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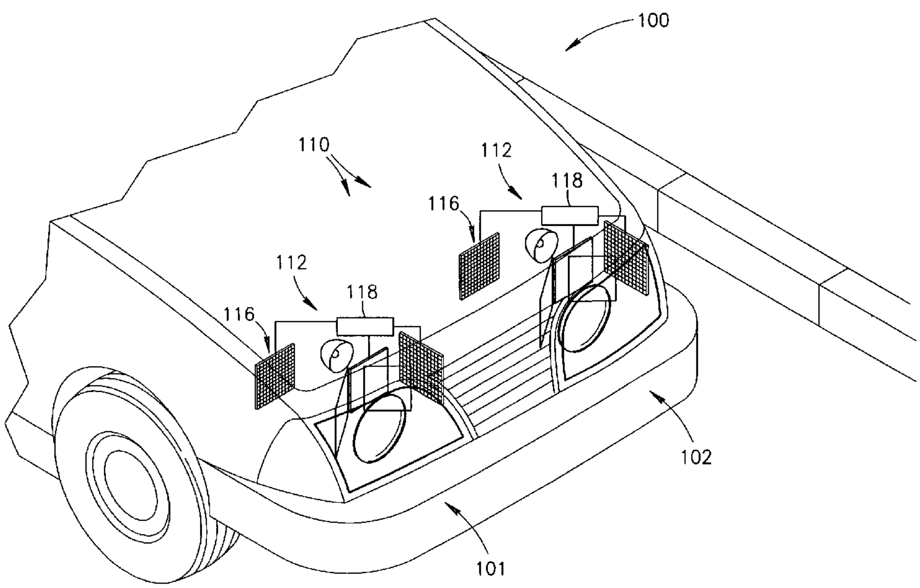
(54) Title: METHOD AND APPARATUS FOR PROVIDING ADAPTIVE ILLUMINATION



(57) Abstract: An illumination system (20, 72, 110, 142) for illuminating a scene comprising: an illuminator (24, 74, 116) having a plurality of substantially contiguous independently controllable light (26, 76) providing regions each of which provides light that illuminates a different region of the scene; optics (30) that directs light from the illuminator to the scene; a range finder (22, 64, 112) that determines distances to regions of the scene; and a controller (28, 29, 118) that controls the plurality of light providing regions to provide light for illuminating the scene responsive to distances determined by the range finder (22, 64, 112).

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METHOD AND APPARATUS FOR PROVIDING ADAPTIVE ILLUMINATION

FIELD OF THE INVENTION

The present invention relates to adapting illumination of a scene responsive to features and characteristics of the scene and in particular to automatically adapting the illumination to characteristics and features of the scene.

BACKGROUND OF THE INVENTION

A visual impression of a scene and objects and features in the scene is generally a function of illumination of the scene. Objects in a scene that are illuminated so that they contrast strongly with their local background tend to capture our attention. Acuity with which the eye is able to distinguish details of features in a scene and impressions of features of a scene are generally dependent upon the power spectrum of light illuminating the features. For example, color of a woman's dress and her fashion accessories may appear harmonious in one light and discordant in another light. In addition, cultural convention has coded color with information that affects our reason and emotions and these cultural conventions affect the way colors in a scene generate responses to the scene. Red, yellow and green lights not only tell us when to stop at traffic lights but also, alert our reason and emotions to various degrees of danger, or lack thereof.

It is therefore seen that when illuminating a scene for a particular desired application, generally many different variables have to be considered and taken into account. As a result, achieving effective illumination of a scene is often a relatively complicated, subtle and arduous task.

US Patent 5,828,485 describes an illumination device for stage lighting comprising an image source that acquires an image of an actor on a stage and an array of digital micromirrors for directing light from a suitable light source to the stage. The array of micromirrors is controlled responsive to the image of the actor to project different shape and color light beams for illuminating the actor. The illumination device is controllable to follow the actor as he or she moves on the stage and illuminate the actor accordingly. The patent notes that characteristics of the projected light beam, *e.g.* its shape and color can be controlled by "image processing software such as Adobe photoshop™, Kai's power tools™ and the like".

