unit. Each light source is configured to emit light encoded with a predetermined modulation pattern in the space. The emitted light from among the plurality of LED light sources is scattered by at least one object in the space. The array of sensors is configured to receive the scattered light from the at least one object in the space. Each sensor is configured to determine a distance between the corresponding light source and the at least one object based on detection of the predetermined modulation pattern in the received scattered light. The space characterization unit is configured to receive the distance from each sensor and to generate an elevation map of the space based upon the distance received from each sensor of the array of sensors and predetermined locations of the sensors in the array of sensors. The elevation map indicates a presence of the at least one object in the space by displaying a height of the at least one object as based upon the distance received from the sensor that senses the at least one object and concurrently displaying a location of the object as based upon the predetermined location of the sensor that senses the at least one object. Each light source includes a plurality of light sources configured to emit the light in different wavelengths, at least one of the sensors configured to determine the distance for each of the different wavelengths, the elevation map including a color map associated with the different wavelengths.

The method of characterizing a space for illumination comprises: emitting light by an array of light emitting diode (LED) light sources disposed in the space for illumination, the emitted light encoded with at least one predetermined modulation pattern, the emitted light being scattered by at least one object in the space; receiving the scattered light from at the at least one object in the space by an array of sensors proximate the array of LED light sources; determining, by each sensor, a distance between the corresponding light source and the at least one object based on detection of the at least one predetermined modulation pattern in the received scattered light; and generating an elevation map of the space based on the distance determined by each sensor in the array of sensors and predetermined locations of the sensors in the array of sensors, the elevation map indicating a presence of the at least one object in the space by displaying a height of the at least one object as based upon the distance received from the sensor that senses the at least one object and concurrently displaying a

location of the object as based upon the predetermined location of the sensor that senses the at least one object, the space for illumination being characterized based on the elevation map; and wherein each light source includes a plurality of light sources configured to emit the light in different wavelengths, at least one of the sensors configured to determine the distance for each of the different wavelengths, the elevation map including a color map associated with the different wavelengths.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts a functional block diagram of an exemplary illumination system for characterizing an illumination space.

FIG. 2 depicts a perspective view diagram of an exemplary illumination system in an illumination space illustrating determination of distance to objects in the space.

FIG. 3 is a flow chart that depicts an exemplary method for characterizing an illumination space.

FIG. 4 is a flow chart that depicts an exemplary method for characterizing an illumination space based on an elevation map.

FIG. 5A is an example image of an office environment.

FIG. 5B is an example time-of-flight (ToF) image of the office environment shown in FIG. 5A, according to an embodiment of the invention.

FIG. 6 is an example elevation map determined from the ToF image shown in FIG. 5B, according to an embodiment of the invention.

FIGS. 7A, 7B, 7C, 7D and 7E are example elevation maps including detected objects, for various multiple person environments, according to an embodiment of the invention.

FIGS. 8A, 8B, 8C and 8D are example elevation maps including detected objects, for the elevation map shown in FIG. 7C with various sensor spacings, according to an embodiment of the invention.

FIGS. 9A and 9B are example graphs of error rate and mean error as a function of sensor spacing for elevation maps of a real office environment, according to an embodiment of the invention.

What is Claimed:

1. An illumination system comprising:

an array of light emitting diode (LED) light sources disposed in a space for illumination, each light source configured to emit light encoded with a predetermined modulation pattern in the space, the emitted light from among the array of LED light sources being scattered by at least one object in the space;

an array of sensors proximate to the array of LED light sources and configured to receive the scattered light from the at least one object in the space, each sensor configured to determine a distance between the corresponding light source and the at least one object based on detection of the predetermined modulation pattern in the received scattered light; and

a space characterization unit configured to receive the distance from each sensor and to generate an elevation map of the space, the elevation map indicating a presence of the at least one object in the space.

2. The illumination system of claim 1, wherein each light source includes at least one of a spot light, a flood light or a panel light.

3. The illumination system of claim 1, wherein each light source includes a monochromatic light source.

4. The illumination system of claim 1, wherein each light source includes a plurality of light sources configured to emit the light in different wavelengths, at least one of the sensors configured to determine the distance for each of the different wavelengths, the elevation map including a color map associated with the different wavelengths.

5. The illumination system of claim 1, wherein the space characterization unit is configured to detect, based on the elevation map, at least one property of the at least one object, to control illumination by the illumination system.

6. The illumination system of claim 1, wherein the space characterization unit is configured to determine, based on the elevation map, at least one of a location of the at least one object, a pose of the at least one object or movement of the at least one object.

7. The illumination system of claim 1, wherein the space characterization unit is configured to determine, based on the elevation map, whether the at least one object is an animate object or an inanimate object.

8. The illumination system of claim 1, wherein each sensor is configured to determine a time-of-flight for the emitted light to be received by the sensor based on the detected predetermined modulation pattern, the distance being determined from the time-of-flight.

9. The illumination system of claim 1, wherein each light source is configured to be independently modulated with the predetermined modulation pattern.

10. The illumination system of claim 1, wherein two or more of the light sources are configured to be synchronously modulated with the predetermined modulation pattern.

