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Bosua et al.

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(54) **DIRECTIONAL LIGHTING SYSTEM AND METHOD**

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(73) Assignee: **Lifi Labs, Inc.** (AU)

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Related U.S. Application Data

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H05B 37/02 (2006.01)
H05B 33/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H05B 37/0227*** (2013.01); ***H05B 33/0845*** (2013.01); ***H05B 33/0896*** (2013.01); ***H05B 37/02*** (2013.01); ***H05B 37/029*** (2013.01); ***H05B 37/0218*** (2013.01); ***H05B 37/0272*** (2013.01)

(58) **Field of Classification Search**
CPC H05B 37/0218; H05B 37/029; H05B 37/0245; H05B 37/0227; H05B 37/02; H05B 37/0272; H05B 33/0845; H05B 33/086; H05B 33/0848; H05B 33/0854; H05B 33/0869; H05B 33/0872; Y02B 20/46; Y02B 20/383; Y02B 20/48
See application file for complete search history.

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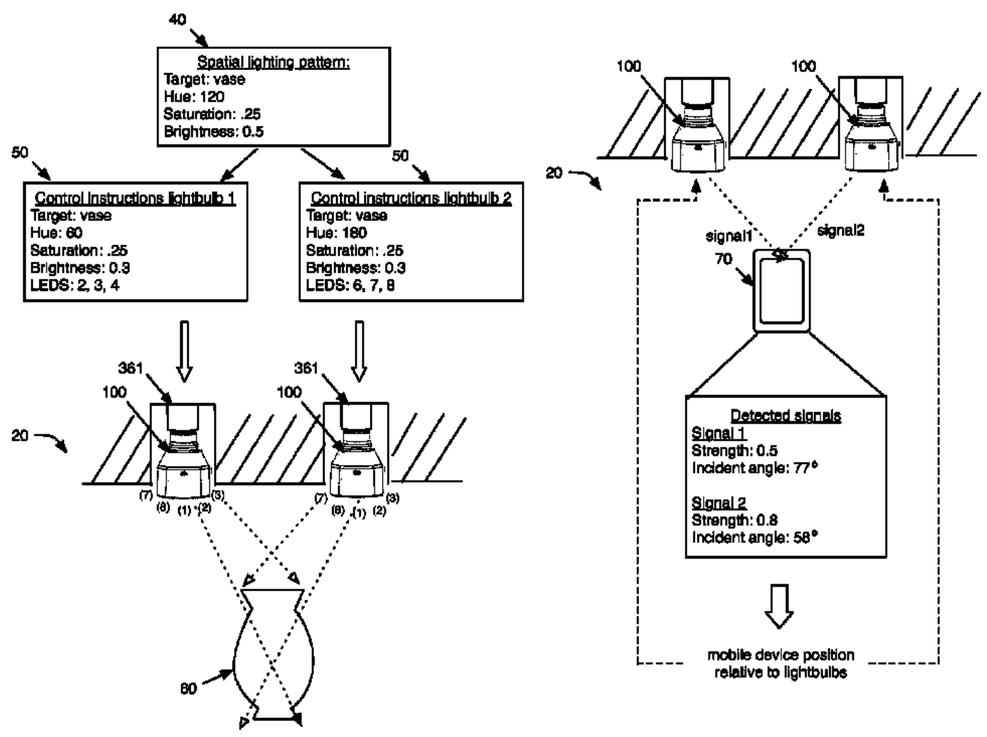
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(57) **ABSTRACT**

The method of spatial lightbulb operation includes determining the position of the lightbulb relative to a physical space, detecting a contextual event, determining a spatial lighting pattern associated with the contextual event, and selectively controlling lightbulb light emitting elements based on the position of the lightbulb and the spatial lighting pattern. A lightbulb including: a plurality of individually controlled light emitting elements mounted in fixed, predetermined positions on the substrate; a light sensor mounted to the substrate; a wireless communication module; and a processor configured to: index each light emitting element; progress each of the plurality of light emitting elements through an orientation pattern; associate a reference point on the lightbulb with an external reference point; and selectively operate individual light emitting elements of the plurality according to lighting instructions, based on a relationship between the reference point on the lightbulb and the external reference point.

