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LIGHTING FOR REMOTE VIEWING SYSTEMS*

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ABSTRACT Scenes viewed by television do not provide the same channels of information for judgment of distances as scenes viewed directly, since television eliminates or degrades several depth perception cues. However, it may be possible to improve depth perception of televised scenes by enhancing the information available through depth cues that are available from lighting. A literature survey and expert opinions were integrated to design a remote lighting arrangement which could enhance depth perception of operators performing remote handling operations. This paper describes the lighting arrangement and discusses some of its advantages and disadvantages.

I. INTRODUCTION

Operators performing remote handling tasks with teleoperators depend on television to provide them with the visual information necessary for locating, identifying, and judging distances between objects in the remote environment. Unfortunately, television attenuates the information available from the environment. Television is less sensitive to fine differences in detail than the human eye because of lower resolution and reduced capacity for detection of subtle differences in shading. The result is lower contrast between adjacent object images than would be observed by direct viewing, and contrast is critical for object visibility.[1-3]

Television also attenuates the information used to make distance judgments. Humans use nine environmental cues to judge distance, including convergence (information derived from the motion of the eyes as they are aimed), retinal disparity (differences in the images on the retinas), accommodation (focusing of the lenses of the eyes), motion parallax (differences in perceived object motion when the head moves), perspective, object size, shadow and texture patterns, object interposition, and the characteristic haziness of distant objects.[4] Television eliminates cues of convergence, retinal disparity, and accommodation because scenes are projected on a flat surface. Television degrades cues of perspective, haziness, shadow patterns, and texture because of the loss of detail from resolution and shading effects. The loss of information is particularly pronounced if the system is monoscopic and achromatic,[5] and losses are aggravated by poor system resolution.[6]

In the past, efforts to improve television viewing concentrated on changing the nature of the system by optimizing camera positions, adding color,[7,8] using stereoscopic systems,[4,7,9] or improving resolution. A recent study conducted at the Oak Ridge National Laboratory (ORNL) considered a different approach. This study investigated the possibility of improving operator depth perception (i.e., by enriching the information available from the remote environment) by improving the quality of specific cues transmitted by television. Specifically, this study examined the potential of using lighting to upgrade texture and shadow pattern cues.

The study considered pertinent psychological literature and the opinions of experts drawn from the population of television lighting practitioners in the Knoxville, Tennessee, area. The experts suggested the lighting arrangement shown in Figs. 1 and 2. This is a simplified version of the standard lighting arrangement used in the television industry, which the experts agree is the best for providing the sensation of depth in a televised scene. This arrangement uses three lights: the key light, the fill light, and the back light.

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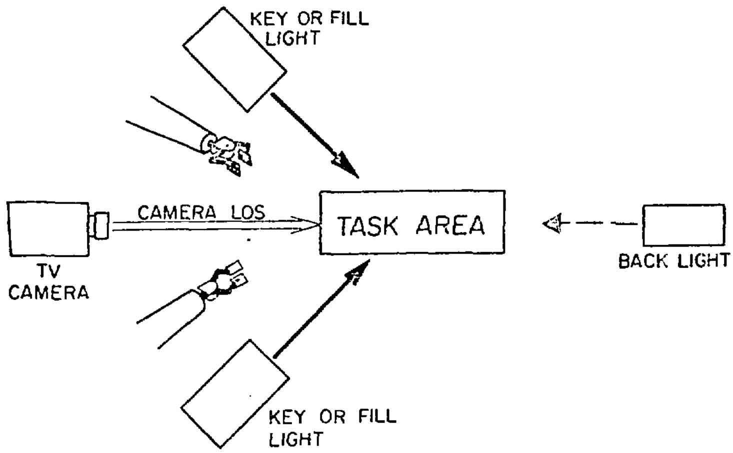

Fig. 1. Plan view of lighting arrangement.

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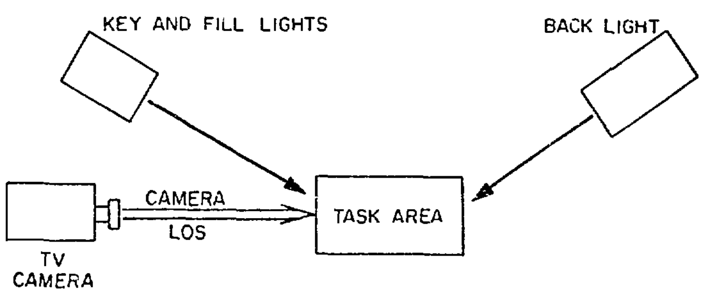

Fig. 2. Elevation of lighting arrangement.

