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# Towards a Design Space for Shadows as Ambient Displays

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**Abstract.** In this paper, we present a design space for using shadows in interactive systems. The main elements of the design space are optical properties, dynamicity, reality, temporality, and projection surface. The paper contributes a systematic approach for designing interactive systems with shadows, adding to the prior art, which consists mostly of focused case studies.

**Keywords:** Shadows · design space · ambient displays · user experience

## 1 Introduction

Shadow is caused by a local and relative deficiency of visible light [1]. Since classical times shadows have been associated with different meanings. The examples of shadow as a communicative metaphor are found in Plato's Republic. In his Allegory of the Cave dialogues, the prisoners chained in the cave can see only shadow-beings, which represent the erroneous vision of truth [7]. Being an integral part of our physical world, shadows surround us everywhere, their shape and appearance changing depending on the illumination and the surface they are cast to. Despite their omnipresence, we are so accustomed to shadows that we hardly notice their presence.

Designing with shadows appears in various domains. The natural phenomenon of shadows is employed in architecture and product design, to create spatial effects, for aesthetics, or for function, e.g. in sundials. Art has explored the visual effects and illusions with shadows, properties which have also been applied in user interface design. Today, a growing domain of digital entertainment demands designing with virtual representations of light and shadows.

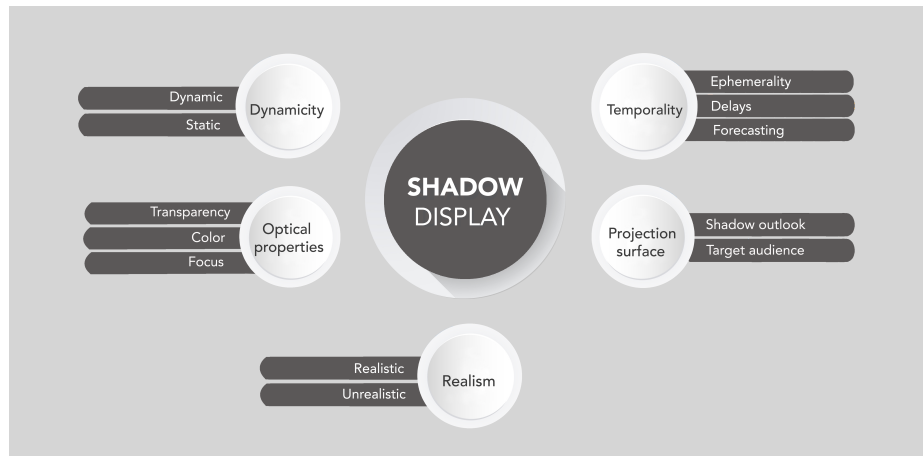
In our research, we are interested in the concept of using shadows as part of the design of interactive systems. In addition to a large body of work in performative arts [4], interactive shadow display concepts have been studied in human-computer interaction (HCI) research. Due to their nature, existing at the periphery of our attention, shadows offer interesting design opportunities as ambient displays. Ambient displays have been defined to locate at the periphery of the user's attention and present non-critical information in abstract and aesthetic ways [9]. As ambient displays, shadows have been demonstrated in HCI in

the context of plants [2], human shadows [11], candles [6], and lamps [8]. In addition, shadows have been integrated as an input method with mobile projector phones [3], and suggested to function as a user guidance [11]. However, the prior art in HCI has been rather scattered and focused more on single design cases.

In this paper, we wish to approach the topic of designing shadow UIs in a more systematic way and present a design space for using shadows as displays in interactive systems.

## 2 Design Space

The proposed design space for using shadow as an ambient display is presented in Figure 1.



**Fig. 1.** Design space for shadow displays.

**Optical Properties.** In the context of its use as a design element, the main characteristics of shadow is its unique optical properties. Shadows in the physical world are affected by optical properties, such as *transparency*, *color*, and *optical focus*. The specific shades of colors can be associated with the type of information, urgency, or intensity. Besides that, color could create a coherency with a change of atmosphere in the physical space, e.g. depending on the time of day.

The transparency, or the opacity of shadow is determined by how well the object blocks light. If the light source is colored, e.g., yellow light, the light area surrounding the shadow is yellow. If there are artificial shadow silhouettes created with projected images, they can be colorful instead of black. Minomo et al. utilized colorful patterns, animations, textual information, photos, and live videos to make shadows colorful more naturally [10].

**Dynamicity.** Another aspect of the design space is the choice between the dynamic and static representation of shadow. While a dynamic change in shadow can provide information about an ongoing process, a static interpretation can be associated with instant events. The dynamic representation of information might include a stage of the process or abrupt indications of a specific event. Choice of expression is one of the challenges of the design space, depending on the type of information or notification to be conveyed.

**Realism.** Shadows created artificially may not always have a realistic outlook, but can give a distorted sense of reality. Perhaps one of the most compelling aspects of the artificial shadow metaphor is its consistency with real objects.

**Temporality.** Another consideration when thinking about the design is to understand the temporality of the display. Visualization of artificial shadows can have temporal elements that change with time. *Ephemerality* is a state of the temporary existence of things only for a short period of time [5]. It is an important part of our experiences with our surroundings. Nature is filled with unique, expressive examples of ephemeral materials. Most of these ephemeral materials are perceived as poetic [5] due to their meaningful, expressive nature.

**Projection surface.** The surface where a shadow is cast affects primarily two aspects, the *outlook of the shadow*, and its *visibility*, which is important if we think to whom, or to which audience, the shadow display is targeted. Shadows are cast within an architectural space e.g. walls, doors, windows, desktops, floors, ceilings, which might provide different functionality of usability. A shadow that is displayed on the surface of water or onto a rough stone paving might provide different aesthetic modalities and modes of interaction.

### 3 Discussion and Conclusion

In this paper, we have described properties and other factors which we considered as creating the design space of shadows. Our design space for shadow as an ambient information display aims to describe broad application areas for shadows as a design element that can provide interesting opportunities and experience-rich applications. Especially the aesthetic, semiotic, and functional qualities of shadow make it a viable option for an ambient information display element. Based on prior research, it is known that temporal aspects in the movement of shadows [11], the movement dynamics [11], and the level of realism in the shape of the shadow [2, 11] influence the user experience with shadow displays. In future work, we aim to gain more insight into quantifying the UX with shadow displays through a systematic empirical study.

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