20 Claims, 13 Drawing Sheets



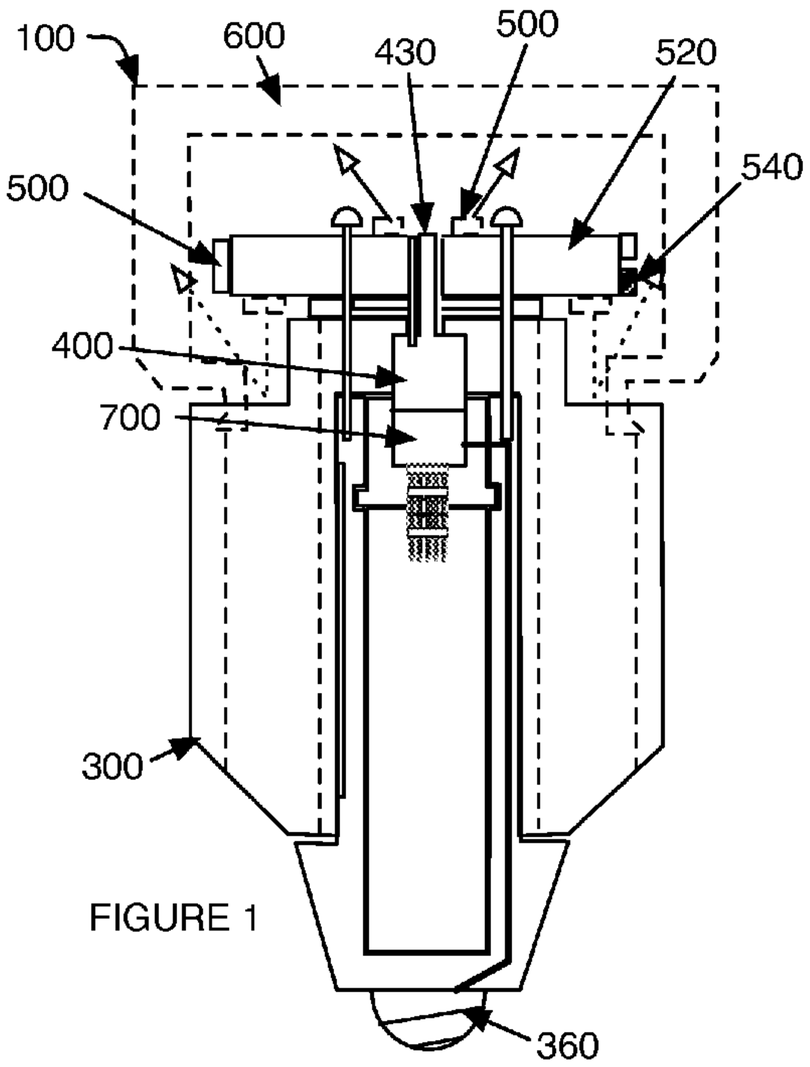


FIGURE 1

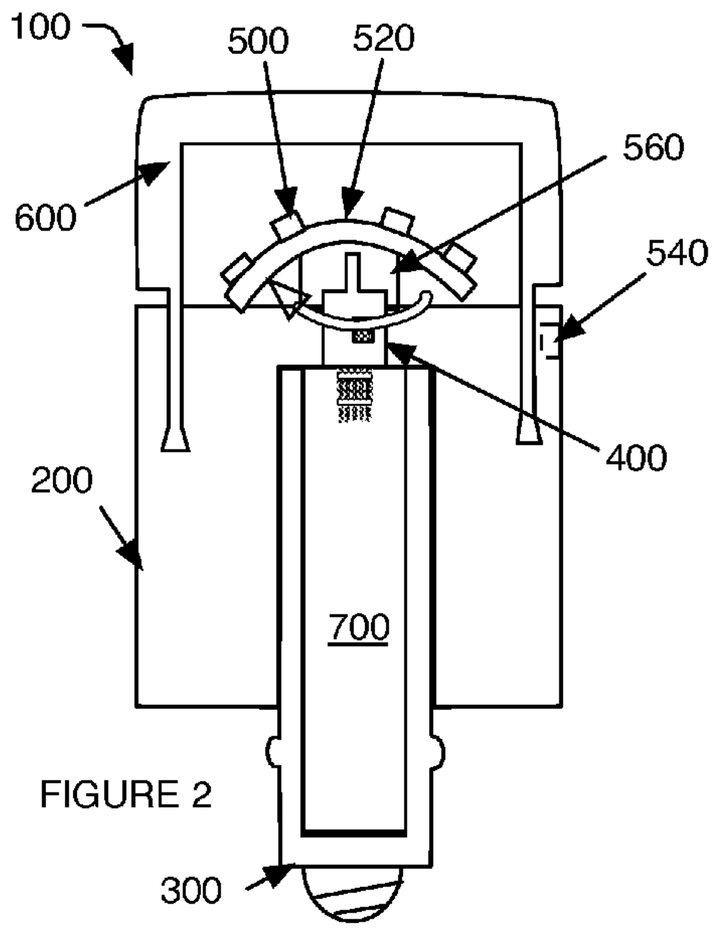


FIGURE 2

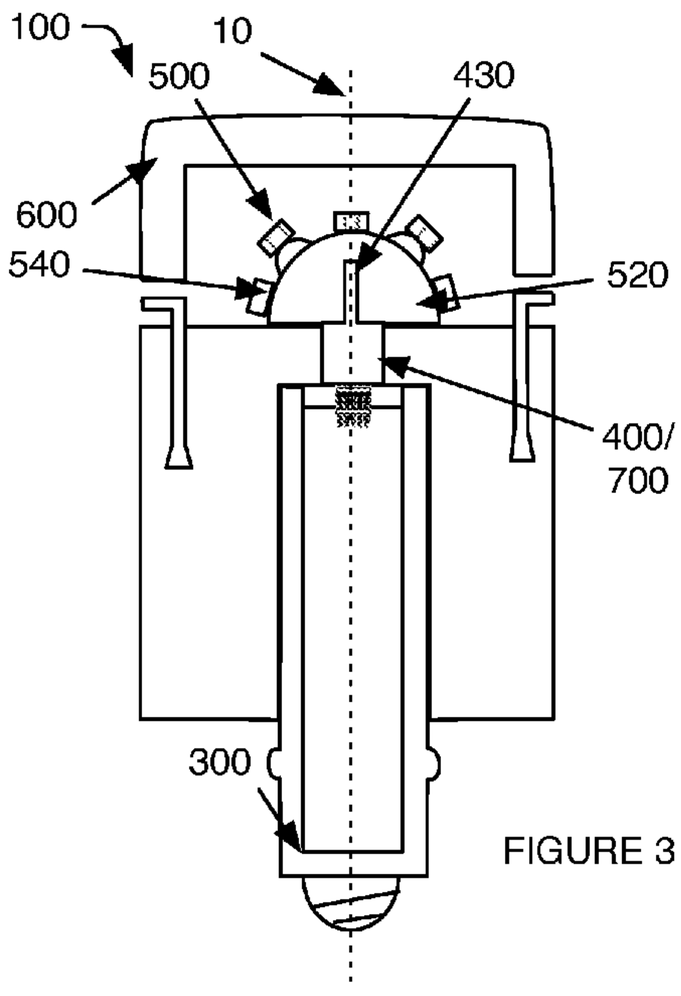


FIGURE 3

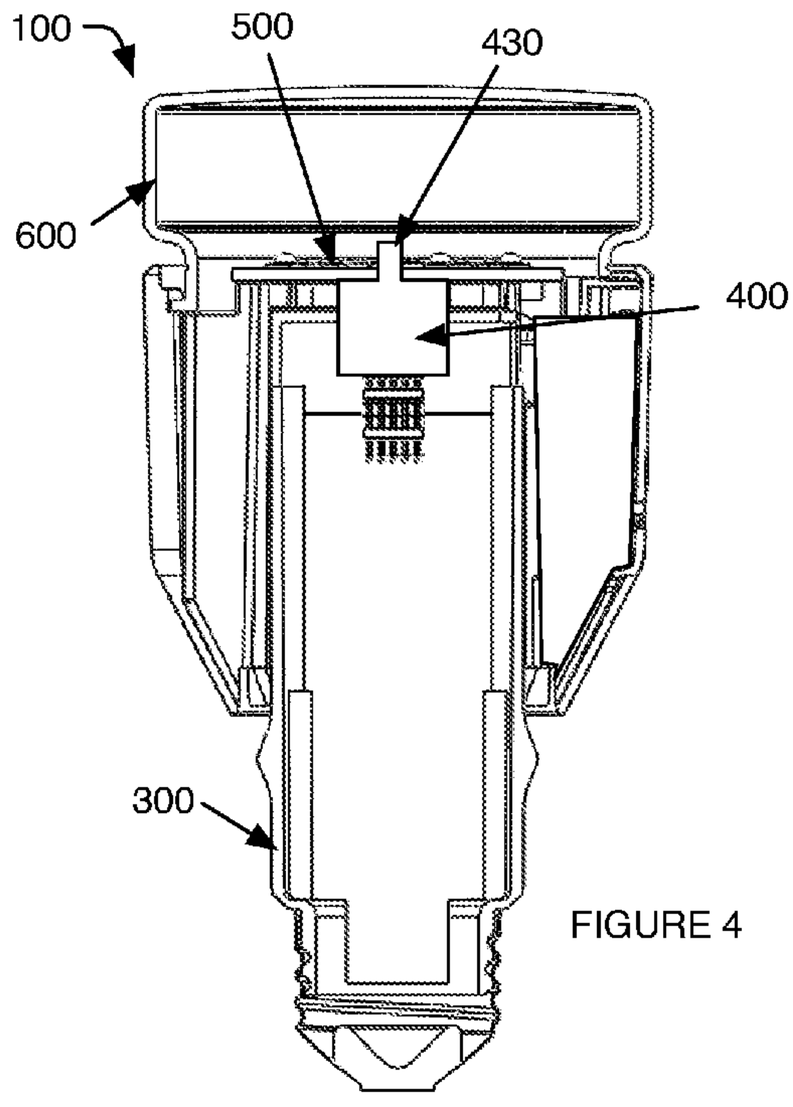


FIGURE 4

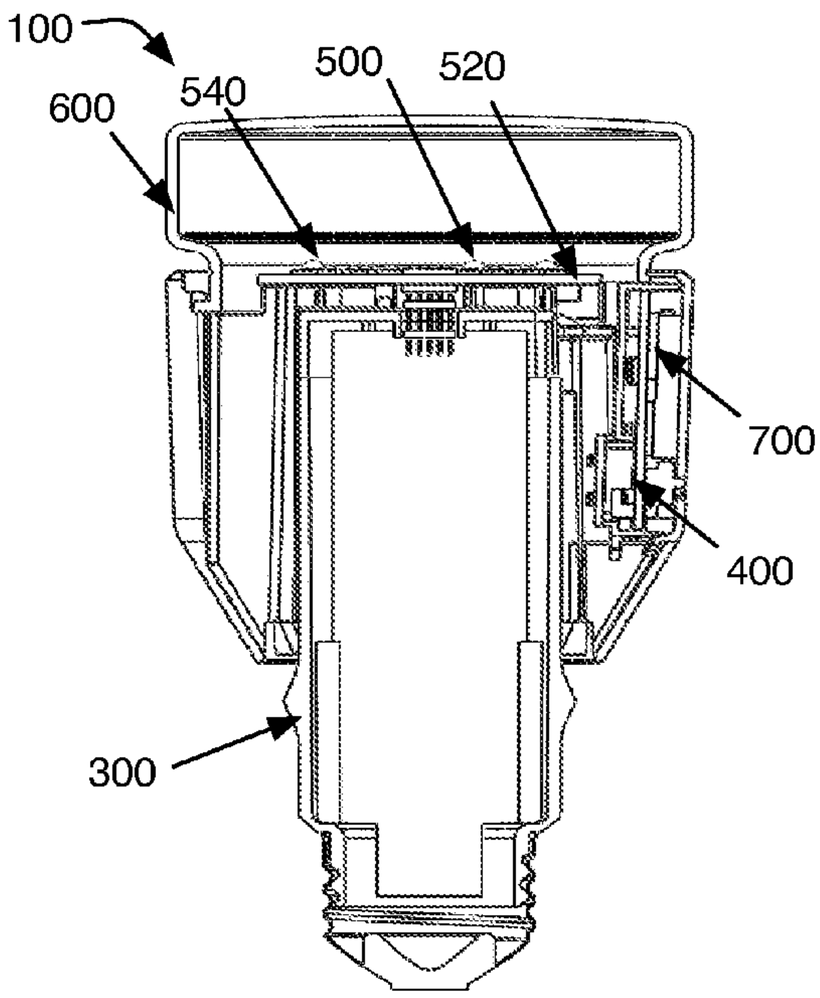


FIGURE 5

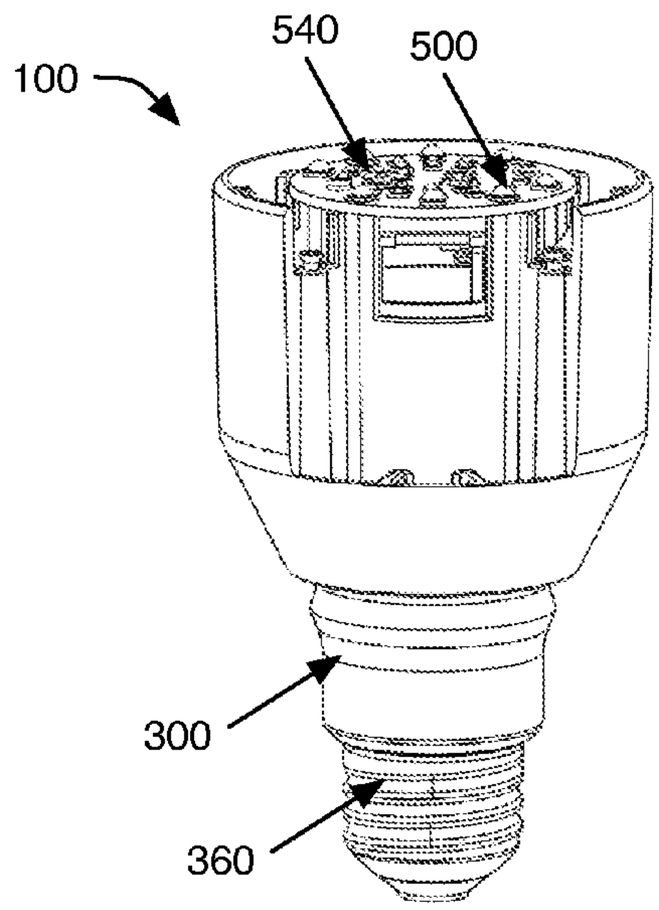


FIGURE 6

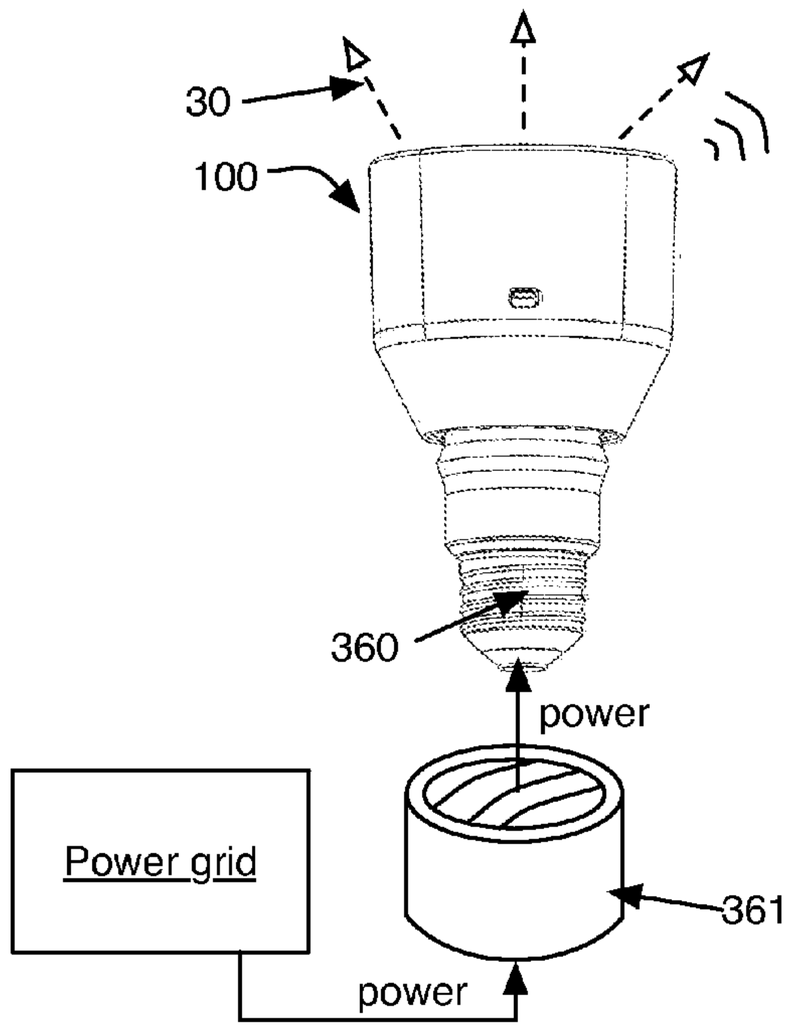


FIGURE 7

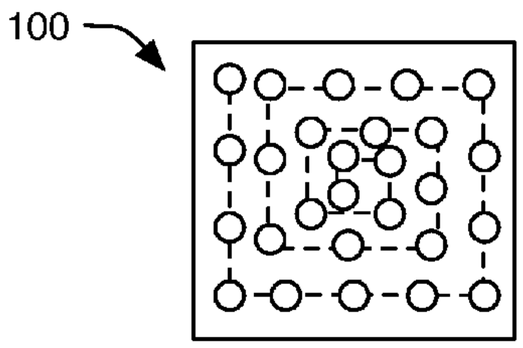


FIGURE 8

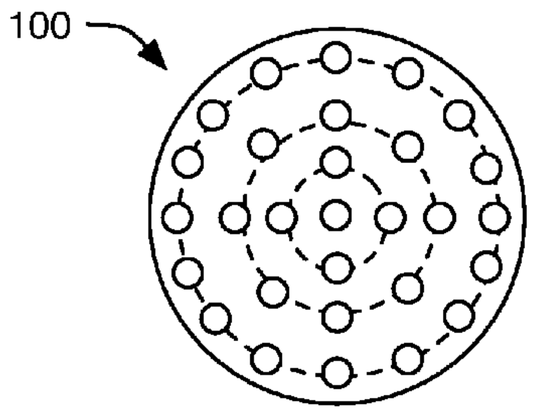


FIGURE 9

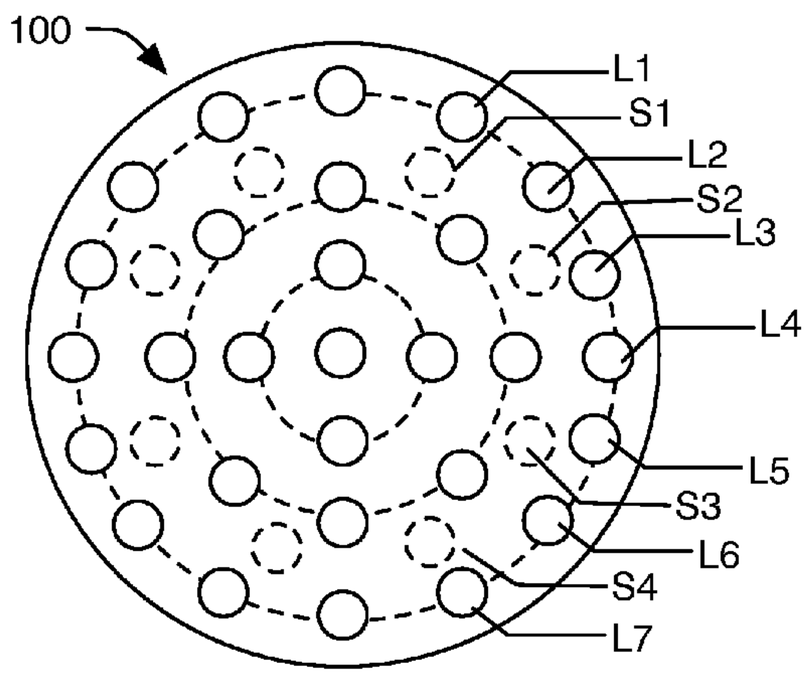


FIGURE 10

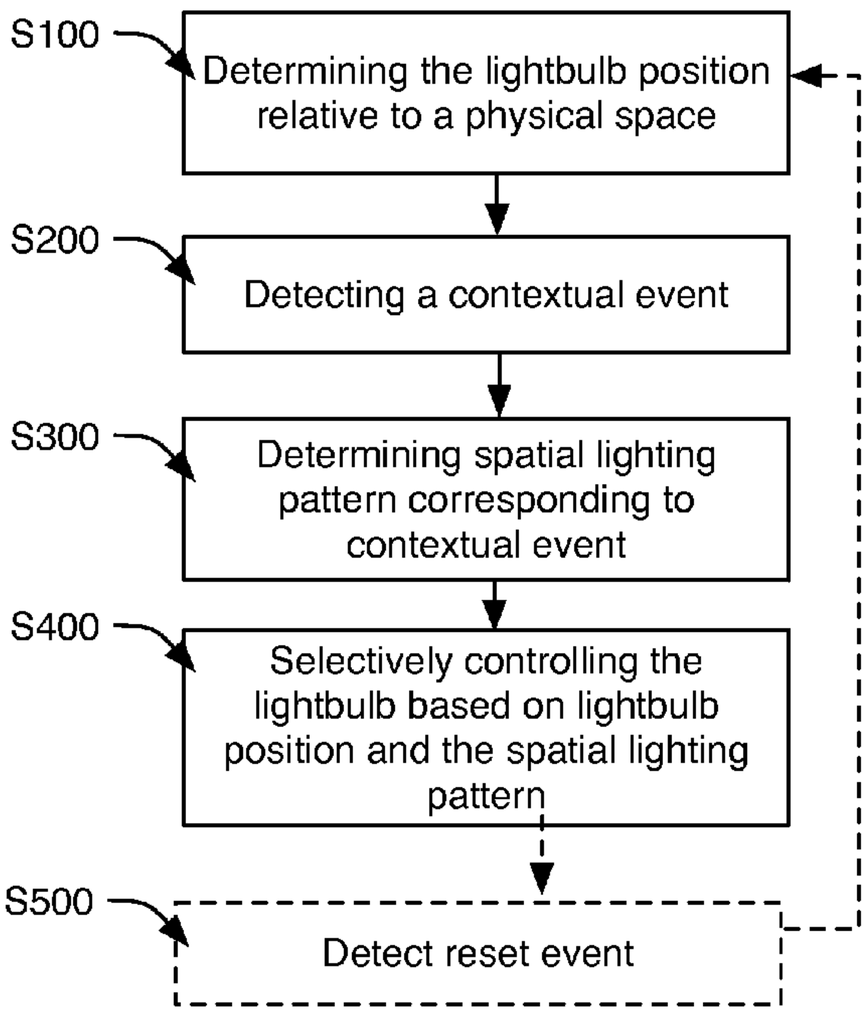


FIGURE 11

FIGURE 12

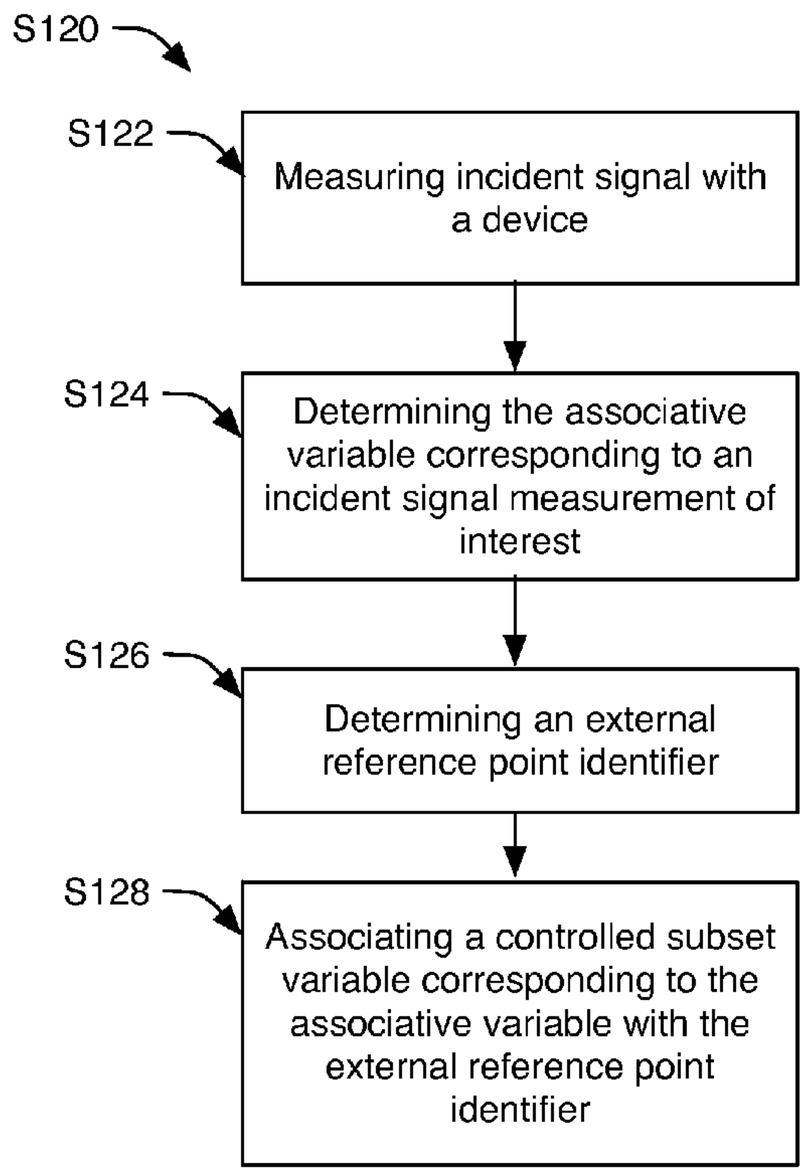


FIGURE 13

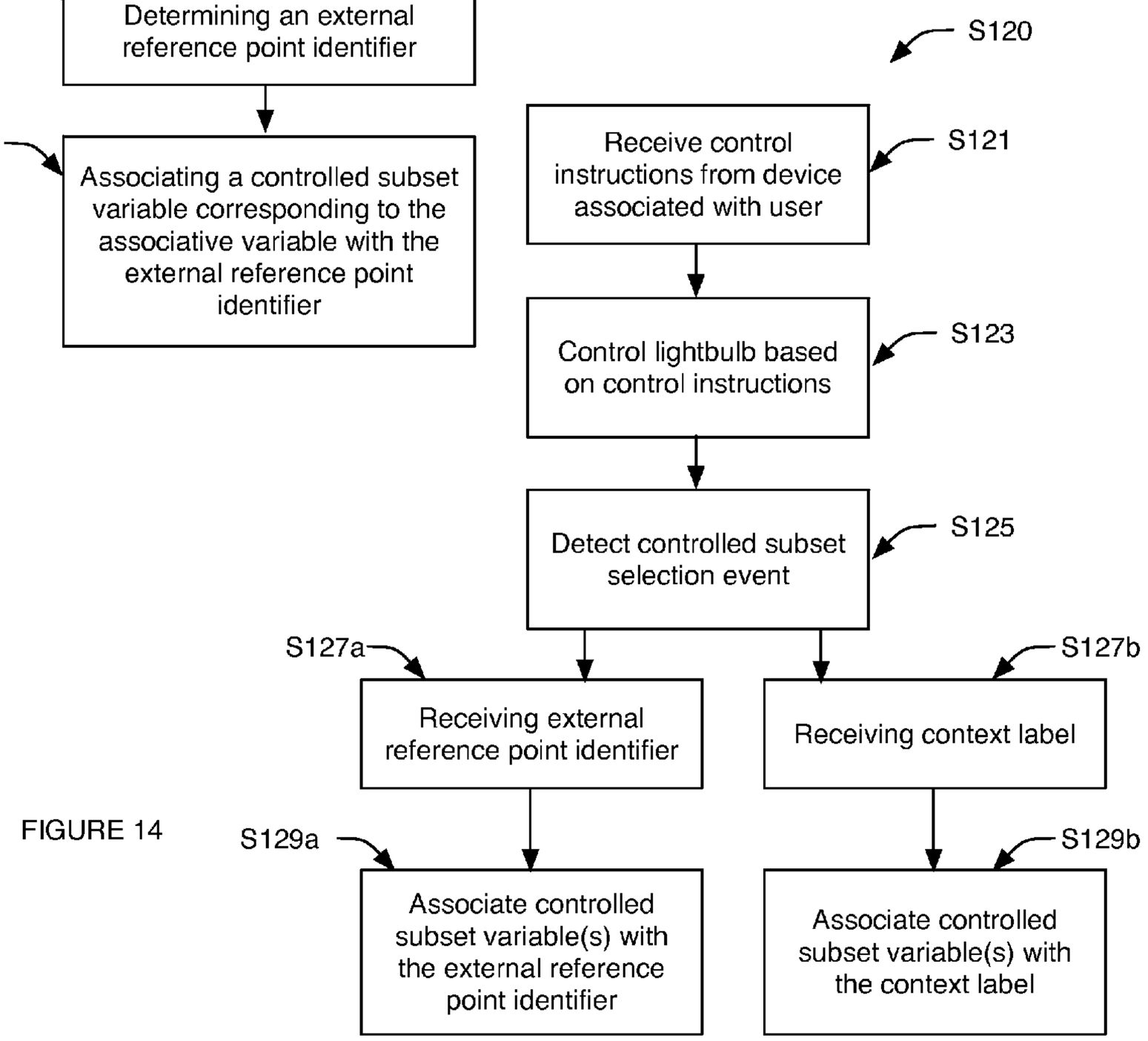


FIGURE 14

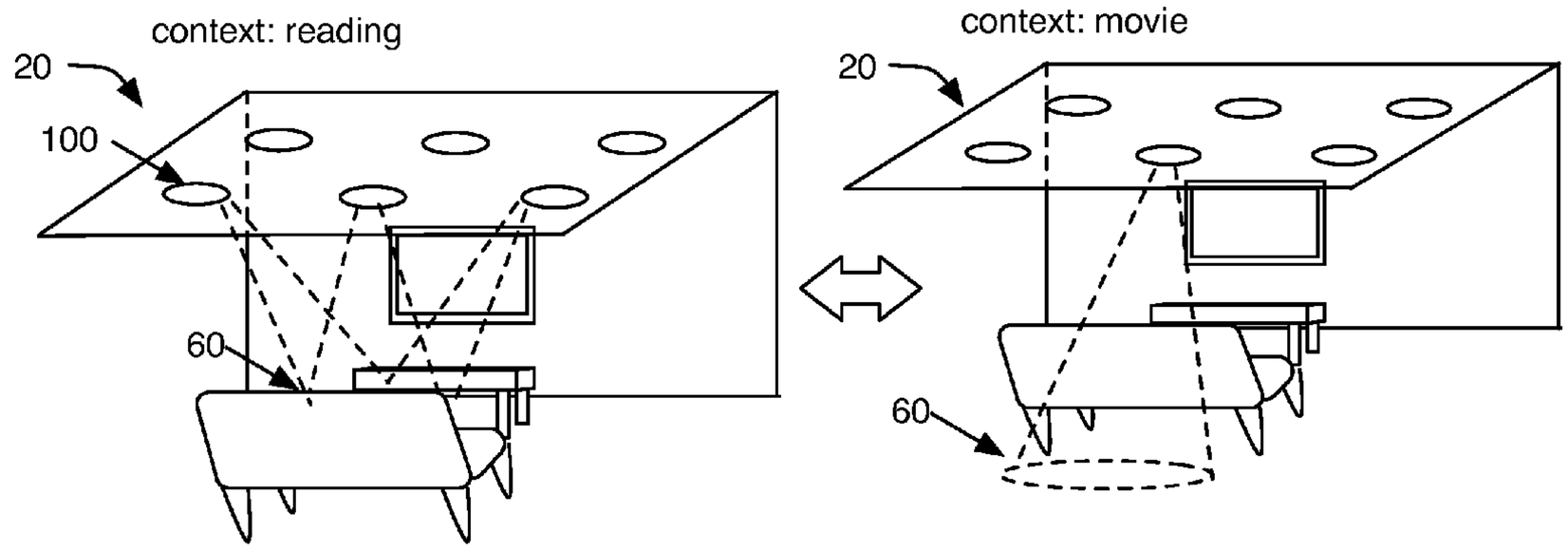


FIGURE 15

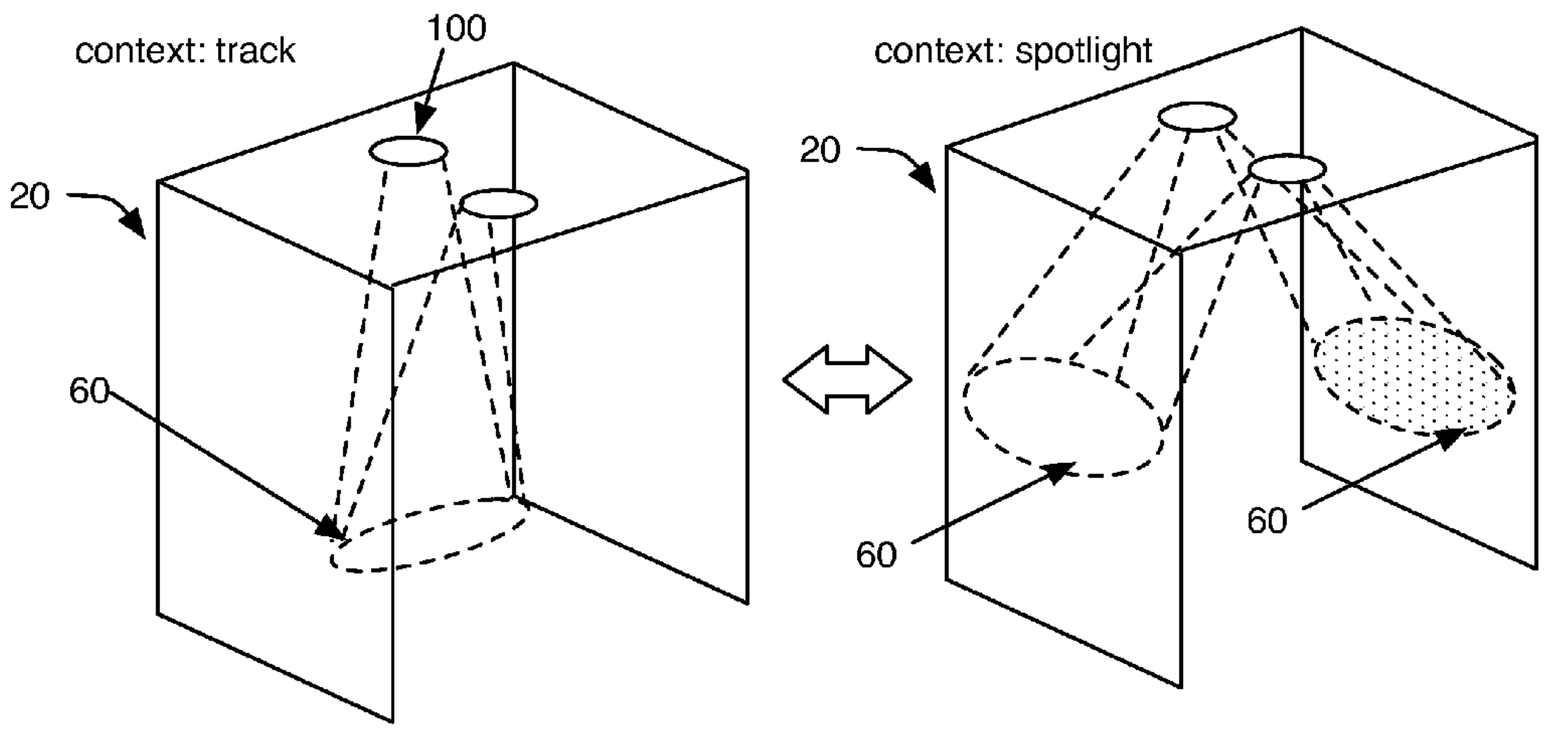