The key light is placed to one side of the camera with the angle described by the camera's line of sight and the aiming line of the light at 45° in the horizontal plane. The vertical separation should produce an angle of 20-40° between camera line of sight and light aiming line.[10] The key light should be a moderately focused source, significantly brighter than the other lights in the arrangement. The actual light levels in this system should be determined by adjusting illumination levels after the system is in place; also all light sources should be equipped with intensity controls.

A fill light is placed on the opposite side of the camera from the key light with the same angular relationship to the camera. The purpose of the fill light is to illuminate areas shadowed by the key light. In order to fill in shadowed areas without creating other shadows, the fill light should be a very diffuse light source, with a light level lower than that of the key light. It should be bright enough to illuminate shadowed areas without eliminating the shadows.

A back light is placed behind the object being viewed. The angle of the line of sight and aiming line intersection should be 30 to 60° in the vertical plane. In the horizontal plane, the light should be directly opposing the camera's line of sight.

The proposed lighting arrangement has several advantages. When brightness levels are properly set, the arrangement provides operators with a coherent shadow pattern. The pattern is coherent since all the shadows are produced by the key light and the relationship of shadow to object is invariant. When a scene is illuminated by two or more equally bright sources, a criss-crossing pattern of shadows is produced. The latter type of pattern is more difficult for operators to interpret than one produced by light coming from a single direction.

Another advantage to this arrangement is a reduced potential for visual illusions because of the natural way in which objects are illuminated. Humans are accustomed to light shining on objects from above. When the assumption of overhead lighting is violated and observers are unable to discover the source of illumination, perceptual illusions may result; for example, concave surfaces may be perceived as convex or vice versa.

A third advantage to the arrangement is the richness of depth cues provided. Since shadows will be produced by one source, shadow cues will be easier to interpret. The illumination of space between background and object enhances the feeling of depth in the scene, as does the improved contrast of object edges provided by the back light. Enrichment of these monocular depth cues will be no less important if a stereo TV system is used. Monocular and binocular cues are used together to estimate depth, and the addition of binocular cues will not eliminate the positive effect of enriched monocular cues.

One disadvantage to the arrangement is the difficulty of placing the lights. It would be easy enough to mount the key and fill lights on booms attached to a transporter, but the back light presents a problem. If the lighting system is arranged with back lights placed on cell walls, an excessive number of lights would be required. If the back light is mounted on a boom, operators will be required to thread it through the remote area before actually beginning repair tasks. The best solution may be to use portable lights placed in position by the manipulator arms at the beginning of the tasks.

There are also some important questions associated with the lighting arrangement described here. First, the arrangement was designed for a camera with line of sight parallel to the horizon and with the direction of movement requiring depth perception along the line of sight, that is, toward and away from the camera. Earlier research at ORNL has found that a camera displaced about 30 to 45° from the center in the vertical and horizontal, together with a mid-line camera, produces the best small-volume task performance. Given an offset camera, should the lighting arrangement be modified (angular relationships of camera and lights maintained) or should the lights be set up as if only the mid-line camera position were used?

Second, there is no empirical support for the recommendations of the subject matter experts. There are no data relevant to the contention that the lighting arrangement described here provides the best sensation of depth from televised scenes, and even if there were such data, is it true that the optimal sensation of depth produces maximum accuracy of depth judgments? These lighting recommendations should be systematically investigated to delineate the effects of position, quantity, focus, and relative output of lights on the ability of operators to make depth judgments from televised remote scenes.

A series of experiments aimed at answering these questions and verifying the value of the proposed lighting arrangement has been started at ORNL. One experiment has been completed, but the results are difficult to interpret because of the instability in the data. In this experiment, subjects adjusted the illumination output level of a single light placed in several different positions and under several background illumination levels. The subjects' task was to adjust the light to the level that provided the best sensation of depth in a televised scene. The data are not highly reliable but seem to indicate that the position of light sources relative to a task area does affect the output level required to provide satisfactory illumination. These data also suggest that there may be a difference in the lighting requirements for monoscopic and stereoscopic television.

The second experiment in the series, under way at the time of this writing, is investigating the effects of varying the relative illumination output of a set of three lights in two different configurations. Subjects attempt to judge the separation of two realistic (i.e., typical of a remote facility) target objects under each lighting condition. The accuracy of their depth judgments will be compared with respect to lighting arrangements and relative output levels.

Conclusion

Literature surveys and expert opinions have been used to identify an optimal remote lighting configuration. The value of this configuration for improving depth perception during remote handling tasks is being experimentally evaluated at this time. The aim of the initial study and the experimental follow-ups are optimal lighting configurations and output levels for remote operations. The optimal configuration and output levels will maximize remote viewing effectiveness under the constraints of achromatic, monoscopic television systems.

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