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The Review of Cast Shadows in Volume Rendering

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Abstract

Recently, cognitive psychologists have turned their attention to the formerly neglected study of cast shadows and the information they purvey. From shadows, it is possible to ascertain characteristics of the light source, the casting object, and the screen that the shadow is cast upon, and so shadows can provide a rich source of additional perceptual information. Also, shadows are the only source of perceptual information about the presence, shape and motion of an object. The aim of this paper is to provide a review of the literature on cast shadow perception , the perception of shadows in human and machine vision, and t the psychology and neuroscience foundation of cast shadow perception.

Keywords: cast shadows, shadow perception, volume rendering

1. Introduction

GPU-based ray casting has emerged as the defacto standard for interactive volume rendering on off-the-shelf graphics hardware. Even though in theory this technique can be easily extended by shadow feelers in order to support shadows, this obvious approach has a major impact on the rendering performance. Shadows play an important role in our understanding of 3D geometry. It can help to understand relative object position and size in a particular scene[1]. For example, without a cast shadow, we are not able to determine the position of an object in space (especially in volume rendering). The second, shadows can also help us understanding the geometry of a complex receive^{r[2].} Finally, shadows provide useful visual cues that help in understanding the geometry of a complex occlude[3].

Cast shadows are caused when a caster comes between a light source and a surface or screen. The information content in these types of shadows can therefore be used to provide knowledge about any or all of these three elements. Human perceptual system values information from shadows very highly in the perception of certain qualities, sometimes even to the detriment of other cues. From shadows, it is possible to ascertain characteristics of the light source, the casting object, and the screen that the shadow is cast upon, and so shadows can provide a rich source of additional perceptual information[4]. Keeping the light source and screen constant, the use of shadows to inform about moving objects out of sight has been known for millennia. Plato's allegory of the cave concerns just this situation [5].

2. Content of cast shadow

When an object casts its shadow on a background surface, the shadow can be informative about the shape of the object, the shape of the background surface and the spatial arrangement of the object relative to the background[6]. In real-world scenes, a detailed model of shadow formation needs to take into account a number of different factors, related to the caster, light source and screen:

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Caster condition:

- The shape and size of the caster determine size and shape of shadow;
- The position (and pose) of the caster, particularly with respect to the light source, affects the shape, size and location of the shadow;
- Opaque objects cast solid shadows, but translucent objects cast coloured or weak shadows.

Light condition:

- The shape and size of the light source determine characteristics of the penumbra;
- The position of the source (along with the position of the caster) determines location of the shadow;
- Light source intensity determines the contrast between shaded and non-shaded areas;
- The intensity of any ambient illumination also affects contrast;
- The colour of ambient illumination determines the colour of the shadow.

Screen condition:

- Screen orientation with regard to light source determines the degree of distortion in shadow shape;
- The shape and location of background clutter can cause shadows to split, distort, or merge.

Now, we can concluded that attached shadows, occuring when the normal of the receiver is facing away from the light source; cast shadows, occuring when a shadow falls on an object whose normal is facing toward the light source. By making assumptions about or keeping constant some of these factors, shadows can be used to determine various aspects of the visual scene. The main idea behind the shadow experiment is to use a simplified version of the shadow caster to generate hard and soft shadows, which would rapidly increase performance and to evaluate up to which degree a simplification is possible, without producing noticeable errors.

The common-sense notion of shadow is a binary status, *i.e.* a pint is either “in shadow” or not. This corresponds to *hardshadows*, as produced by point light sources: indeed, a point light source is either visible or occluded from any receiving point. However, point light sources do not exist in practice and hard shadows give a rather unrealistic feeling to images. Note that even the sun, probably the most common shadow-creating light source in our daily life, has a significant angular extent and does not create hard shadows.

Soft shadows are obviously much more realistic than hard shadows; especially the degree of softness (blur) in the shadow varies dramatically with the distances involved between the source, occluder, and receiver. Note also that a hard shadow, with its crisp boundary, could be mistakenly perceived as an object in the scene, while this would hardly happen with a soft shadow.

There are several methods to compute soft shadows using image-based techniques, which is as following:

1. Combining several shadow textures taken from point samples on the extended light source[7,8].
2. Using layered attenuation maps, replacing the shadow map with a Layered Depth Image, storing depth information about all objects visible from at least one point of the light source.
3. Using several shadow maps[9,10], taken from point samples on the light source, and an algorithm to compute the percentage of the light source that is visible.
4. Using a standard shadow map, combined with image analysis techniques to compute soft shadows[11,12].
5. Convolving a standard shadow map with an image of the light source[13] and user-defined light source directions[14].