FIGURE 16

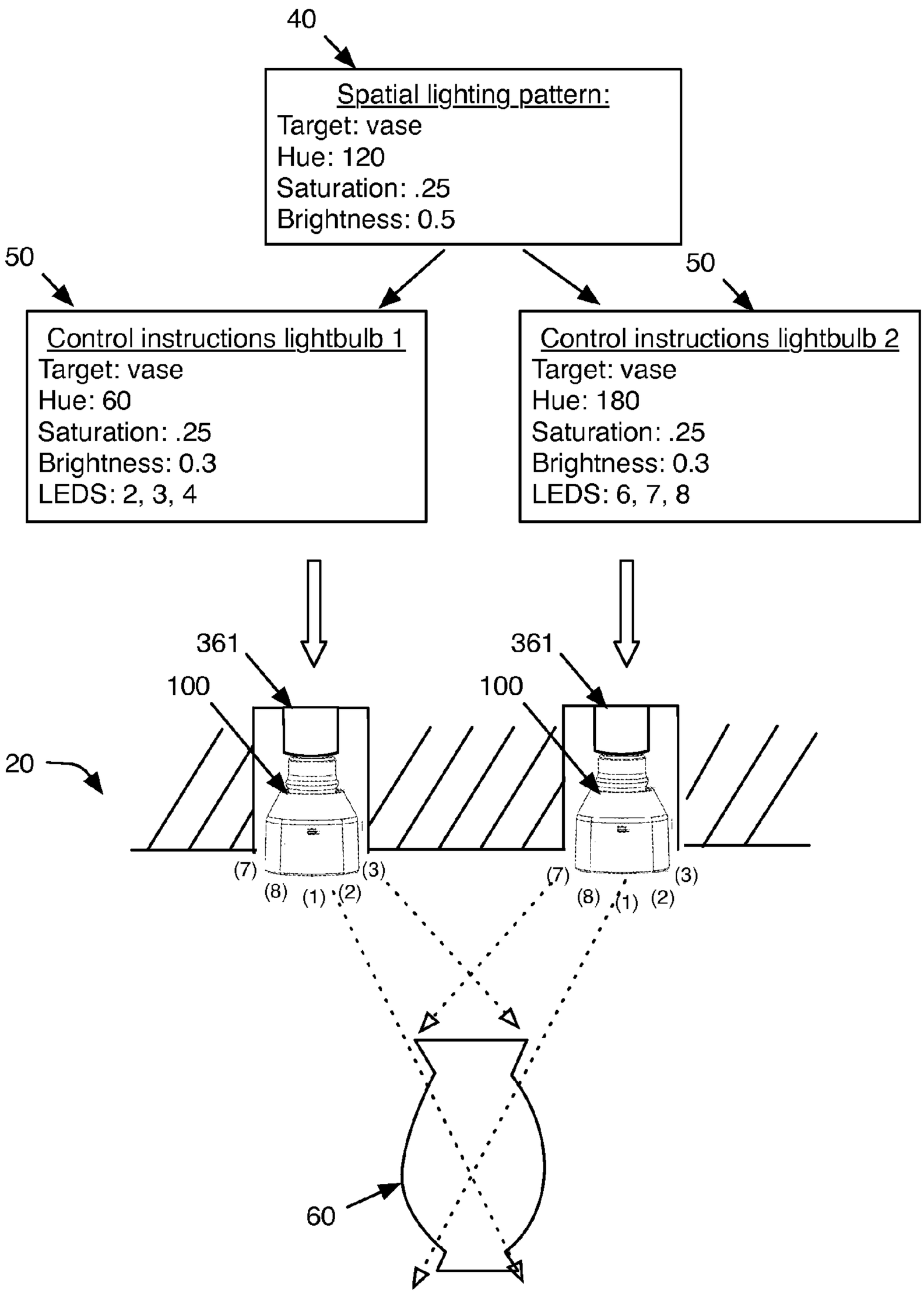

40
Spatial lighting pattern:
Target: vase
Hue: 120
Saturation: .25
Brightness: 0.5
50
Control instructions lightbulb 1
Target: vase
Hue: 60
Saturation: .25
Brightness: 0.3
LEDS: 2, 3, 4
50
Control instructions lightbulb 2
Target: vase
Hue: 180
Saturation: .25
Brightness: 0.3
LEDS: 6, 7, 8
361
100
361
100
20
(7)
(8)
(1)
(2)
(3)
(7)
(8)
(1)
(2)
(3)
60

FIGURE 17

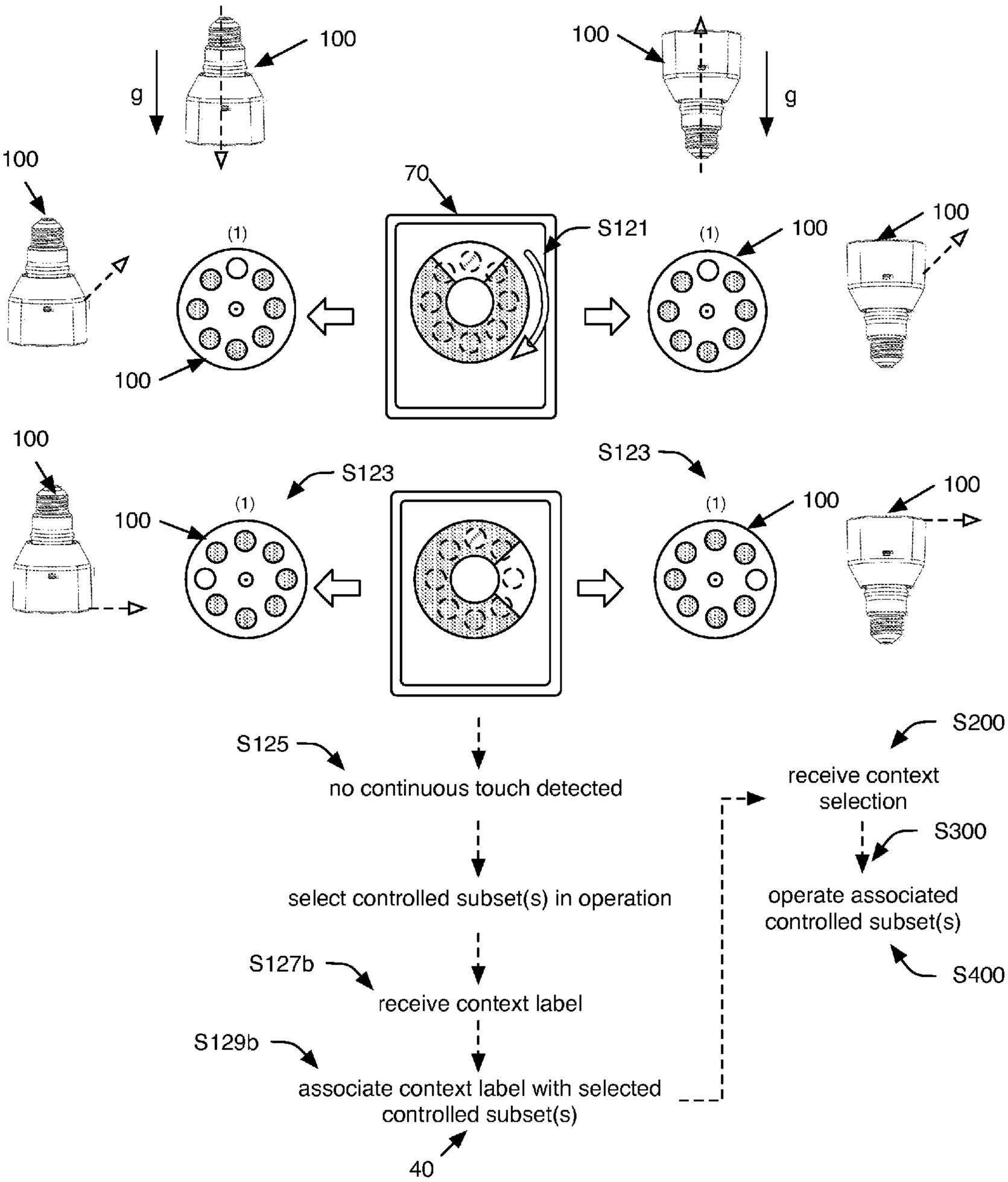

100
g
100
g
100
70
(1)
S121
(1)
100
100
100
100
S123
(1)
100
S123
(1)
100
100
S125
no continuous touch detected
S127b
receive context label
S129b
associate context label with selected controlled subset(s)
40
S200
receive context selection
S300
operate associated controlled subset(s)
S400

FIGURE 18

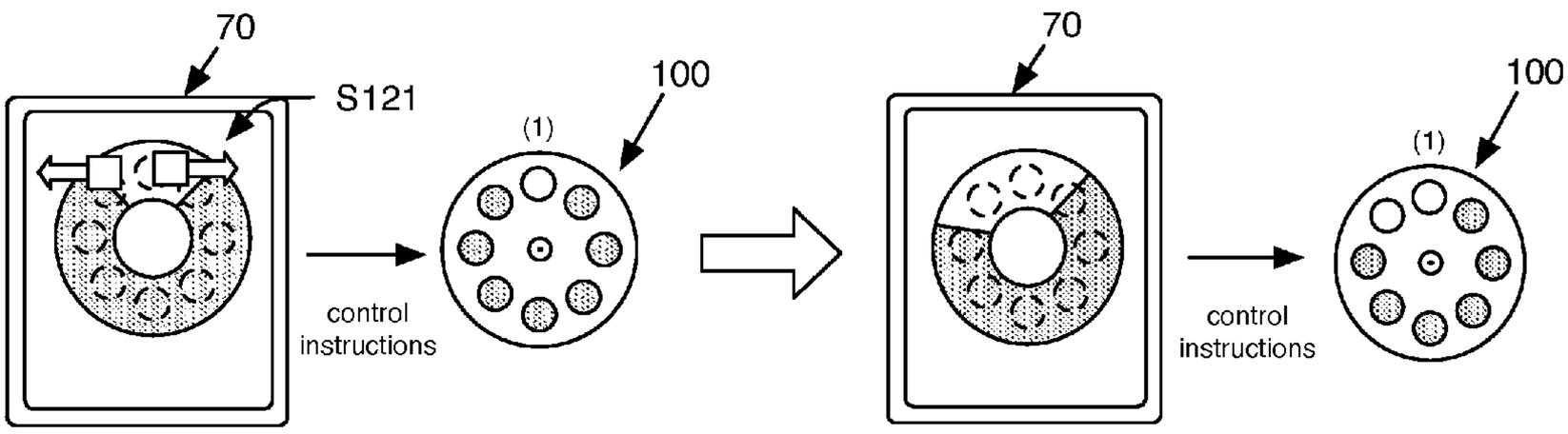
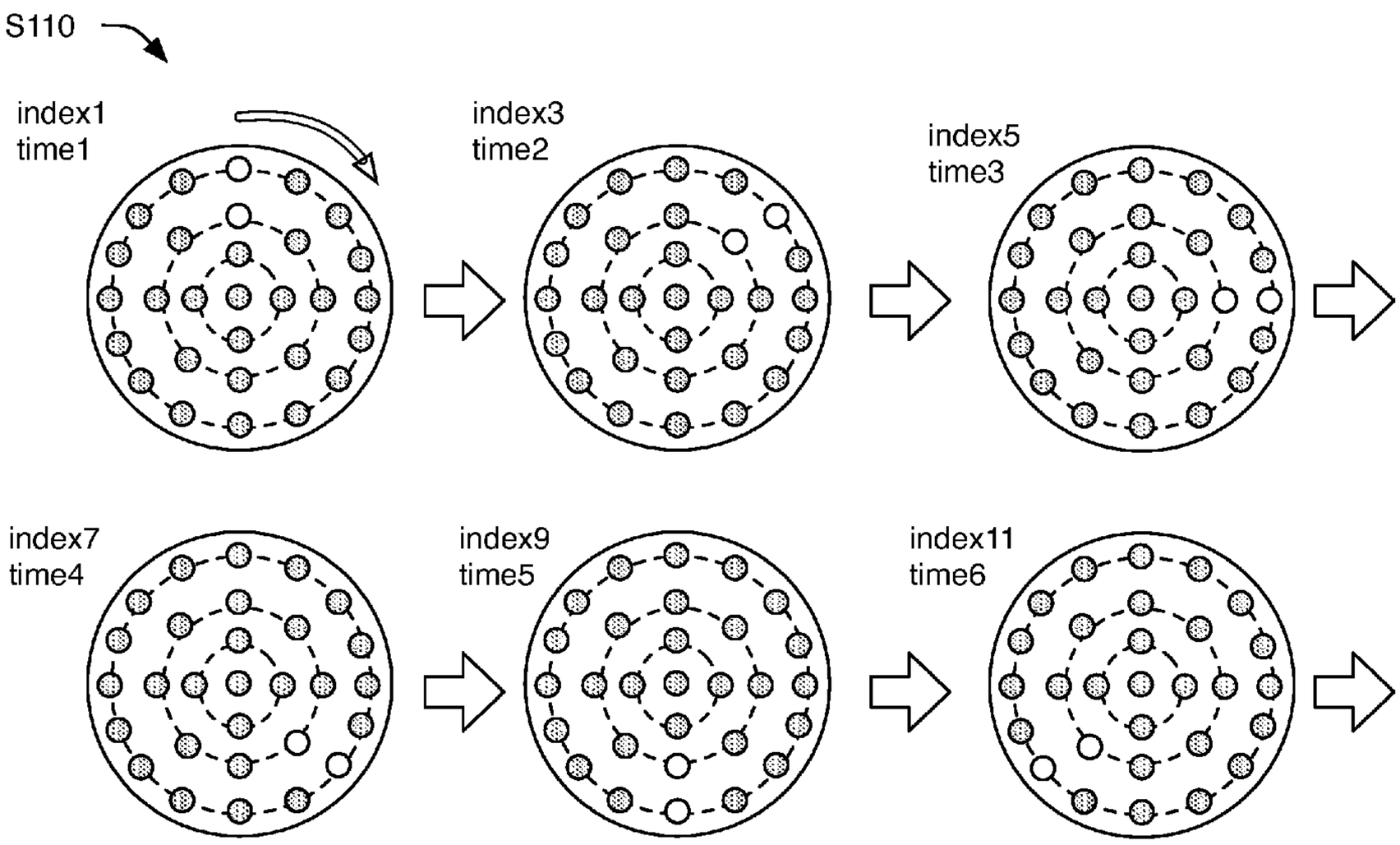


