**Remnance of Form: Interactive Shadows as Altered Views of Objects**

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**Abstract**

The projective nature of light results in distorted shadows, the remnants of physical forms, no different from any human perception that is governed by subjectivity. This work seeks to widen the gap between the objective world and the perception of it by programatically altering the association between an object and its shadow. The shadow can transform or be animated, demonstrating a range of personality and emotion. On the other hand, the visual and interaction gestalts of our installation are carefully designed to emulate physical shadows. By juxtaposing the poetic interpretation of the shadow and realistic visuals, we explore the evocation of strong personal connections with an object and its shadow.

The shadow of an object transforms and displays human characters. It is shy at times and disappears when approached, turns hostile and spiky, or morphs into various geometric shapes. A light bulb can be moved or swung like a pendulum, where such actions could reveal hidden faces of the resulting shadow. This poses a stark contrast between the static nature of a dormant object and its dynamic augmentation—a programmatic shadow. Even the most mundane objects become no longer simple or disregardable.

*Remnance of Form* is an interactive experience that forces one to rethink the relationship between objects and their shadows. By fusing light, projection and computer vision, the shadow can be detached from its ordinary role. It takes our perception apart from the universally governing rule of physics, and the interaction between a viewer and the shadow becomes increasingly personal. The viewer is not a mere observer of the scene but a central part of how it is interpreted.

The shadow seeps into our peripheral vision, into the space around us and into the subliminal avenues of our mind that complete the elastic perception of the shadow. The vignette *Dream of Flying* embodies the human desire to transcend our physical limits and defy gravity (Fig. 1). A flying shadow is seen as a distant wonder at first; however, one soon realizes it is what we have always imagined. The shadow in this work embodies human cognitive process; it represents visual properties of the object and reflections that could occur in our minds.

**Research Question**

The interaction gestalt of *Remnance of Form* brings about intriguing yet unfathomable engagements with a shadow. The shadow responds to the manipulation of the light bulb as well as to the distance between the object and a viewer [1]. The shadow is interpreted through multiple different modalities: as a computational response, a social entity and a proxy for reflection. The tension between the modalities is the focus of our research—on how people’s perception of physical objects could change through a convincing visual presentation. On that note, we also seek to successfully integrate computational forms into the environment and investigate affordances that could tie them together. The forms refer not only to geometric shapes but also to their behaviors and transitions, which opens up an opportunity in weaving digital agents into the physical space and use them as a medium for expression and reflection.

**Related Work**

Historically, people have utilized shadows as an artistic medium; shadow puppets in Asia are one example. Their minimal presentation and projective nature also attracted artists in graphics [2,3] and sculpture [4–7]. New media artists have also experimented with going beyond the conventional representation of shadows in interactive works such as *Videoplace* [8], *The Manual Input Workstation* [9], *The Treachery of Sanctuaries* [10], *Shadow* [11], *Shadow Inverted* [12] and *Shadow Monster* [13]. These installations use captured body silhouettes of viewers for interaction and/or programmatic modification. Other tabletop interaction systems have also used the shadow metaphor for augmenting physical objects [14,15]. The work most relevant to ours is *Parade* [16], where a swinging light source is tracked to create a dancing animation.

**Installation**

The installation setup, in a cubic space, consists of a spherical object, a light bulb and projected graphics (Fig. 2). A projector casts programatically generated lighting and shadow effects on a projection panel in the back of the installation space. Kinect and IR cameras mounted on the ceiling track the viewers’ activities as well as the positions of the object and the light bulb. The relationship between the 3D positions of the bulb, the object and the projection plane are defined as a projective matrix, where the distances between them are used to determine the size of the shadow.

Our software renders the animations of the shadow by putting predesigned primitives together. A shadow can be composed of multiple animated parts (Fig. 1) that follow predefined motion paths or continually change shape based on the tracking information (Fig. 3). The proximity and height of the viewers are tracked when they are within 50 cm of the front of the installation. This way, the shadow responds only when someone approaches and manipulates the light bulb. A shader is applied at the final step to render a blurred boundary for the shadow. The parameters are chosen to closely replicate the physicality of a natural shadow cast by the light bulb.

Key considerations are how to leverage the property of light, choice of color and material for the floor, and the dimming of...
the light bulb, in order to realize visually convincing effects. We chose to utilize front projection, since back-projection would cause different light scattering and diffusion and therefore unnatural visuals. We also used a reflective acrylic sheet for the floor, so that natural shadows are effectively canceled out. Finally, the brightness of the projection and the bulb are optimized with respect to the intensity of ambient light, so that remaining natural shadows are successfully overridden.

Experience

The installation continuously cycles through several pre-scribed vignettes. It makes transitions between vignettes only when there is no audience nearby, so that on each encounter there is a chance to engage with a new experience. Five of the vignettes revolve around the social distance between the object and the viewer. Vignettes Spike and Disappear give the shadow a socially awkward personality. Once the viewer approaches, the shadow either shows hostility by growing spikes, much like hackles on the back of an animal, or shies away and disappears. The size of the spikes is determined by the detected height of the viewer—escalating from alarm to hostility.

Other proximity-based vignettes exhibit playful behaviors of the shadow. The shadow changes its shape—becoming a square instead of a circle, growing twice as big or having ears like that of an animal. These effects are often subtle, so that a viewer passing by may not notice them. Often during previous exhibitions people have not recognized an anomaly in the shadow and have chosen to skip the installation. However, once the viewer discovers and approaches the installation, the shadow will quickly turn back to its original shape, forcing the viewer to think, “What just happened?”

Many Faces is a mode that responds only to the position of the light bulb (Fig. 3). The further the light bulb moves away from the center location, the more the shadow’s shape deforms—into polygons. This vignette experiments with unexpected behavior by the shadow, which is only discoverable through direct manipulation of the light bulb. In contrast to other vignettes, the responses from the shadow are rendered direct and continuous, inviting the viewers’ active, hands-on exploration.

The last vignette, Dream of Flying (Fig. 1), is designed to appear once the object is left unattended for an extended period. The time was set to between 30 seconds and 2 minutes, based on how busy the exhibition space is. The vignette invites the viewer to consider the ephemeral and distant wonder of nature, like a bird flying away once we approach it. We have observed people responding strongly to this last vignette. Some tried and asked how to restart this hidden vignette, and some even tried moving the light bulb or making wing flapping gestures, expecting them to do something.

These are particularly notable observations regarding how an interactive system elicits highly embodied means of communication. Would it be the motions of the shadow similar to human movements or the overall behavioral trait that pictures the shadow as a social agent? The audience also kept spontaneously swinging the light bulb so that it could continue moving like a pendulum. It may be worth questioning whether their motivation was to reassure that what they saw was a real shadow or to force the juxtaposition of ordinary (shadow following the light) and extraordinary (shadow-transforming) phenomena.

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References and Notes