity shape musical interaction in outdoor contexts.

6 Discussion

The design and deployment of nocturneAR demonstrate how darkness and limited visual information can function as generative materials in musical interface design rather than as constraints to be mitigated. By situating AR-based musical interaction in a dimly lit outdoor environment, the installation challenges prevailing assumptions that effective AR requires visual clarity, spatial completeness, and stable tracking conditions.

Observations from the exploratory deployment indicate that reduced visibility significantly altered how participants interacted with the system and their surroundings. Instead of focusing on precise control or visual confirmation, participants relied more heavily on listening, bodily movement, and spatial awareness.

An important limitation of the system is that it is not intended to function reliably in brightly lit environments. Because nocturneAR relies on LED-based visible light communication, ambient illumination can interfere with light pattern detection and reduce system stability. While similar concerns were raised in earlier work on DarkAR, this limitation is closely aligned with the conceptual framing of nocturneAR. The system is deliberately designed for dark environments. Rather than pursuing universal robustness, nocturneAR adopts a context-dependent approach in which darkness is a prerequisite for interaction rather than a technical obstacle.

7 Conclusion

This paper presented nocturneAR, a participatory outdoor music installation that explores augmented reality as a musical interface in dark environments. Building upon the DarkAR method, the system extends LED-based visible light communication from visual augmentation toward spatial sound interaction, reframing light as a navigational and musical element.

Through an exploratory deployment in a nighttime forest, nocturneAR demonstrated how darkness, limited visibility, and ambiguity can support embodied and exploratory forms of musical engagement. By coupling light-oriented navigation with sound layering and open harmonic structures, the installation enables musical experiences that emerge through movement, listening, and spatial perception rather than explicit control.

This work contributes to NIME research by proposing a context-dependent approach to AR-based musical interfaces, in which environmental conditions are treated as generative design parameters rather than technical constraints. By positioning darkness

as a prerequisite for interaction rather than a limitation, nocturneAR expands the design space of AR-based musical systems and suggests new possibilities for site-specific and perceptually situated musical experiences.

8 Ethical Standards

Participants were informed that their facial features would be visible in the supplementary video materials, and they provided explicit written consent for the public dissemination of these recordings for academic publication and presentation.

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