FIGURE 19



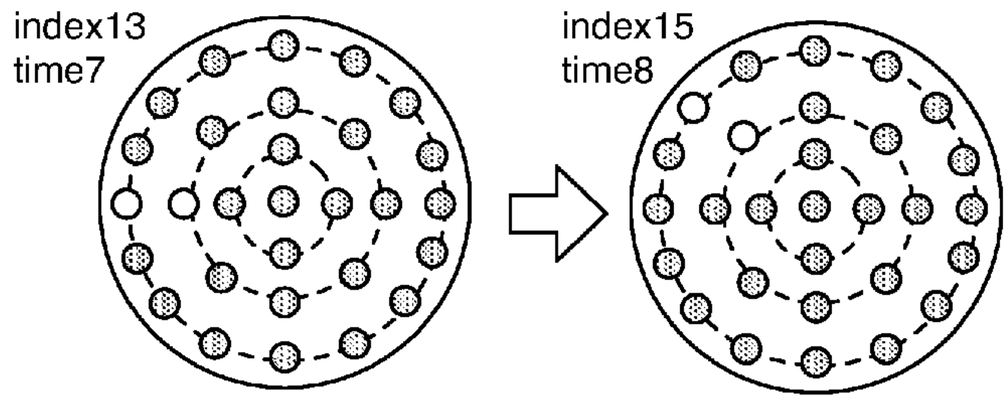


FIGURE 20

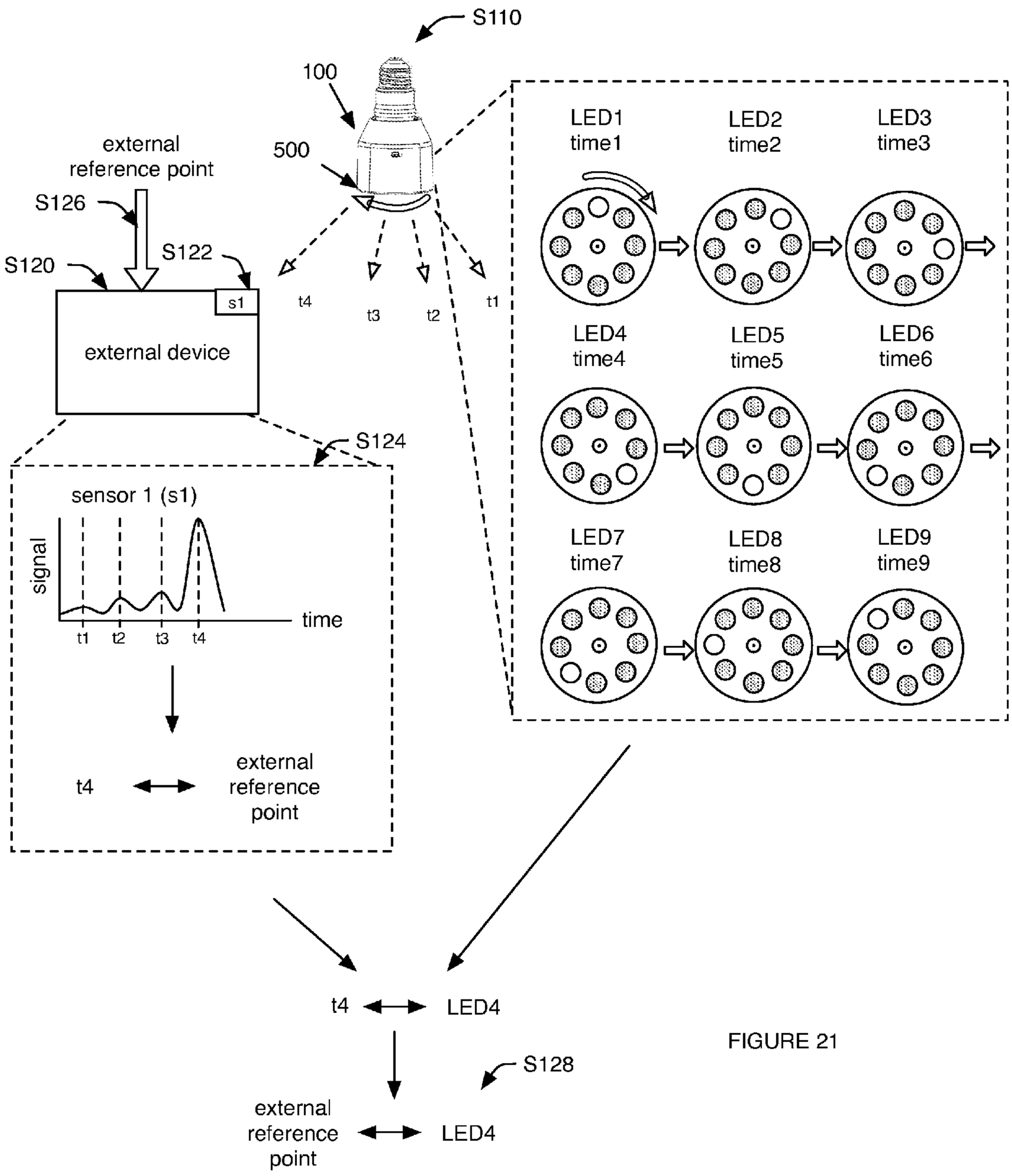

S110
100
500
external reference point
S126
S120
S122
s1
external device
t4
t3
t2
t1
S124
sensor 1 (s1)
signal
time
t1
t2
t3
t4
t4
external reference point
LED1 time1
LED2 time2
LED3 time3
LED4 time4
LED5 time5
LED6 time6
LED7 time7
LED8 time8
LED9 time9
t4
LED4
S128
external reference point
LED4

FIGURE 21

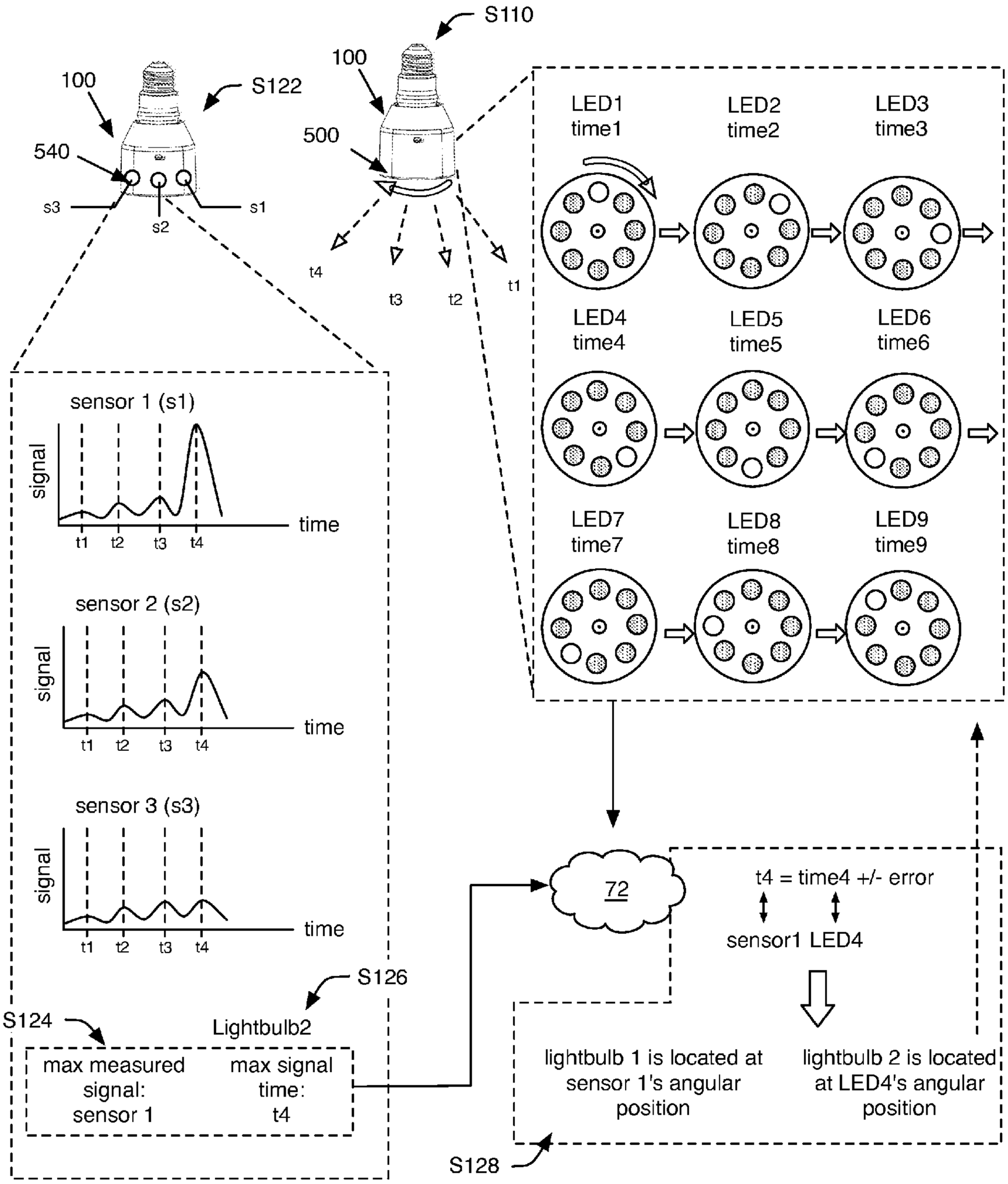

S110
100
S122
100
540
500
s3
s2
s1
t4
t3
t2
t1
LED1
time1
LED2
time2
LED3
time3
LED4
time4
LED5
time5
LED6
time6
LED7
time7
LED8
time8
LED9
time9
sensor 1 (s1)
signal
time
t1 t2 t3 t4
sensor 2 (s2)
signal
time
t1 t2 t3 t4
sensor 3 (s3)
signal
time
t1 t2 t3 t4
72
t4 = time4 +/- error
sensor1 LED4
S126
S124
Lightbulb2
max measured signal: sensor 1
max signal time: t4
lightbulb 1 is located at sensor 1's angular position
lightbulb 2 is located at LED4's angular position
S128

FIGURE 22

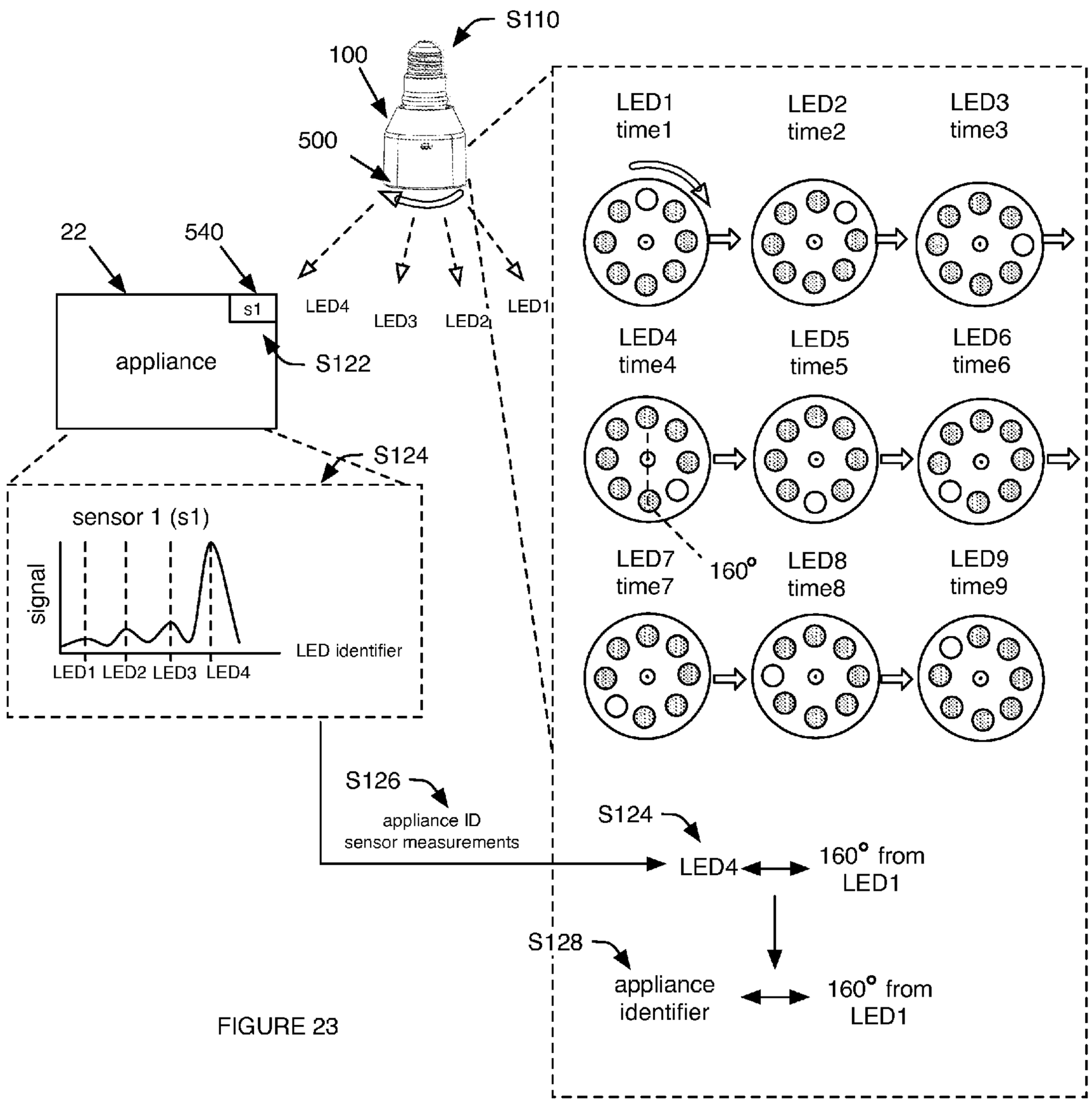

S110
100
500
22
540
s1
appliance
S122
LED4
LED3
LED2
LED1
S124
sensor 1 (s1)
signal
LED identifier
LED1 LED2 LED3 LED4
S126
appliance ID
sensor measurements
LED1
time1
LED2
time2
LED3
time3
LED4
time4
LED5
time5
LED6
time6
LED7
time7
160°
LED8
time8
LED9
time9
S124
LED4
160° from
LED1
S128
appliance
identifier
160° from
LED1

FIGURE 23

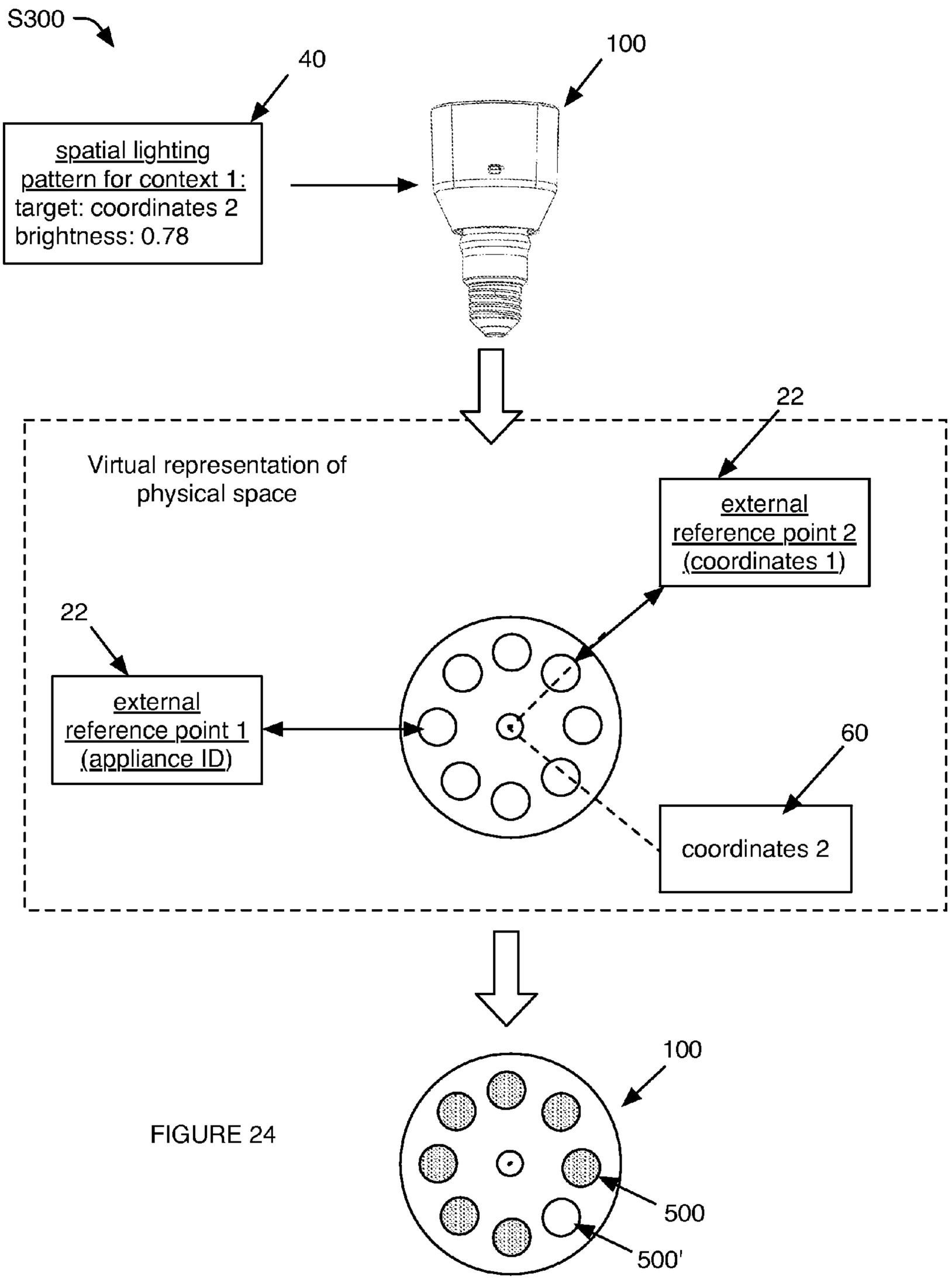

S300
40
100
spatial lighting pattern for context 1:
target: coordinates 2
brightness: 0.78
22
Virtual representation of physical space
external reference point 2 (coordinates 1)
22
external reference point 1 (appliance ID)
60
coordinates 2
100
500
500'