3. The psychology and neuroscience foundation of cast shadow perception

The psychological work reported in [15-18] discusses experimental results which suggest that the human perceptual system prefers cues provided by shadows over other information in order to infer 3D motion of objects.

Some people's subjects were presented with a computer simulation in which the shadow of a static square moves away from its caster. Some findings indicated that the human perceptual system is biased to use shadow information for the interpretation of 3D motion and that shadow information can even override notions of conservation of object size. Psychological studies investigating the relationship between shadow perception and object recognition tell a less clear story. Braje [19] et al. explored the effect of shadows on recognition of natural objects, and the results showed that recognition of natural objects is highly invariant to the complex luminance patterns caused by shadows. Castiello in reports an experiment with contrasting results, in which the perception of objects is hindered when presented
with incongruent cast shadows (wrong shadow) or incongruent lighting with respect to the shadows (shadow on the wrong side with respect to the light source). Costs in response time were found for naming objects in incongruent lighting and shadow conditions, that is, when the object was presented with a cast shadow that originated from a different object and when it was also non-congruently illuminated.

The relation between the perception of shadows and the determination of optical contact is also subject of psychological research**[17,21]**. In particular, investigates the difference in depth perceptions of a floating object with relation with an object on the ground following it "like a shadow". Psychological research also suggests that our perceptual system uses cast shadows as a coarse cue: it does not matter if the shadow is the wrong shape for the casting object, it just has to be associated with the caster and telling a coherent story about the object motion or location. Bonfiglioli[22] et al. carried out two experiments for investigating the effects of cast shadows on different real-life tasks. Results showed that cast shadows did not influence identification of real 3-D objects, but they affected movement kinematics, producing distractor-like interference, particularly on movement trajectory. These findings suggest a task-dependent influence of cast shadows on human performance. Ostrovsky[23] et al investigated shadows which arise from inconsistent illumination present results which contradict earlier studies. They found that the visual system displays a remarkable lack of sensitivity to illumination inconsistencies, both in experimental stimuli and in images of real scenes. And their results allow them to draw inferences regarding how the visual system encodes illumination distributions across scenes. Specifically, they suggest that the visual system does not verify the global consistency of locally derived estimates of illumination direction.
Rensink[24] et al in present compelling evidence for the hypotheses that shadows are processed early in the visual pathway and then discarded, and that we use an assumption of a single overhead light source in doing this. Results support the proposal that an early-level system rapidly identifies regions as shadows and then discounts them, making their shapes more difficult to access. Casati comes to the same conclusion in [25], through the observation that dark patches in paintings, sometimes bearing no resemblance to real shadows. The human perceptual system seems to extract position information from shadows early on in processing, then filters them out in order to avoid interpreting shadows as objects in further spatial inferences. Whether shadow processing is implicit or explicit, there is evidence that shadows cast by a person's own body parts are used more effectively in judgements about extra-personal space than shadows from other objects carrying analogous information. This has been observed by Pavani and Castiello in [26]. These findings suggest that shadows cast by a person's own body parts can bridge the gap between personal and extra-personal space. Following a similar experimental setup, Galfano and Pavani find support for the hypothesis that body-shadows act as cues for attention[27].

The perception of shadows seems to rely on the assumption that there is a single overhead stationary light source[28-30], but the human perceptual system probably does not rely on cast shadows to determine shape, and nor does it seem to use shadows as a source of information about the screen upon which they are cast. The use of the information content of cast shadows, however, presupposes the solution of the shadow correspondence problem [31,32], which involves the segmentation of shadows in scenes and the connection of shadows to their relative casters. Shadows, like holes, are dependent objects without a caster, they do not occur. Matching shadows to their casters is a hard problem for various reasons: there may be various competing possible matches between shadows and objects in a complex scene (i.e. the shadow correspondence problem is under-constrained); the screen may not be planar, which may turn a point-to-point matching into a complex non-linear registration procedure; and shadows of close objects may merge. In agreement with the hypothesis of early-visual processing for shadows, psychological experiments suggest that the human visual system utilises an initial coarse matching between shadows and their casters that would allow for a re-evaluation given evidences from high-level reasoning procedures.

4 Conclusions

In this State of the art review, we have described the issues encountered when working with shadows.

We have presented the Content of cast shadow and the psychology and neuroscience foundation of cast shadow perception. We know of no work to date within artificial intelligence or computer vision that uses shadows in the same way that human systems do { that is, using a coarse shadow representation early in processing, to determine spatial relationships between elements of the 3D scene and to assist in depth perception. Let us expect that shadows will soon become a common standard in real-time rendering.

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