US Patent 4,501,961 describes a range finder having a photosurface for imaging an object, whose distance from the range finder is to be determined, and an array of LEDs for illuminating the object. To prevent parallax, light from the array of LEDs is focussed on the object by a same lens that collects light from the object and focuses the collected light on the photosurface. A controller controls the array of LEDs to illuminate the object with a pattern of light which when imaged on the photosurface provides information for determining range to the object. The range finder comprises a negative lens to adjust the size of the illumination pattern to the size of the photosurface.

SUMMARY OF THE INVENTION

An aspect of some embodiments of the present invention relates to providing an illumination system that comprises an illuminator having an array of substantially contiguous, independently controllable light providing regions and a range finder for determining distances to regions of the scene. Each of the light providing regions, hereinafter referred to as "luxels", illuminates a different region of the scene. The illumination system comprises a controller that controls the luxels to provide light responsive to distances determined by the range finder.

Preferably, the array of luxels in the illuminator is a planar array and the illumination system comprises optics that directs light from the luxels in the array to illuminate the scene. Optionally, the illuminator is similar to an illuminator comprising luxels used to provide light for a 3D range-camera described in PCT/IL00/00404, the disclosure of which is incorporated herein by reference. The optics has a focal plane, referred to as an "illumination plane", towards which the optics focuses light from the luxels. Light from each luxel is focused to a different region of the illumination plane. Assuming that the luxels are substantially contiguous, the different regions of the illumination plane towards which light from different luxels is focused are substantially contiguous and non-overlapping. For surfaces of a scene illuminated by the illumination system that are located relative to the illumination plane within a depth of field of the optics, the optics focuses light from the luxels to form relatively sharp images of the luxels on the surface.

In some embodiments of the present invention, position of the illumination plane relative to the illumination system is adjustable. In some embodiments of the present invention, position of the illumination plane is fixed. Optionally the illumination plane is fixed at infinity. Optionally, the illumination plane is located at a distance from the illumination system that is equal to an average of distances to scenes that the illumination system is intended to illuminate.

According to an aspect of some embodiments of the present invention, the controller controls luxels so that intensity of light provided by a luxel is substantially proportional to the square of a distance from the array of luxels to a region of the scene illuminated by the luxel. As a result, intensity of light (joules/m^2) incident on regions of the scene is substantially uniform.

Optionally, each luxel can be controlled to provide white light and/or R, G or B light. In some embodiments of the present invention a luxel can be controlled to provide IR light. In some embodiments of the present invention the luxels are grouped into groups of four substantially contiguous luxels. Each luxel in a group of luxels provides a different one of R, G, B and IR light.

In some embodiments of the present invention, the range finder comprises a 3D range-camera such as, for example, a 3D range-camera described in PCT Application PCT/IL00/0404 referenced above, and in PCT Publications WO 00/36372, WO 00/19705, WO 01/18563 and US Patents, 6,057,909, 6,091,905 and 6,100,517, the disclosures of all of which are incorporated herein by reference. Range-cameras known in the art other than those described in these documents can be used in the practice of the present invention.

In 3D range-cameras described in the referenced documents, a train of light pulses is radiated by a range camera light source to illuminate the scene. Following each light pulse the camera is gated open to receive light reflected from the light pulse by regions in the scene and image the received light on a photosurface comprised in the camera. Distance to a region is determined from timing of the gates with respect to emission times of the light pulses and a total amount of light from the region that is received and imaged during the gates on a pixel of the photosurface that images the region.

In some embodiments of the present invention, the array of luxels in the illumination system functions as the range camera light source. The illumination system controller controls luxels in the array to generate the train of light pulses that illuminates the scene. Optionally, the illumination system comprises a fast shutter, which the controller controls to shutter light from the array of luxels to generate the train of light pulses. Optionally, luxels controlled to generate the train of light pulses provides infrared (IR) light.

In some embodiments of the present invention the 3D range-camera photosurface is boresighted with the illumination system optics so that a virtual image of the photosurface is substantially coincident with the illuminator. The illumination system optics, which directs light from the luxels to illuminate a scene, therefore also collects light from the scene and focuses the collected light on the photosurface. For such cases, preferably, the controller gates the photosurface in synchrony with the fast shutter so that when the fast shutter is open to

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