FIGURE 24

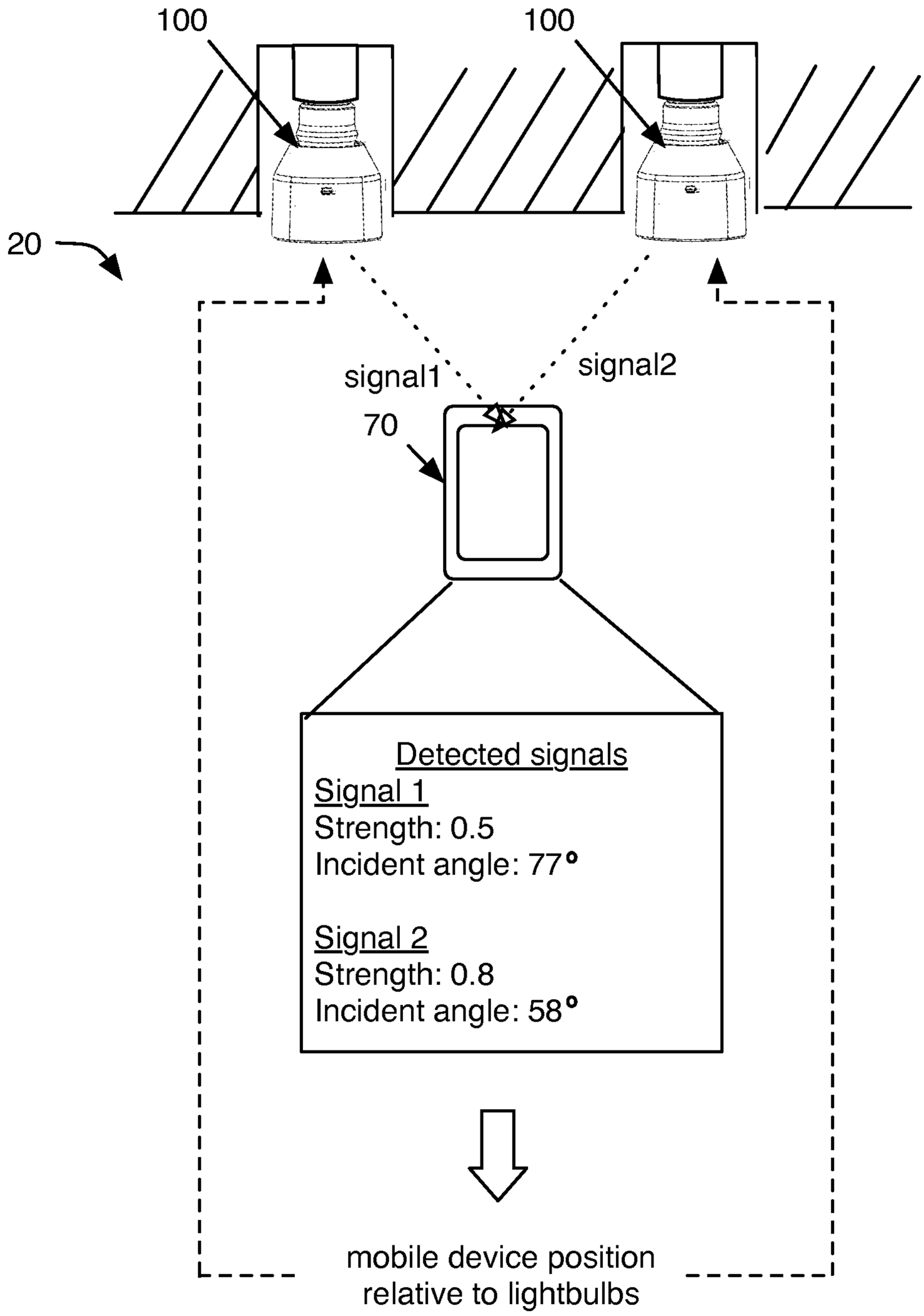

100
100
20
signal1
signal2
70
Detected signals
Signal 1
Strength: 0.5
Incident angle: 77°
Signal 2
Strength: 0.8
Incident angle: 58°
mobile device position
relative to lightbulbs

FIGURE 25

DIRECTIONAL LIGHTING SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 62/002,102 filed 22 May 2014, and 62/063,038 filed 13 Oct. 2014, which are incorporated in their entireties by this reference.

This application is related to U.S. application Ser. No. 14/425,266 filed 2 Mar. 2015, U.S. application Ser. No. 14/512,669 filed 13 Oct. 2014, and U.S. application Ser. No. 14/542,312 filed 14 Nov. 2014, which are incorporated in their entirety by this reference.

TECHNICAL FIELD

This invention relates generally to the lighting field, and more specifically to a new and useful responsive lighting system and method in the lighting field.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a cutaway schematic representation of a first example of the lightbulb, wherein the lightbulb includes sensors enclosed within the lightbulb by the diffuser.

FIG. **2** is a cutaway schematic representation of a second example of the lightbulb, wherein the lightbulb includes a pivotal support and an exposed sensor.

FIG. **3** is a cutaway schematic representation of a third example of the lightbulb, wherein the lightbulb includes a substrate with protrusions.

FIG. **4** is a cutaway schematic representation of a fourth example of the lightbulb.

FIG. **5** is a cutaway schematic representation of a fifth example of the lightbulb, wherein the processor and communications module are arranged on the side of the lightbulb.

FIG. **6** is a perspective schematic representation of a sixth example of the lightbulb.

FIG. **7** is a schematic representation of a lightbulb having a standard base that couples to a standard lighting fixture, wherein the lighting fixture is connected to a power grid.

FIG. **8** is an end-on, schematic representation of an example of light emitting element arrangement on the substrate in a spiral pattern.

FIG. **9** is an end-on, schematic representation of an example of light emitting element arrangement on the substrate in a concentric pattern.

FIG. **10** is a schematic representation of an example of light emitting element and sensor indexing (indicated by L and S, respectively).

FIG. **11** is a flowchart representation of the method of directional lightbulb operation.

FIG. **12** is a flowchart representation of a variation of determining a lightbulb position relative to a physical space.

FIG. **13** is a flowchart representation of a first variation of determining a lightbulb position using signals emitted during the orientation process, including automatically determining the lightbulb position using a device.

FIG. **14** is a flowchart representation of a first variation of determining a lightbulb position using signals emitted during the orientation process, including manually or pseudo-manually determining the lightbulb position.

FIG. **15** is a schematic representation of a first example of selective lightbulb operation based on context, including cooperatively illuminating a first illumination target (a seating area) in a first context (reading), and cooperatively illuminating a second illumination target (a physical region behind the seating area) in a second context (movie).

FIG. **16** is a schematic representation of a second example of selective lightbulb operation based on context, including cooperatively illuminating a first illumination target (the hallway) in a first context (tracking), and cooperatively illuminating a second illumination target (features on the walls) in a second context (spotlight).

FIG. **17** is a schematic representation of an example of selective, cooperative lightbulb operation based on the spatial lighting pattern.

FIG. **18** is a schematic representation of an example of pseudo-manual lightbulb position determination using a graphical representation of the lightbulb, and orientation-dependent lightbulb response.

FIG. **19** is a schematic representation of an example of generating control instructions specifying an angular range of light emitting elements to be concurrently lit, control instruction receipt, and selective lightbulb operation based on the control instruction.

FIG. **20** is a schematic representation of an example of proceeding the lightbulb through an orientation process according to an orientation pattern.

FIG. **21** is a schematic representation of an example of determining the lightbulb position relative to a physical space using an external device.

FIG. **22** is a schematic representation of an example of determining the lightbulb position relative to a physical space using a second lightbulb, further including an example of determining the position of the second lightbulb.

FIG. **23** is a schematic representation of an example of determining the lightbulb position relative to a physical space using a connected appliance.

FIG. **24** is a schematic representation of an example of selectively operating a lightbulb based on a spatial lighting pattern.

FIG. **25** is a schematic representation of an example of mobile device triangulation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description of the preferred embodiments of the invention is not intended to limit the invention to these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

1. System.

As shown in FIGS. **1-6**, the directional lightbulb **100** includes a light emitting element **500** mounted in a fixed position on the lightbulb **100**, a communication module **400**, and a processor **700** electrically connected to the light emitting element **500** and the communication module **400**. The lightbulb **100** can additionally include a set of sensors **540** connected to the processor **700**, a substrate **520** supporting the light emitting element **500** and sensors **540**, and/or a diffuser **600** enclosing the light bulb components. However, the lightbulb **100** can include any other suitable set of components.

The lightbulb **100** functions to selectively direct light relative to an external reference point **22**, such as toward a desired illumination target **60**. The lightbulb **100** preferably performs the method described below, but can alternatively be operated in any other suitable manner. The lightbulb **100** preferably enables light direction adjustment while the lightbulb **100** remains powered and physically connected to the power source, but can alternatively enable light direction adjustment after lightbulb **100** shutoff, cessation of power provision to

the circuit to which the lightbulb **100** is connected, or enable light direction adjustment in any other suitable operation state. In a first variation, the lightbulb **100** directs light by selectively operating (e.g., selectively powering or turning on) individual light emitting elements positioned at select locations on the lightbulb **100**. The selectively controlled light emitting elements **500** are preferably those closest the desired illumination target **60**, but can alternatively be other light emitting elements **500**. In this variation, the lightbulb position can be fixed within a lighting fixture **361** (e.g., a standard lighting fixture, such as a ceiling fixture, as shown in FIG. **17**), and the light emitting elements **500** can be fixed in known positions on the lightbulb **100**.

In a second variation, the lightbulb **100** selectively directs light by moving a powered light emitting element **500** (e.g., via the pivoted support **560**) to point toward the desired illumination target **60**. In this variation, the lightbulb **100** can be retained within a fixed lighting fixture, such that the lightbulb **100** moves the light emitting element **500** relative to the lightbulb base **360**, or be retained within a movable lighting fixture, such that the lightbulb **100** controls an external actuation mechanism to move the entire lightbulb **100**. However, the lightbulb **100** can otherwise direct light toward a desired illumination target **60**.

This lightbulb **100** can confer several benefits over conventional lightbulbs **100**. First, the lightbulb **100** can reduce energy consumption by selectively powering only the light emitting elements **500** that are needed. Second, the same lightbulb **100** can provide multiple different ranges of lighting angles. This can function to reduce the need to install additional lighting fixtures and lightbulbs **100** that selectively direct light toward different illumination targets **60**.

Third, the lightbulb **100** can determine and store its rotational and/or geographic position relative to an external reference point **22**. This relative orientation or position can subsequently be used to determine the position of the desired illumination target **60** relative to a reference point on the lightbulb **100**, and to determine each light emitting element's position relative to the desired illumination target **60**. The lightbulb **100** can be capable of rotationally orienting or geographically positioning itself using only the light emitting elements **500** and wireless communication system, using only the light emitting elements **500** and an ambient light sensor, using only the wireless communication system, or using any other suitable combination of components to rotationally or geographically orient itself in any other suitable manner. The lightbulb **100** rotational and/or geographic position can be automatically determined or manually determined. The lightbulb **100** rotational and/or geographic position can be determined solely by the lightbulb **100**, cooperatively determined with a user device, cooperatively determined with other similar lightbulbs **100**, or otherwise determined. Because the lightbulb **100** is mounted to a lighting fixture, which is typically static, the lightbulb **100** rotational and/or geographic position can be stored and reliably used for subsequent lighting events after initial position determination. Furthermore, in some lightbulb **100** variants including orientation or position sensors (e.g., accelerometers, gyroscopes, GPS systems, etc.), detection of movement beyond a threshold change (e.g., above 0.1 m/s^2, 0.5 m/s^2, 5 m/s^2, 0 m/s^2, etc.) can trigger position re-determination. However, the lightbulb **100** orientation can be re-determined in response to switching of a reset switch, sudden cessation and/or power supply, or in response to any other suitable reset event.

Fourth, the lightbulb **100** can provide context-responsive lighting. In a first example, as shown in FIG. **16**, the same lightbulb **100** (or plurality of lightbulbs **100**) can anticipatorily light a user's path in the hallway while minimally lighting the hallway walls in a first context, and selectively illuminate paintings hung on the hallway walls (e.g., spotlight the paintings) while minimally lighting the hallway corridor in a second context. In a second example, as shown in FIG. **15**, the same lightbulb **100** can provide downlight for a user reading a book on the couch in front of the television in a first context, or provide ambient backlight directed away from the television for the same user in the same location. In a third example, as shown in FIG. **16**, the same lightbulb **100** can simultaneously provide light having a first set of parameters to a first geographic region, and provide light having a second set of parameters to a second geographic region. In a specific example, the lightbulb **100** can flash light, in synchronization with flashes on a television, toward a first region of a couch, while concurrently providing a substantially constant light (e.g., for reading) toward a second region of the couch distinct from the first region. However, the lightbulb **100** can selectively operate the light emitting elements **500** in any other suitable manner in response to determination of any other suitable context. The lightbulb **100** can additionally confer any other suitable benefit.

The lightbulb **100** preferably enables a plurality of light parameters to be automatically or manually controlled. Examples of controllable light parameters for each lightbulb **100** include: the light direction, which light emitting element **500** is lit, the emission pattern for each light emitting element **500**, the number of concurrently lit light emitting elements **500**, the pattern of concurrently lit light emitting elements **500'**, the parameters of the emitted light (e.g., hue, saturation, brightness, correlated color temperature, color rendering index, attenuation, etc.), the shape of the emitted light (e.g., conical, beam, etc.), the quality of the emitted light (e.g., collimated, disperse, etc.), or include any other suitable light parameter.

The parameters of a plurality or population of lightbulbs **100** can additionally be automatically or manually controlled to achieve a desired illumination effect within a physical space **20** or on an illumination target **60**. The population of lightbulbs **100** preferably includes all lightbulbs **100** within a physical space **20** (e.g., within a room, within a house, etc.), but can alternatively include all lightbulbs **100** arranged on the same sub-circuit, all lightbulbs **100** controlled by the same switch, all lightbulbs **100** connected to the same local area network (LAN), lightbulbs **100** located in geographically disparate locations, lightbulbs **100** associated with the same user account, or be any other suitable population of lightbulbs **100**. Examples of lightbulb population parameters that can be controlled include: which lightbulb **100** has lit light emitting elements **500**, the parameters of light emitted by each lightbulb **100**, when each lightbulb **100** is operated (e.g., relative timing between lightbulbs **100**), the spatial light focus of the lightbulb population (e.g., wherein beams of low light from a first and second lightbulb **100** cooperatively illuminate a single volumetric region with a higher intensity than the emitted light, an example of which is shown in FIG. **17**), or be any other suitable population parameter.

The light emitting element **500** of the lightbulb **100** functions to emit electromagnetic radiation or signal **30**, such as light. The light emitting element can be an LED, OLED, solid-state light emitting element, or be any other suitable light emitting element. The lightbulb **100** preferably includes a plurality of light emitting elements **500**, but can alternatively include a single light emitting element **500** or any suitable number of light emitting elements **500**. Each light emitting element **500** can be independently controlled, such

that each light emitting element **500** operates independently from the other light emitting elements **500**. Alternatively, a group of light emitting elements **500** (e.g., a cluster or subset of the light emitting elements **500**) can be independently controlled, such that the group of light emitting elements **500** can operate independently from the other of the light emitting elements **500**. Each controlled subset (e.g., individual light emitting element **500** or cluster) is preferably wired in parallel relative to other controlled subsets of the lightbulb **100**, but can alternatively be wired in series, wired in a combination of in parallel and in series, or be wired in any other suitable manner. The controlled subsets of the lightbulb **100** are preferably controlled by the lightbulb **100** processor **700**, but can alternatively be controlled by a remote computing system **72** (e.g., server system), external device **30** (e.g., mobile device **70**, appliance, etc.), or by any other computing system.

Each controlled subset is preferably identified by a locally unique identifier (e.g., with respect to the lightbulb **100**), such that the controlled subset can be individually controlled, but can alternatively be identified by a globally unique identifier, be identified by a nonunique identifier, or be identified in any other suitable manner. The identifier can be an index value (e.g., number), a position on the lightbulb **100** (component position, light emitting element position, etc.), or be any other suitable identifier. When an index is used, the index value for adjacently positioned subsets are preferably sequential (e.g., as shown in FIG. **10**), but the subsets can alternatively be randomly or otherwise indexed, independent of the respective controlled subset position on the lightbulb **100**. The identifiers for each subset is preferably stored by the lightbulb **100**, but can alternatively be stored by a remote computing system (e.g., server system), external device **30** (e.g., mobile device **70**, appliance, etc.), or other computing system.