11. A method of characterizing a space for illumination, the method comprising:

emitting light by an array of light emitting diode (LED) light sources disposed in the space for illumination, the emitted light encoded with at least one predetermined modulation pattern, the emitted light being scattered by at least one object in the space;

receiving the scattered light from at the at least one object in the space by an array of sensors proximate the array of LED light sources;

determining, by each sensor, a distance between the corresponding light source and the at least one object based on detection of the at least one predetermined modulation pattern in the received scattered light; and

generating an elevation map of the space based on the distance determined by each sensor, the elevation map indicating a presence of the at least one object in the space, the space for illumination being characterized based on the elevation map.

12. The method of claim 11, the method further comprising detecting, based on the elevation map, at least one property of the at least one object, to control illumination by the array of LED light sources.

13. The method of claim 11, the method further comprising determining, based on the elevation map, at least one of a location of the at least one object, a pose of the at least one object or movement of the at least one object.

14. The method of claim 11, the method further comprising determining, based on the elevation map, whether the at least one object is an animate object or an inanimate object.

15. The method of claim 11, wherein the determining of the distance includes determining a time-of-flight for the emitted light to be received by the respective sensor based on the detected at least one predetermined modulation pattern, the distance being determined from the time-of-flight.

What is Claimed :

1. An illumination system comprising:

an array of light emitting diode (LED) light sources disposed in a space for illumination, each light source configured to emit light encoded with a predetermined modulation pattern in the space, the emitted light from among the array of LED light sources being scattered by at least one object in the space;

an array of sensors proximate to the array of LED light sources and configured to receive the scattered light from the at least one object in the space, each sensor configured to determine a distance between the corresponding light source and the at least one object based on detection of the predetermined modulation pattern in the received scattered light; and

a space characterization unit configured to receive the distance from each sensor and to generate an elevation map of the space based upon the distance received from each sensor of the array of sensors and predetermined locations of the sensors in the array of sensors, the elevation map indicating a presence of the at least one object in the space by displaying a height of the at least one object as based upon the distance received from the sensor that senses the at least one object and concurrently displaying a location of the object as based upon the predetermined location of the sensor that senses the at least one object;

wherein each light source includes a plurality of light sources configured to emit the light in different wavelengths, at least one of the sensors configured to determine the distance for each of the different wavelengths, the elevation map including a color map associated with the different wavelengths.

2. The illumination system of claim 1, wherein each light source includes at least one of a spot light, a flood light or a panel light.

3. The illumination system of claim 1, wherein each light source includes a monochromatic light source.

4. The illumination system of claim 1, wherein the space characterization unit is configured to detect, based on the elevation map, at least one property of the at least one object, to control illumination by the illumination system.

5. The illumination system of claim 1, wherein the space characterization unit is configured to determine, based on the elevation map, at least one of the location of the at least one object, a pose of the at least one object or movement of the at least one object.

6. The illumination system of claim 1, wherein the space characterization unit is configured to determine, based on the elevation map, whether the at least one object is an animate object or an inanimate object.

7. The illumination system of claim 1, wherein each sensor is configured to determine a time-of-flight for the emitted light to be received by the sensor based on the detected predetermined modulation pattern, the distance being determined from the time-of-flight.

8. The illumination system of claim 1, wherein each light source is configured to be independently modulated with the predetermined modulation pattern.

9. The illumination system of claim 1, wherein two or more of the light sources are configured to be synchronously modulated with the predetermined modulation pattern.

10. A method of characterizing a space for illumination, the method comprising:

emitting light by an array of light emitting diode (LED) light sources disposed in the space for illumination, the emitted light encoded with at least one predetermined modulation pattern, the emitted light being scattered by at least one object in the space;

receiving the scattered light from at the at least one object in the space by an array of sensors proximate the array of LED light sources;

determining, by each sensor, a distance between the corresponding light source and the at least one object based on detection of the at least one predetermined modulation pattern in the received scattered light; and

generating an elevation map of the space based on the distance determined by each sensor in the array of sensors and predetermined locations of the sensors in the array of sensors, the elevation map indicating a presence of the at least one object in the space by displaying a height of the at least one object as based upon the distance received from the sensor that senses the at least one object and concurrently displaying a location of the object as based upon the predetermined location of the sensor that senses the at least one object, the space for illumination being characterized based on the elevation map; and

wherein each light source includes a plurality of light sources configured to emit the light in different wavelengths, at least one of the sensors configured to determine the distance for each of the different wavelengths, the elevation map including a color map associated with the different wavelengths.

11. The method of claim 10, the method further comprising detecting, based on the elevation map, at least one property of the at least one object, to control illumination by the array of LED light sources.

12. The method of claim 10, the method further comprising determining, based on the elevation map, at least one of the location of the at least one object, a pose of the at least one object or movement of the at least one object.

13. The method of claim 10, the method further comprising determining, based on the elevation map, whether the at least one object is an animate object or an inanimate object.

14. The method of claim 10, wherein the determining of the distance includes determining a time-of-flight for the emitted light to be received by the respective sensor based on the detected at least one predetermined modulation pattern, the distance being determined from the time-of-flight.