The controlled subsets are preferably mounted in fixed positions on the lightbulb **100**, but can alternatively be mounted in movable positions or be otherwise affixed to the lightbulb **100**. The light emitting elements **500** are preferably mounted to a substrate **520**, which is mounted to a lightbulb housing **300**, but the light emitting elements **500** can alternatively be mounted to any other suitable lightbulb component. The light emitting elements **500** can be mounted on one or more broad faces of the substrate **520**, along one or more sides of the substrate **520**, or be mounted along any other suitable portion of the substrate **520**. The substrate **520** can be substantially flat, curved, polygonal, or have any other suitable configuration. The substrate **520** can additionally or alternatively include one or more protrusions (e.g., as shown in FIG. **3**), divots, or other feature, wherein one or more controlled subsets are arranged on each feature. Alternatively, the substrate **520** can be substantially featureless. The light emitting elements **500** can be mounted in an array, in concentric rings (e.g., circles, rectangles, etc.; example shown in FIG. **9**), in a spiral (e.g., circular spiral, logarithmic spiral, square spiral, etc.; example shown in FIG. **8**), in a boustrophedonic pattern, randomly positioned, or be mounted in any other suitable pattern.

In some variants, the lightbulb **100** can additionally include a pivoted support **560** mounted to the light emitting element **500** that functions to selectively position the light emitting element **500** in one of a predetermined set of positions. In other variants, the light emitting elements **500** can be statically retained relative to the lightbulb base **360**, housing **300**, or other component, and exclude a pivoted support **560**. The pivoted support **560** can rotate the light emitting element **500** about a rotational axis (e.g., rotate the light emitting element **500** 45 degrees, 0 degrees, 180 degrees, 30 degrees, etc.), actuate the light emitting element **500** along an axis (e.g., along the lightbulb **100** longitudinal axis **10**, along a lightbulb **100** radial axis, etc.), or otherwise position the light emitting element **500**. The rotational axis can be the lightbulb **100** longitudinal axis **10**, an axis parallel to the lightbulb **100** longitudinal axis **10**, or an axis at a non-zero angle, such as 0 degrees, to the lightbulb **100** longitudinal axis **10**, or be any other suitable rotational axis.

The pivoted support **560** is preferably mounted to the substrate **520**, but can alternatively be mounted to individual controlled subsets (e.g., wherein the substrate **520** can be formed from multiple components), groups of controlled subsets, or be mounted to any other suitable set of light emitting elements **500**. The pivoted support **560** is preferably mounted at the other end to the lighting housing **300** or base **360**, but can alternatively be mounted to any other suitable component.

The pivoted support **560** preferably actuates the light emitting elements **500** relative to the base **360** of the lightbulb **100**, but can alternatively actuate the light emitting elements **500** relative to the lightbulb housing **300**, the lightbulb **100** diffuser **600**, or any other suitable lightbulb component. Alternatively or additionally, the pivoted support **560** can actuate the light emitting elements **500** relative to an external reference point **22** (e.g., wherein the pivoted support **560** rotates the light fixture **361**). The pivoted support **560** can be active (e.g., driven by a motor, electromagnet, or other actuation mechanism) or passive. The pivoted support **560** can additionally include a position sensor that measures the position (e.g., angular position, radial position, etc.) of the light emitting element **500** or substrate **520**. Examples of the position sensor include a rotary sensor (e.g., an optical encoder, magnetic encoder, capacitive encoder, mechanical encoder, geared encoder, battery-powered encoder, self-powered multi-turn encoder, etc.), linear encoder (e.g., optical, magnetic, capacitive, inductive, eddy current, etc.), or be any other suitable encoder. The pivoted support **560** can be a gimbal system, a ball and joint, a knuckle joint, a turnbuckle, a pin joint, a cotter joint, or any other suitable joint; a scissor lift, linear actuator, or any other suitable actuation mechanism.

The position of each controlled subset on the lightbulb **100** is preferably known and stored in association with the respective identifier, but can alternatively be otherwise determined. The subset position for each subset on the lightbulb **100** can be determined by the manufacturer, automatically by the lightbulb **100**, by an external device **30** (e.g., a mobile device **70** or appliance), or be determined by any other suitable system. The subset position for each subset is preferably stored by the lightbulb **100**, but can alternatively be stored by a remote computing system (e.g., server system), external device **30** (e.g., mobile device **70**, appliance, etc.), or other computing system.

The position of each controlled subset is preferably a position relative to a reference point on the lightbulb **100** (lightbulb **100** reference point), but can alternatively be a location within a grid, wherein each grid intersection is a known, fixed distance from the next grid intersection, or be otherwise determined. The lightbulb **100** reference point can be a real reference point or an imaginary reference point. The lightbulb **100** reference point can be a light emitting element **500** (e.g., a first light emitting element **500**), a controlled subset, a sensor **540** (e.g., a light sensor), a notch on the lightbulb **100**, a lightbulb longitudinal axis **10**, a position determined by a rotary encoder, or be any other suitable reference point. The reference point is preferably static, but can alternatively move, wherein the lightbulb **100** can track the new reference

point position and determine new position coordinates for each light emitting element **500**.

The light emitting elements **500** can be LEDs (light emitting diodes), OLEDs (organic light emitting diodes), PLEDs (polymer LEDs), solid-state lighting, LECs (light emitting electrochemical cells), other electroluminescent lighting, lasers, bioluminescent lighting, chemoluninescent lighting, fluorescent lighting, gas discharge lighting, phosphorescent lighting, ESL lighting, incandescent lighting, or be any other suitable component capable of emitting electromagnetic or blackbody radiation **30**. The radiation **30** emitted by the light emitting elements **500** can be visible or invisible, and can include the entire visible spectrum, portions of the visible spectrum (e.g., red, green, and blue; deep red; etc.), portions of the invisible spectrum (e.g., IR, etc.), or include any other suitable portion of the electromagnetic spectrum.

Each light emitting element **500** of the lightbulb **100** is preferably substantially identical, but can alternatively be different. In one variation, the light emitting elements **500** are all capable of emitting the same plurality of colors (e.g., white only, blue, red, and green, full color, etc.) and/or be the same type of light emitting element **500** (e.g., be RGB LEDs). In a second variation, the light emitting elements **500** are grouped into clusters, wherein each cluster is independently controllable and includes the same combination of light emitting elements **500**. For example, each cluster can include a red, blue, and green light emitting element **500**. In a third variation, the majority of the light emitting elements **500** (e.g., 0%, 75%, etc.) can be substantially similar (e.g., emit the same colors, include substantially the same group of light emitting elements **500**, etc.), while a minority of light emitting elements **500** can have different properties (e.g., be a different type of light emitting element **500**, emit light at a different frequency, such as deep red, etc.). For example, the majority of light emitting elements **500** can be white LEDs, but include one or more (e.g., one, two, five, etc.) deep red LEDs or IR LEDs. However, the lightbulb **100** can include any other suitable set of light emitting elements **500** arranged and controlled in any other suitable manner.

The set of light emitting elements can additionally include a set of dividers that separate light emitting elements or controlled subsets. The dividers preferably separate adjacent, individually indexed controlled subsets, but can alternatively separate adjacent groups of controlled subsets or be arranged in any other suitable position. Alternatively, the lightbulb can exclude dividers, such that the physical space between adjacent controlled subsets is substantially unobstructed. The divider can be opaque, transparent, translucent, or have any other suitable optical property. The divider optical properties can be fixed or adjustable (e.g., adjusted by applying a variable voltage to the divider). The divider can extend a portion of the distance between the adjacent controlled subsets (e.g., be half length), extend along the entirety of the distance between the adjacent controlled subsets, or have any other suitable length. The divider can extend a portion of the distance from the substrate to the diffuser or outer covering (e.g., be half height), extend the full distance between the substrate and the diffuser, or have any other suitable height. However, the divider can have any other suitable dimension. The divider can be formed between channels defined within the substrate **520** (e.g., wherein the light emitting elements can be arranged within the channels), defined by protrusions extending from the substrate, or be otherwise defined.

The communication module **400** of the lightbulb **100** functions to communicate data between the lightbulb **100** and a secondary device. The secondary device can be a LAN node (e.g., a router), a second lightbulb **100**, a mobile device **70** associated with a user (e.g., a smartphone, tablet, smartwatch, etc.), a connected appliance (e.g., a television, switch, etc.), or be any other suitable secondary device. The communication module **400** can support wireless and/or wired communication. The wireless communication module **400** preferably includes a transceiver, but can alternatively be a transmitter or a receiver. Additionally or alternatively, the wireless communication module **400** can be a router. The communication module **400** preferably supports one or more communication protocol standards, but can alternatively support any other suitable communication protocol. The communication module **400** can be mounted on the substrate **520**, mounted to the processor board, mounted to a separate and distinct board, mounted to the lightbulb housing, or be mounted to any other suitable lightbulb component. The wireless communication module **400** preferably includes an antenna **430** electrically connected to the processor **700** of the lightbulb **100**, and can additionally include intervening circuitry that supports the communication protocol. In one variation, the antenna **430** extends through the substrate **520** (e.g., along the longitudinal axis **10** of the lightbulb **100**), such that the substrate **520** can rotate about the antenna **430** in articulating variants. In a second variation, the antenna **430** extends along a radial or lateral portion of the lightbulb housing **300** (e.g., as shown in FIG. **5**). However, the antenna **430** can be otherwise arranged. The lightbulb **100** can include one or more communication modules **400**, wherein different modules of the plurality can support the same or different communication protocols. The communication protocol can be WiFi, WiMAX, mesh, zigbee, Z-WAVE, wireless USB, UWB, thread, IR, US, radio, cell, GPS, satellite, NFC, RF, Bluetooth, microwave, modulated light, powerline, Ethernet, coaxial cable, ITU-TG.hn, twisted pair wire, optical fiber, or be any other suitable communication protocol.

The processor **700** of the lightbulb **100** functions to operate the light emitting elements **500** according to control instructions **50**. The control instructions **50** can be received from the secondary device through the communication module **400**, retrieved from on-device storage (e.g., volatile or non-volatile lightbulb **100** memory), automatically generated by the processor **700** based on sensor measurements or received information, or be determined in any other suitable manner. The processor **700** can additionally or alternatively index the light emitting elements **500**, selectively control the light emitting elements **500** based on the respective index value or light emitting element position, determine the gravitational or rotational position of the lightbulb **100** (e.g., a reference point on the lightbulb **100**) relative to an external reference point **22** (e.g., by progressing the lightbulb **100** through an orientation pattern), determine the occurrence of contextual events and operate the light emitting elements **500** based on control instructions **50** associated with the contextual events, or otherwise operate the lightbulb **100**. The processor **700** can additionally store the position of the lightbulb **100** relative to the external reference point **22**, such that the processor **700** can repeatedly illuminate the desired illumination target **60** for each determined context. The processor **700** is preferably a CPU, but can alternatively be a microprocessor **700**, a GPU, or any other suitable processing unit. The processor **700** is preferably electrically connected to the active components of the lightbulb **100** (e.g., light emitting elements **500**, communication module **400**, pivoted support **560**, sensors **540**, etc.), but can alternatively be connected to a subset of the active components, or be connected to any other suitable set of components. The processor **700** is preferably mounted to the

substrate **520**, but can alternatively be mounted to the communication module **400** or be mounted to any other suitable portion of the lightbulb **100**.

As shown in FIGS. **1** and **2**, the lightbulb **100** can additionally include a set of sensors **540** that function to measure lightbulb **100** parameters and/or ambient environment parameters. The sensors **540** are preferably arranged on the substrate **520** (e.g., on the same, adjacent, or opposing face as the light emitting elements **500**), but can alternatively be arranged along the housing **300** (e.g., as shown in FIG. **2**), the diffuser **600**, the base **360**, or be arranged along any other suitable lightbulb component. The sensors **540** are preferably electrically connected to the processor **700**, but can alternatively be electrically connected to the communication module **400** or be otherwise connected. Examples of sensors **540** that can include light sensors, positioning systems, orientation sensors, power sensors, sound sensors, or include any other suitable sensor. Light sensors can include ambient light sensors (e.g., photometers, photodiodes, photoresistors, phototransistors, etc.), image sensors or cameras (e.g., CCD cameras, CMOS cameras, etc.), optical detectors, or be any other suitable light sensor. In a specific variation, the lightbulb **100** excludes a camera. However, the lightbulb **100** can leverage the feed from an on-board or external camera, or function in any other suitable manner. Positioning systems can include GPS units, cellular triangulation units, trilateration units, optical sensing system, such as a LIDAR system, acoustic sensing system, or be any other suitable positioning system. Orientation sensors can include accelerometers, gyroscopes, digital compasses, or any other suitable orientation sensors. Power sensors can include Hall effect sensors, voltage sensors, or any other suitable sensor capable of measuring a power parameter. Sound sensors can include microphones, transducers, or any other suitable sound sensor. However, the lightbulb **100** can include any other suitable set of sensors.

The lightbulb **100** can additionally include a diffuser **600** and housing **300**, which function to encapsulate the lightbulb components. The diffuser **600** can additionally function to diffuse the light emitted by the light emitting elements **500**, particularly when the light emitting elements **500** are LEDs (e.g., to increase the diffusion angle). The diffuser **600** is preferably statically coupled to the housing **300** or substrate **520**, but can alternatively be actuatable. The diffuser **600** preferably has a substantially static translucency, but can alternatively have a translucency that can be dynamically adjusted (e.g., by the processor **700**). The diffuser **600** preferably has a substantially constant translucency over its surface, but can alternatively have a variable translucency over its surface. The diffuser **600** preferably encapsulates the sensors (e.g., the ambient light sensor) within the lightbulb **100** (e.g., as shown in FIG. **1**), but can alternatively include apertures or other features to expose the sensors to the ambient environment.

The housing **300** can additionally function to cool the active components and/or function as a structural support for the active components. The power source is preferably a lighting fixture **361**, more preferably a standard light fixture (e.g., a ceiling socket or lamp) that is connected to a local circuit, which in turn, is connected to a power grid (as shown in FIG. **7**), but can alternatively be a battery, renewable system, or be any other suitable power source. The housing **300** can include a base **360**, which functions to electrically connect the lightbulb **100** to a power source. The base **360** is preferably a standard lightbulb base **360** (e.g., an Edison screw, bayonet, bi-post, bi-pin, wedge, fluorescent base **360**, etc.), but can alternatively be a custom base **360** or any other suitable type of base **360**. Alternatively, the lightbulb **100** can be directly wired into the local circuit or be otherwise powered.

2. Method.

As shown in FIG. **1**, the method of spatial lightbulb operation includes determining the position of the lightbulb relative to a physical space S**100**, detecting a contextual event S**200**, determining a spatial lighting pattern associated with the contextual event S**300**, and selectively controlling lightbulb light emitting elements based on the position of the lightbulb and the spatial lighting pattern S**400**. The method functions to automatically determine the rotational and/or gravitational lightbulb orientation within the space. The method can additionally function to automatically operate the lightbulb to illuminate desired illumination targets with light having a desired set of parameters in response to the occurrence of contextual events. The method is preferably performed with the lightbulb described above, but can alternatively be performed with any other suitable lighting system.

Determining the position of the lightbulb relative to a physical space (lightbulb position) S**100** functions to spatially orient the lightbulb. In particular, determining the lightbulb position S**100** can include determining the physical position of the lightbulb within the physical space, determining the angular or rotational position of the lightbulb relative to an external reference point, determining the pitch of the lightbulb relative to a gravity vector, and/or determining the lightbulb yaw relative to a gravity vector. Determining the lightbulb position can additionally include: associating a reference point on the lightbulb (lightbulb reference point) with a reference point external the lightbulb (external reference point), such that the relationship can subsequently be used to determine which light emitting elements to operate to illuminate a desired external illumination target with minimal or no additional orientation input. The lightbulb position is preferably automatically determined by the lightbulb, but can alternatively be cooperatively determined (e.g., with the lightbulb) or entirely determined by an external device within the physical space (e.g., a second lightbulb, a mobile device, an appliance, etc.), a remote system **72** outside of the physical space (e.g., a remote server system), or any other suitable system.

In a first variation, determining the lightbulb position S**100** includes progressing the lightbulb through an orientation process Silo (e.g., operating the lightbulb in an orientation mode) and determining the lightbulb position by using signals emitted during the orientation process S**120**, as shown in FIG. **12**. However, the lightbulb position can be otherwise determined. In this variation, the lightbulb position can be automatically determined by only the lightbulb, be cooperatively determined by the lightbulb and an external device, or be determined by any other suitable system.

The orientation process functions to operate lightbulb components having known positions, such that the lightbulb or an external device can index the rotational orientation of the lightbulb. The orientation process preferably includes sequentially operating individual controlled subsets in a predetermined mode in a predetermined pattern. The orientation process can additionally include identifying an associative variable for use in automated lightbulb position determination.

The controlled subset can be an individual light emitting element (e.g., as shown in FIG. **21**), a cluster or group of light emitting elements (e.g., as shown in FIG. **20**), or be any other suitable set of lightbulb components. Each controlled subset is preferably individually identified, such that it has a locally unique identifier (e.g., index value), but can alternatively

share an identifier with a second controlled subset of the lightbulb, or be otherwise identified. Each controlled subset (or the respective identifier) is preferably associated with a known, stored spatial position on the lightbulb (controlled subset position). The controlled subset position can include the arcuate position, radial position, position along an axis (e.g., along the longitudinal axis), set of coordinates, grid position, or be any other suitable position. The controlled subset positions are preferably stored by the lightbulb **100** (e.g., on volatile or non-volatile memory), but can alternatively or additionally be stored by the remote system **72**, external device **30**, or by any other suitable system.

The predetermined mode is preferably for a controlled subset, and can be associated with a set of light emitting element operation parameter values, such as values for emitted light parameters (e.g., intensity, color, collinearity, etc.), light emission duration or frequency, or any other suitable operation parameter. Operating the controlled subset in the predetermined mode can include controlling the controlled subset based on the operation parameter values or controlling the controlled subset to meet the operation parameter values. The predetermined mode for each controlled subset is preferably substantially similar in the orientation process (e.g., same brightness or intensity, same color, same dispersion, etc.), but can alternatively be different for each controlled subset. However, the operation parameter values can be otherwise used.

Examples of predetermined modes that can be used include a high emission mode, a low emission mode, a strobe mode, a user-defined mode, or be any other suitable mode. In the high emission mode (**500'**), the controlled subset can be controlled to emit substantially constant high intensity light (e.g., 100% power, over 50% power, etc.) in a wavelength detectable by a sensor or a human eye (e.g., visible light). Substantially constant light can be light that is perceived as constant by a human eye, light that oscillates at a frequency of 50 Hz or higher (e.g., when PWM is used), or be achieved in any other suitable manner. In the low emission mode, the controlled subset can remain unpowered, be controlled to emit substantially constant low intensity light, be controlled to emit non-visible or low-detectability light, or be controlled to meet any other suitable set of parameter values. In the strobe mode, the controlled subset can be controlled to switch between the high and low emission mode at a predetermined frequency. However, the orientation pattern can specify any other suitable operation mode.

The predetermined pattern can include sequentially operating adjacent controlled subsets (e.g., adjacent light emitting elements), sequentially operating the controlled subsets according to the respective index value (e.g., operating controlled subset 1, then operating controlled subset 2), randomly operating the controlled subsets, sequentially operating every other adjacent controlled subset, concurrently operating multiple controlled subsets (e.g., concurrently operating light emitting elements on a first half of the lightbulb, concurrently operating the outer ring of light emitting elements, etc.), or include any other suitable pattern of light emitting element operation. The lightbulb preferably tracks the identifier of each controlled subset being operated in the pattern and the timestamp at which the respective controlled subset is operated, but can alternatively track any other suitable orientation process parameter.

In one example, the predetermined pattern includes operating a first light emitting element in the high emission mode while operating the remainder of the light emitting elements in a low emission mode, then operating a second light emitting element adjacent the first light emitting element in the high emission mode while operating the remainder of the light emitting elements (including the first light emitting element) in a low emission mode, and repeating the process for each successive light emitting element on the entire lightbulb or lightbulb segment (e.g., perimeter). In a second example, the predetermined pattern can be substantially similar to the first example, except that instead of the second light emitting element being the light emitting element adjacent the first light emitting element, the second light emitting element can be the light emitting element located a predetermined number of light emitting elements away from the first light emitting element. In a specific example, every other light emitting element can be sequentially operated in the high emission mode. In a third example, the predetermined pattern includes concurrently operating a first plurality of light emitting elements (e.g., on a first half of the lightbulb) in a high emission mode while operating a second plurality of light emitting elements (e.g., on a second half of the lightbulb) in a low emission mode, then concurrently operating the second plurality of light emitting elements in the high emission mode while operating the first plurality of light emitting elements in the low emission mode. The first and second pluralities can be separate and distinct, overlap, or be related in any other suitable manner. However, the light emitting elements can be operated in any other suitable pattern during the orientation process.

Identifying an associative variable functions to determine a variable that can be used to link a detected signal with the controlled subset that emitted the signal. Because the position of the controlled subset on the lightbulb is known, this information can be used to determine the rotational orientation of the lightbulb relative to the external reference point.

In a first variation, the associative variable can be a timestamp. For example, a set of timestamps can be recorded and associated with a controlled subset identifier when the respective controlled subset is operated in the predetermined mode. The timestamp can subsequently be used to determine which controlled subset emitted the detected light (e.g., by an external device or the lightbulb).

In a second variation, the associative variable can be the controlled subset identifier. For example, the controlled subset identifier can be communicated as part of the signal emitted by the respective controlled subset (e.g., thorough light modulation). However, any other suitable associative variable can be used.

Determining the lightbulb position using signals emitted during the orientation process **S120** functions to determine the rotational orientation of the lightbulb, and can additionally function to determine the lightbulb location within the physical space, the lightbulb yaw, lightbulb pitch, or determine any other suitable lightbulb position parameter.

In a first variation of determining the lightbulb position using the orientation process **S120**, a device detects the signals emitted during the orientation process and determines the value of the associative variable corresponding to the detected signal. In this variation, determining the lightbulb position using signals emitted during the orientation process **S120** preferably includes measuring the incident signal with the device **S122**, determining the associative variable corresponding to an incident signal measurement of interest **S124**, determining an external reference point identifier **S126**, and associating a variable of the controlled subset identified by the associative variable with the external reference point identifier **S128**, as shown in FIG. **13**. However, the lightbulb position can be otherwise determined using signals emitted during the orientation process.

Measuring the incident signal with the device S**122** functions to measure the relative strengths of the emitted signal received at the device. The incident signal is preferably measured concurrently (e.g., during) lightbulb progression through the orientation process, but can be measured at any other suitable time. The incident signal is preferably the signal emitted by the lightbulb during the orientation process, such as light or other electromagnetic signals emitted by the lightbulb. However, any other suitable incident signal can be measured.

In a first variation, measuring the incident signal S**122** includes measuring the signal with a device is external the lightbulb (external device), as shown in FIG. **21**. The external device can be a mobile device, an appliance, a second lightbulb, or be any other suitable external device. The external device can additionally record or determine the associative variable corresponding to each measurement (e.g., record a timestamp, as shown in FIGS. **21** and **22**; determine a controlled subset identifier, as shown in FIG. **23**; etc.). In this variation, data associated with the measurements, such as raw measurements, processed measurements, measurements of interest, associative values corresponding to the measurements, or other data, can be transmitted from the external device to the system associating the controlled subset variable with the associative variable (e.g., the lightbulb **100**, remote system **72**, mobile device **70**, etc.), in variants where the external device does not perform the association. The data can be communicated through a LAN enabled by an external router, a peer-to-peer network, or through any other suitable communication channel. However, the method can be otherwise performed. In a second variation, measuring the incident signal includes measuring the signal with the lightbulb. However, the incident signal can be otherwise measured.

When the external device is a mobile device (e.g., smartphone, tablet, etc.), the mobile device, more preferably a light sensor of the mobile device (e.g., an ambient light sensor, camera, etc.) or any other suitable mobile device component, can detect the incident light emitted by the lightbulb as the lightbulb progresses through the orientation process. The mobile device can additionally record the timestamp at which each incident light measurement was recorded, determine the controlled subset identifier from the incident light, or determine any other suitable associative variable value. The external reference point identifier can be the absolute or relative geographic location of the mobile device, which can be automatically determined by the mobile device (e.g., the GPS system, cell triangulation system, beacon triangulation system, etc.), or be determined by any other suitable system. The external reference point identifier can be the location of the mobile device during the orientation process, the location of the mobile device measured while the incident light is being measured, the location of the mobile device measured within a threshold time duration of the incident light measurement, the location of the mobile device measured within a threshold time duration of light emission, the location of the mobile device measured within a threshold time duration of the orientation process, be the location of the mobile device entered by the user, or be the mobile device location measured any other suitable time.

Alternatively, the external reference point identifier can be received from a user in association with the orientation process. The external reference point identifier is preferably received from the user at the mobile device and subsequently communicated to the lightbulb or a remote system associated with the lightbulb, but can alternatively be otherwise received. The external reference point identifier can be a geographic location identifier (e.g., venue name, such as "couch," "stove," "preparation station," geographic coordinates, physical object identifier, such as "painting," etc.), an identifier for a second external device (e.g., "television," "oven," "stove," etc.), or be any other suitable identifier. The mobile device is preferably located proximal the external reference point associated with the external reference point identifier when the mobile device detects the incident light, but can alternatively be arranged in another location.

When the external device is an appliance, the appliance, more preferably a light sensor or camera of the appliance but alternatively any other suitable component, can measure the incident signal emitted by the lightbulb as the lightbulb progresses through the orientation process. The appliance can be substantially static (e.g., be a fixture), or can be mobile. The appliance can be a connected appliance having wired or wireless communication capabilities, or be disconnected. Examples of appliances include televisions, ovens, or other fixtures. The appliance can record the timestamp at which each incident light measurement was recorded, determine the controlled subset identifier from the incident light, or determine any other suitable associative variable value. The external reference point identifier can be the appliance identifier (e.g., a descriptor, such as "television 1," an SKU number, a user-specified identifier, or be any other suitable identifier), an example of which is shown in FIG. **23**; an appliance geographical location (entered by the user or automatically determined by the appliance); or be any other suitable identifier.

When the external device is a second lightbulb, the second lightbulb, more preferably a light sensor or camera of the second lightbulb but alternatively any other suitable component, can measure the incident signal emitted by the first lightbulb as the first lightbulb progresses through the orientation process. The second lightbulb is preferably arranged within the same physical space as the first lightbulb, more preferably connected to the same sub-circuit as the first lightbulb, but can alternatively be arranged in any other suitable position. The first and/or second lightbulbs can determine whether they are on the same sub-circuit based on the power provision time, based on whether they can communicate with each other using short-range communication protocols, or determine that they are on the same sub-circuit in any other suitable manner.

As shown in FIG. **22**, the second lightbulb preferably measures the incident signal at a sensor located on-board the second lightbulb, but can otherwise measure the incident signal. The sensor can be an ambient light sensor (e.g., wherein the signal is light), a microphone (e.g., wherein the signal is sound), or be any other suitable sensor. In one variation in which the second lightbulb light sensor is enclosed within the lightbulb by the diffuser, the second lightbulb is preferably operated in the low emission mode during the orientation process to prevent measurement contamination by secondary light emitted by the second lightbulb. Alternatively, the second lightbulb can operate all or a subset of its light emitting elements in the high emission mode and automatically correct for the measurement contamination. In a second variation in which the second lightbulb light sensor is exposed, the second lightbulb can be operated in any suitable mode. The second lightbulb preferably includes a plurality of sensors, but can alternatively include a single sensor or a pair of sensors. Each sensor can be associated with a sensor identifier and a sensor position on the lightbulb. The sensor positions (spatial orientations) on the second lightbulb are preferably fixed, known, and stored.

The second lightbulb can record the timestamp at which each incident signal measurement was recorded, determine

the controlled subset identifier from the incident signal, or determine any other suitable associative variable value. The external reference point identifier can be the second lightbulb identifier, an identifier for a sensor of the second lightbulb (sensor identifier), a second lightbulb geographical location (entered by the user or automatically determined by the second lightbulb), or be any other suitable identifier. In one example, the second lightbulb includes a plurality of light sensors arranged in fixed, known positions on the lightbulb, wherein the external reference point identifier can be the identifier for the sensor that measured the brightest incident light emitted by the first lightbulb.

Additionally or alternatively, as shown in FIG. **22**, the second lightbulb can determine its position relative to the first lightbulb. This can enable the first lightbulb to know the angular position of the second lightbulb relative to the first lightbulb, and enable the second lightbulb to know the angular position of the first lightbulb relative to the second lightbulb. In one variation, the second lightbulb can determine which of its sensors is most proximal the first lightbulb. The sensor most proximal the first lightbulb can be the sensor that measured the brightest incident light, the sensor that measured incident light for the longest time duration or for the highest number of controlled subset operations, or be characterized in any suitable manner. In a second variation, the second lightbulb can triangulate the relative position of the first lightbulb based on the stereovision. However, the position of the second lightbulb relative to the first lightbulb can be otherwise determined.

In a second variation, measuring the incident signal S**122** includes measuring the signal with the lightbulb, such that the lightbulb can subsequently automatically determine its own position. The lightbulb can emit the light during the orientation process, measure the light reflected off of adjacent surfaces, and automatically determine its position relative to adjacent surfaces based on the incident light. In this variation, the lightbulb preferably includes one or more sensors that measure the reflected light. The sensors are preferably arranged on the lightbulb exterior (e.g., to prevent light measurement contamination), but can alternatively be arranged behind the diffuser or be otherwise arranged. The lightbulb can determine the relative distance of the adjacent surface (e.g., based on the intensity of the reflected light), the curvature of the adjacent surface, the material of the adjacent surface, or determine any other suitable parameter of the adjacent surface. The lightbulb can additionally coordinate with adjacent lightbulbs, such that two adjacent lightbulbs are not concurrently operated in the orientation mode (e.g., to prevent measurement interference). However, the lightbulb can otherwise automatically determine its position relative to adjacent surfaces.

Determining the associative variable corresponding to an incident signal measurement of interest S**124** functions to identify the controlled subset (indexing controlled subset) that is spatially related to the external reference point. The incident signal measurement of interest can be the strongest incident signal measured during the orientation process (e.g., brightest or most intense measured light), weakest incident signal measured during the orientation process (e.g., dimmest or least intense measured light), the signal measurement having a value exceeding a threshold value (e.g., measuring light over threshold intensity), or be any other measurement having signal parameters of interest. The associative variable preferably corresponds to the signal measurement of interest, but can be any other associative variable. The associative variable can be a timestamp (e.g., a recordation timestamp at which the incident signal is measured, etc.), a controlled subset identifier, or be any other suitable associative variable. The signal measurement of interest and/or corresponding associative variable can be determined by the device, by the remote system, by the lightbulb, or by any other suitable system. When the signal measurement and/or corresponding associative variable is not determined by the device, the device preferably communicates the measurements (raw or processed) to the processing system. In one example, the timestamp at which the measured incident light exceeds a threshold intensity is identified as the recordation timestamp of interest. The threshold intensity can be determined based on the intensity of the emitted light (e.g., be more than 80% of the emitted light intensity, substantially match the emitted light intensity, etc.), the ambient light intensity prior to orientation process initiation, or based on any other suitable variable value.

Determining an external reference point identifier S**126** functions to determine an identifier that can be subsequently used to identify the external reference point, such as for context-related illumination. The external reference point identifier can be received from a user, automatically determined by the device, automatically determined by the lightbulb, or be otherwise determined. The external reference point identifier can be a geographic location, a label, a device identifier, or be any other suitable identifier of the external reference point.

Associating the variable of the controlled subset, identified by the associative variable, with the external reference point identifier S**128** functions to spatially relate a lightbulb reference point with the external reference point. The association is preferably stored for use in contextual control. The association can be stored by the lightbulb, remote system, mobile device, or other system. The lightbulb preferably determines which controlled subset is identified by the associative variable, but the controlled subset can alternatively be determined by a remote system, the external device, or by any other suitable system. The recordation associative variable (measured by the external device) corresponding to the signal measurement of interest is preferably matched or otherwise correlated with an orientation associative variable (recorded by the lightbulb during the orientation process), wherein the controlled subset that emitted signals corresponding to the orientation associative variable is preferably the controlled subset associated with the external reference point. In one example, the associative variable is a timestamp. The recordation timestamp corresponding to the brightest light measured by the external device is substantially matched (e.g., matched within a time duration margin of error, such as 0.5 s, 2 milliseconds, or any other suitable time duration margin of error, to accommodate for signal travel time or signal transmission time from the lightbulb to the external device, etc.) to the origination timestamp, wherein the LED that was lit during the origination timestamp can be the controlled subset for which variables are associated with the external reference point. The controlled subset that is associated with the external reference point can be the controlled subset that is proximal (or most proximal) the identified external reference point, but can alternatively be the controlled subset that is distal (or most distal) the identified external reference point or be the controlled subset positioned in a predetermined orientation relative to the external reference point.

The controlled subset variable is preferably associated with an angular position on the lightbulb, such that an angular position of the lightbulb is associated with the external reference point. However, the controlled subset variable can be associated with any other suitable parameter. The controlled subset variable can be the controlled subset identifier, the controlled subset position on the lightbulb, the position of the

controlled subset relative to a reference point on the lightbulb (e.g., a notch position), or be any other suitable variable of the controlled subset. The controlled subset variable is preferably stored in association with the external reference point identifier, but can alternatively be otherwise associated with the external reference point identifier. In one example, the fifth indexed LED is associated with a television when the brightest light emitted by the lightbulb, as determined by the television, was emitted by the fifth indexed LED.

In this variation, the method can additionally include determining the absolute location of the lightbulb within a physical space. For example, the position of the lightbulb can be determined based on the angle of the incident light at the mobile device, the incident light parameters (e.g., phase and intensity), the heading of the mobile device (e.g., based on a digital compass), and the angular orientation of the mobile device relative to a gravity vector (e.g., based on the accelerometer). The mobile device parameters can be used to determine the location and orientation of the mobile device, the incident light angle can be used to determine the angular position and direction of the lightbulb relative to the mobile device, and the phase and/or intensity difference between the emitted light and measured light can be used to determine the distance of the lightbulb away from the mobile device. The phase and/or intensity differences can additionally or alternatively be used to determine the yaw, pitch, or other orientation parameter of the lightbulb. Alternatively, these lightbulb orientation parameters can be determined by lightbulb sensors, cooperatively determined by the lightbulb and signals measured by the external device, or otherwise determined.

In a second variation of determining the lightbulb position by leveraging the orientation process S**120**, the lightbulb position is pseudo-manually determined. In this variation, the user can control which controlled subset is lit during the orientation process, and manually associate an external reference point identifier with the lit controlled subset. The method can include receiving a control instruction from a device associated with a user S**121** (e.g., through a logged in user account), controlling the lightbulb based on the control instructions S**123**, detecting a controlled subset selection event S**125**, receiving an external reference point identifier S**127***a* (and/or context label S**127***b*), and associating variable(s) of the selected controlled subset(s) with the external reference point identifier S**129***a* (or context label S**129***b*), as shown in FIG. **14**. For example, individual controlled subsets (e.g., light emitting elements) of the lightbulb can be sequentially lit (example of S**123**) as the user scrolls through a complimentary lightbulb representation on the user interface of a mobile device (example of S**121**) (e.g., by entering a control instruction, such as a light control vector, which can be linear, arcuate, or have any other suitable shape). As shown in FIG. **18**, the direction that the controlled subsets are sequentially lit (clockwise or counterclockwise) is preferably determined based on the orientation of the lightbulb relative to a gravity vector, but can be otherwise determined. The orientation of the lightbulb relative to a gravity vector is preferably determined by the orientation sensor of the lightbulb (e.g., accelerometer, gyroscope, etc.), but can be otherwise determined. In response to the lightbulb diffuser being arranged below the base (e.g., when the lightbulb is downward facing), receipt of a clockwise control instruction (e.g., clockwise control vector) can control sequential light emitting elements to be lit in a counterclockwise pattern (e.g., sequentially lit to the left) when viewed end-on from the diffuser. In response to the lightbulb diffuser being arranged above the base (e.g., when the lightbulb is upward facing), receipt of a clockwise control instruction (e.g., clockwise control vector) can control sequential light emitting elements to be lit in a clockwise pattern (e.g., sequentially lit to the right) when viewed end-on from the diffuser. Receipt of a counterclockwise control vector can control the light emitting elements to be lit in the opposite manner. However, the lightbulb orientation relative to a gravity vector can be otherwise accommodated.

When one or more controlled subsets have been selected (e.g., when the user halts control instruction input; when a position confirmation, such as selection of a corresponding controlled subset representation, is received; etc.), the user can enter an external reference point identifier (example of S**127***a*), such as a label (e.g., "painting," "wall," "television," etc.), geographic location, or any other suitable external reference point identifier that will subsequently be associated with the selected controlled subsets. Alternatively, the user can enter a context label (example of S**127***b*), such as "night," "party," or any other suitable contextual label. This can function to store the selected lightbulb parameters (e.g., the parameters of the light emitting elements at the time the context label is received) in association with the context or context label, such that subsequent detection of the respective context can cause the lightbulb to emit light at substantially the same parameters as those selected during the orientation process. The method can additionally include verifying or confirming the selected controlled subsets. For example, the mobile device can verify that the emitted light is being received at the mobile device location using the ambient light sensor of the mobile device. In another example, the mobile device can be controlled to display a query, requesting the user to verify that the emitted light is illuminating the desired illumination target. However, the controlled subset selection can be otherwise verified.

In a specific example, as shown in FIG. **19**, the user can additionally specify the number of lit light emitting elements (e.g., by entering the number, dragging two fingers apart on the lightbulb representation, etc.), rotate the lit set of light emitting elements about the lightbulb until the lit set of light emitting elements illuminate a desired illumination target (e.g., television, wall, table), and enter a descriptor for the illuminated target (e.g., "television," "wall," "table," respectively), which functions as the external reference point identifier. The external reference point identifier can be stored in association with the controlled subset variable (e.g., position, identifier, etc.) of the selected controlled subset. However, the lightbulb position can be otherwise determined using the orientation process.

In a second variation, determining the lightbulb position includes scanning or imaging the lightbulb environment. The lightbulb environment can be scanned by a LIDAR system, imaged by a camera system, or otherwise recorded. The lightbulb environment can be scanned with an optical sensing system on the lightbulb or with an external optical sensing system. When the latter is used, the scanned coordinates are preferably transformed to lightbulb coordinates. However, the data can be otherwise used. Environmental features, such as walls, furniture, or other fixtures, can be determined based on the images. However, the lightbulb position can be determined using a digital compass (e.g., wherein the lightbulb position relative to external features can be determined based on a virtual map), or be determined in any other suitable manner.

The method can additionally include detecting a contextual event S**200**, identifying a spatial lighting pattern associated with the contextual event S**300**, and controlling the lightbulb based on the spatial lighting pattern S**400**. This enables the lightbulb population to selectively create context-based light-

ing scenes. For example, as shown in FIG. **15**, the lightbulb can selectively highlight the couch during a reading context, and direct light behind the couch during a television or movie watching context.

Detecting a contextual event S**200** functions to identify a set of event parameters for which lighting is needed. The contextual event can be supply of power to the lightbulb, user entry into a room, receipt of a startup signal from an appliance, receipt of a context selection, or detection of any other suitable contextual event. User entry into a room can be determined when a mobile device associated with the user wirelessly connects to the lightbulb (e.g., via NFC) or a local area network (LAN). The LAN can be enabled by an external device (e.g., an external router), enabled by the lightbulb or population of lightbulbs (e.g., a Bluetooth network, mesh network, etc.), or be enabled by any other suitable device. Alternatively, user proximity to the lightbulb can be detected by an external device (e.g., a camera, an appliance, etc.), or be detected in any other suitable manner.

Determining a spatial lighting pattern associated with the contextual event S**300** functions to identify the target illumination scenes or lightbulb operation parameters associated with the context. The spatial lighting pattern **40** can be received from a remote system, retrieved from lightbulb storage, received from a mobile device, or be determined in any other suitable manner. The spatial lighting pattern **40** include a set of operation parameters for each lightbulb within the physical space, a set of operation parameters for each light emitting element, a set of specified illumination targets (e.g., by a previously associated external reference point identifier; by a virtual location in 3D virtual space, as shown in FIG. **24**; etc.), a set of illumination parameters for a specified illumination target (e.g., wherein the lightbulb population cooperatively illuminates the illumination target with the illumination parameters, wherein the lightbulb population or other system can determine the operation parameters for each lightbulb to achieve the effect), or include any other suitable set of operation parameters. The spatial lighting pattern **40** can be automatically determined by the plurality of lightbulbs; previously or currently received from a user, user account, or mobile device; be a predetermined pattern associated with the contextual event or selected by a user; be a pattern determined from user population preferences; or be determined in any other suitable manner. In a first example, the user can select a "reading" context, where the lightbulb population can spotlight a region proximal the user mobile device, spotlight a pre-specified reading area, or interact with the physical space in any other suitable manner. In a second example, the user can individually rotate the lit light emitting elements on each lightbulb to illuminate the illumination target. However, the spatial lighting pattern **40** can be otherwise determined.

Controlling the lightbulb based on the spatial lighting pattern S**400** functions to execute the spatial lighting pattern. Controlling the lightbulb based on the spatial lighting pattern can include controlling individual light emitting elements based on the spatial lighting pattern and the association between the controlled subset variable and the external reference point. In one example, the lightbulb can automatically illuminate an illumination target, given the illumination target position relative to the external reference point or relative to the indexing controlled subset. The relative position between the target and the reference point can be automatically determined, determined in a virtual 3D space, determined by a mobile device, determined based on the communication signal strength and/or direction between the external reference point and the illumination target, or be otherwise determined. In a specific example, when the illumination target is the external reference point, the controlled subsets associated with the external reference point can be operated to illuminate the target. In a second specific example, when the illumination target is a given number of degrees away from the external reference point, the controlled subsets positioned the number of degrees away from the indexing controlled subset on the lightbulb in the same direction can be operated to illuminate the target. However, the lightbulb can be otherwise controlled. In a third specific example, when the illumination target is a second geographic location, a second lightbulb proximal the second geographic location can be selected and operate to illuminate the target location, region, or volume.

In one example of the method, the lightbulbs track the user, more specifically the user mobile device, in response to mobile device connection to a short-range communication system of the lightbulb (e.g., beacon, Bluetooth, etc.). In this example, the method selectively controls individual light emitting elements to direct light toward the mobile device physical position, based on the mobile device position and the physical light emitting element position corresponding to the stored light emitting element identifier. The method can include cooperatively identifying a mobile device position relative to a first and second lightbulb, generating control instructions for the first and second lightbulbs based on the mobile device position; and controlling the first and second lightbulbs based on the control instructions. Identifying the mobile device position relative to a first and second lightbulb can include determining the mobile device position through trilateration, receiving the location from the mobile device, determining the mobile device position based on first and second signals emitted by the first and second lightbulbs and received at the mobile device, or be determined in any other suitable manner. In one variation, as shown in FIG. **25**, identifying a mobile device position relative to the first and second lightbulbs through trilateration includes: emitting a first nonvisual signal from the first lightbulb; emitting a second nonvisual signal from the second lightbulb; detecting the first and second nonvisual signals at the mobile device; determining the mobile device position based on the received first and second nonvisual signals at the mobile device; generating control instructions for the first and second lightbulbs based on the mobile device position (e.g., based on the position of the mobile device relative to the position of the indexing controlled subsets on the lightbulbs); and controlling light emitting elements proximal the mobile device to cooperatively illuminate the physical region proximal the mobile device. The method can additionally include verifying that the emitted light illuminates the region using the ambient light sensor on the mobile device, and can additionally include adjusting the parameters of the emitted light (e.g., increase or decrease brightness) based on the measured incident light. This verification or adjustment can be performed when the mobile device is in one of a limited set of positions (e.g., horizontal, etc.), be performed at any time, or not be performed at all.

In a second example of the method, as shown in FIG. **15**, the spatial lighting pattern backlights the couch, such as when a user is watching the television or watching a movie. In this example, the spatial lighting pattern specifies high emissivity light directed away from the external device (e.g., the television), wherein selectively controlling individual light emitting elements based on the spatial lighting pattern includes operating the light emitting element physically opposing the indexing controlled subset across the lightbulb in the high emission mode (e.g., when the external reference point was the television, and the indexing controlled subset emitted the

brightest lights measured by the television). However, a physical region can be otherwise targeted.

As shown in FIG. **11**, the method can additionally include resetting the spatial orientation of the lightbulb in response to detection of a reset event S**500**. This can function to identify when the lightbulb has been moved, such that the lightbulb position within the physical space should be redetermined. The reset event can be detection of a reset switch toggle (e.g., when the lightbulb reset switch is in a different position than a stored position), actuation of a contact button arranged in or proximal the lightbulb base, detection of lightbulb acceleration above threshold acceleration (e.g., 0.5 m/s^2), determination that a second lightbulb's signal is being received at a different sensor of the first lightbulb than that previously receiving the second lightbulb's signal, receipt of a notification from a user device, or be any other suitable reset event. Resetting the spatial orientation of the lightbulb can include re-determining the position of the lightbulb relative to a physical space, such as by initiating the orientation process for the lightbulb. The method can additionally include erasing the previously stored orientation.

An alternative embodiment preferably implements the above methods in a computer-readable medium storing computer-readable instructions. The instructions are preferably executed by computer-executable components preferably integrated with a directional lighting system. The directional lighting system can include an angular orientation system configured to determine the angular position of a directional lighting system reference point relative to an external reference point; a context identification system configured to determine the occurrence of a contextual event; and a directional control system configured to identify an illumination target based on the contextual event, determine the illumination target angular position relative to the directional lighting system reference point and/or the external reference point, and select and control light emitting elements on the directional lighting system to illuminate the target. The computer-readable medium may be stored on any suitable computer readable media such as RAMs, ROMs, flash memory, EEPROMs, optical devices (CD or DVD), hard drives, floppy drives, or any suitable device. The computer-executable component is preferably a processor but the instructions may alternatively or additionally be executed by any suitable dedicated hardware device.

Although omitted for conciseness, the preferred embodiments include every combination and permutation of the various system components and the various method processes.

As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

We claim:

1. A method for spatial orientation determination for a lightbulb, the lightbulb including a plurality of indexed light emitting elements, the method comprising:

progressing the lightbulb through an orientation pattern, comprising:

sequentially transitioning individual light emitting elements of the lightbulb from a low emission mode, to a high emission mode, to the low emission mode, wherein each light emitting element is fixed at an angular light emitting element position on the lightbulb and is associated with a light emitting element identifier;

recording an origination timestamp for each light emitting element identifier during lightbulb progression through the orientation pattern, each timestamp corresponding to operation of the respective light emitting element in the high emission mode;

receiving, from an external device, data associated with measurements of light emitted by the lightbulb during lightbulb progression through the orientation pattern, wherein each measurement is associated with a recordation timestamp;

identifying the light emitting element identifier corresponding to an origination timestamp, the origination timestamp within a threshold time duration of a recordation timestamp, the recordation timestamp corresponding to a brightest light measurement as determined from the data; and

storing the light emitting element identifier in association with an identifier for the external device.

2. The method of claim **1**, wherein receiving data from the external device comprises receiving data at the lightbulb through a local area network.

3. The method of claim **1**, wherein the lightbulb automatically controls lightbulb progression through the orientation pattern, identifies the light emitting element corresponding to the origination timestamp, and stores the light emitting element identifier.

4. The method of claim **3**, wherein a remote computing system receives the data from the external device and determines the recordation timestamp corresponding to the brightest light measurement from the data, wherein the remote computing system sends the recordation timestamp to the lightbulb.

5. The method of claim **1**, wherein the data comprises incident light intensity measurements.

6. The method of claim **5**, wherein the external device comprises a second lightbulb, the second lightbulb comprising a plurality of individually controllable light emitting elements and an ambient light sensor, wherein the method further comprises:

operating all light emitting elements of the second lightbulb in the low emission mode concurrently with first lightbulb progression through the orientation pattern;

recording incident light, emitted by the first lightbulb, at a plurality of timestamps by the second lightbulb concurrently with first lightbulb progression through the orientation pattern;

determining the origination timestamp corresponding to a brightest incident light recorded by the second lightbulb prior to identification of the light emitting element corresponding to the origination timestamp; and

wherein storing the light emitting element identifier in association with an identifier for the external device comprises: associating the second lightbulb with an angular position on the first lightbulb, the angular position corresponding to an angular position of a first light emitting element of the first lightbulb, wherein the first light emitting element is identified by the light emitting element identifier associated with the high emission mode timestamp that substantially matches the origination timestamp.

7. The method of claim **6**, wherein the second lightbulb comprises a plurality of light sensors arranged in known, fixed angular positions on the second lightbulb, wherein recording incident light by the second lightbulb comprises:

measuring incident light emitted by the first lightbulb at the plurality of light sensors; and

storing the incident light measurements in association with an identifier for the respective light sensor and a respective measurement timestamp; and

wherein the method further comprises:

identifying the light sensor that recorded with the brightest incident light;

associating the first lightbulb with an angular position of the identified light sensor.

8. The method of claim **6**, further comprising:

detecting a mobile device wirelessly connecting to the lightbulb;

identifying a spatial lighting pattern, comprising tracking the mobile device, that is associated with detecting the mobile device wirelessly connecting with the lightbulb, wherein tracking the mobile device comprises cooperatively identifying a mobile device position relative to the first and second lightbulbs; and

selectively controlling individual light emitting elements to direct light toward the mobile device position, based on the mobile device position and the angular light emitting element position corresponding to the stored light emitting element identifier.

9. The method of claim **8**, wherein identifying a mobile device position relative to the first and second lightbulbs comprises: identifying a mobile device position relative to the first and second lightbulbs through trilateration, comprising:

emitting a first nonvisual signal from the first lightbulb;

emitting a second nonvisual signal from the second lightbulb;

detecting the first and second nonvisual signals at the mobile device;

determining the mobile device position based on the first and second nonvisual signals at the mobile device;

generating control instructions for the first and second lightbulbs based on the mobile device position; and

controlling the first and second lightbulbs based on the control instructions.

10. The method of claim **1**, further comprising:

detecting a contextual event;

identifying a spatial lighting pattern associated with the contextual event; and

selectively controlling individual light emitting elements based on the spatial lighting pattern and the angular light emitting element position corresponding to the stored light emitting element identifier.

11. The method of claim **10**, wherein identifying the spatial lighting pattern comprises receiving the spatial lighting pattern from a remote computing system.

12. The method of claim **10**, wherein the spatial lighting pattern comprises high emissivity light directed away from the external device, wherein selectively controlling individual light emitting elements based on the spatial lighting pattern comprises operating the light emitting element physically opposing the identified light emitting element across the lightbulb in the high emission mode.

13. The method of claim **12**, wherein the external device comprises a connected home appliance, wherein detecting the contextual event comprises receiving a startup signal from the home appliance.

14. The method of claim **10**, wherein the identifier for the external device comprises a geographic location for the external device, wherein the spatial lighting pattern comprises directing light toward a second geographic location, wherein selectively controlling individual light emitting elements based on the spatial lighting pattern comprises:

identifying a second light emitting element of the lightbulb proximal the second geographic location, based on the position of the external device geographic location relative to the second geographic location; and

operating the second light emitting element based on lighting parameters specified by the spatial lighting pattern.

15. A method for lightbulb rotational orientation, comprising:

operating an individual light emitting element set in a high emission mode and operating a remainder of the light emitting elements in a low emission mode;

receiving a light control instruction from an external device, the light control instruction comprising a light control vector;

controlling sequential light emitting elements along the light control vector to operate in the high emission mode; and

storing an identifier for the light emitting element in association with a physical position indicator associated with the external device.

16. The method of claim **15**, wherein controlling sequential light emitting elements along the light control vector to operate in the high emission mode comprises:

determining a gravitational orientation of the lightbulb based on an orientation measurement of an orientation mechanism of the lightbulb;

in response to lightbulb gravitational orientation in a first direction, sequentially lighting individual light emitting element sets to the right of the first light emitting element set based on the light control vector; and

in response to lightbulb gravitational orientation in a second direction opposing the first, sequentially lighting individual light emitting element sets to the left of the first light emitting element set based on the light control vector.

17. The method of claim **15**, wherein the external device comprises a mobile device that transmits the light control instruction to the lightbulb, the mobile device comprising a global positioning system, wherein storing an identifier for the light emitting element in association with a physical position indicator associated with the external device comprises storing the identifier for the light emitting element in association with a physical geographic location recorded by the global positioning system within a threshold time period of light control instruction transmission to the lightbulb.

18. The method of claim **15**, further comprising:

detecting a contextual event;

identifying a spatial lighting pattern associated with the contextual event; and

selectively controlling individual light emitting elements based on the spatial lighting pattern and a physical position of the light emitting element corresponding to the stored light emitting element identifier on the lightbulb.

19. The method of claim **15**, wherein:

storing an identifier for the light emitting element in association with a physical position indicator associated with the external device comprises: receiving the physical position indicator from the external device, wherein the physical position indicator is an identifier for a second external object;

the spatial lighting pattern comprises instructions to direct light having a predetermined set of light parameters toward the second external object; and

selectively controlling individual light emitting elements based on the spatial lighting pattern comprises controlling the light emitting element identified by the light emitting element identifier stored in association with the second external object identifier to emit light having the predetermined set of light parameters.

20. A lightbulb comprising:

a substrate;

a plurality of individually controlled light emitting elements mounted in fixed, predetermined positions on the substrate;

a plurality of light sensors mounted to the substrate;

a wireless communication module;

a diffuser enclosing the light emitting elements, light sensors, and wireless communication module within the lightbulb; and

a processor electrically connected to each light emitting element, light sensor, and the wireless communication module, the processor configured to:

index each light emitting element;

progress the each of the plurality of light emitting elements through an orientation pattern;

associate a reference point on the lightbulb with an external reference point; and

selectively operate individual light emitting elements of the plurality according to lighting instructions, based on a relationship between the reference point on the lightbulb and the external reference point.

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