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Cherney et al.

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(54) **PEDESTRIAN WARNING WITH LIGHT SPECTRUM THAT DOES NOT AFFECT CAMERA BASED OBJECT DETECTION AT NIGHT**

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B60Q 1/52	(2006.01)
B60Q 5/00	(2006.01)
E02F 9/26	(2006.01)
G06V 20/58	(2022.01)

(52) **U.S. Cl.**

CPC ***B60Q 1/525*** (2013.01); ***B60Q 1/52*** (2013.01); ***B60Q 5/006*** (2013.01); ***E02F 9/261*** (2013.01); ***G06V 20/58*** (2022.01); *B60Q 2800/20* (2022.05); *G06V 2201/07* (2022.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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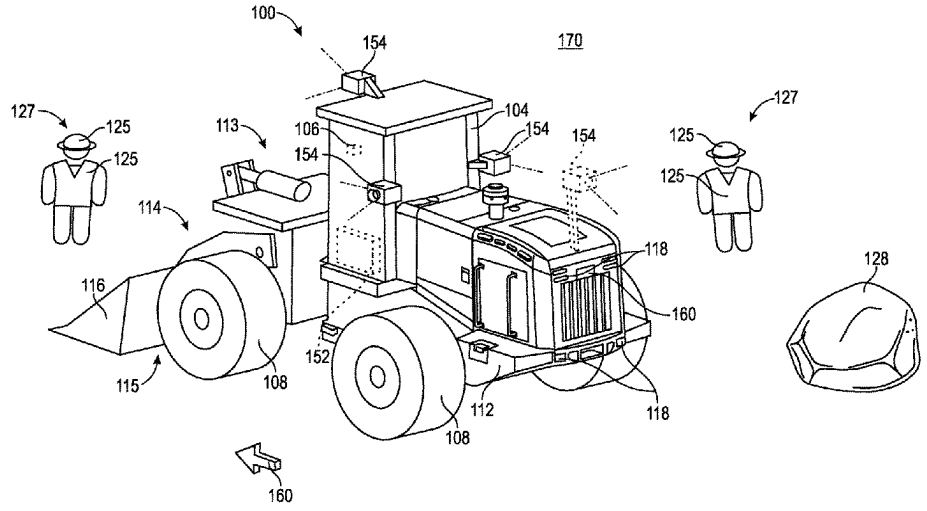
(57) **ABSTRACT**

A pedestrian warning system for a work vehicle at a worksite that includes a sensor system that captures images of an identified target located at the worksite. An electronic data processor is communicatively coupled to the sensor system, and the electronic data processor determines whether the identified target from the captured image is an intended target based on one or more identifying characteristics associated with the identified target. When the intended target is identified, an alert directed to the intended target is generated that includes operation of one or more lights mounted on the work vehicle. The one or more lights operate in a light spectrum range that is not visible by the sensor system. The sensor system may include an optical filter to block light that corresponds to the light spectrum range of the one or more lights. The lights may operate in a strobing function.

20 Claims, 6 Drawing Sheets



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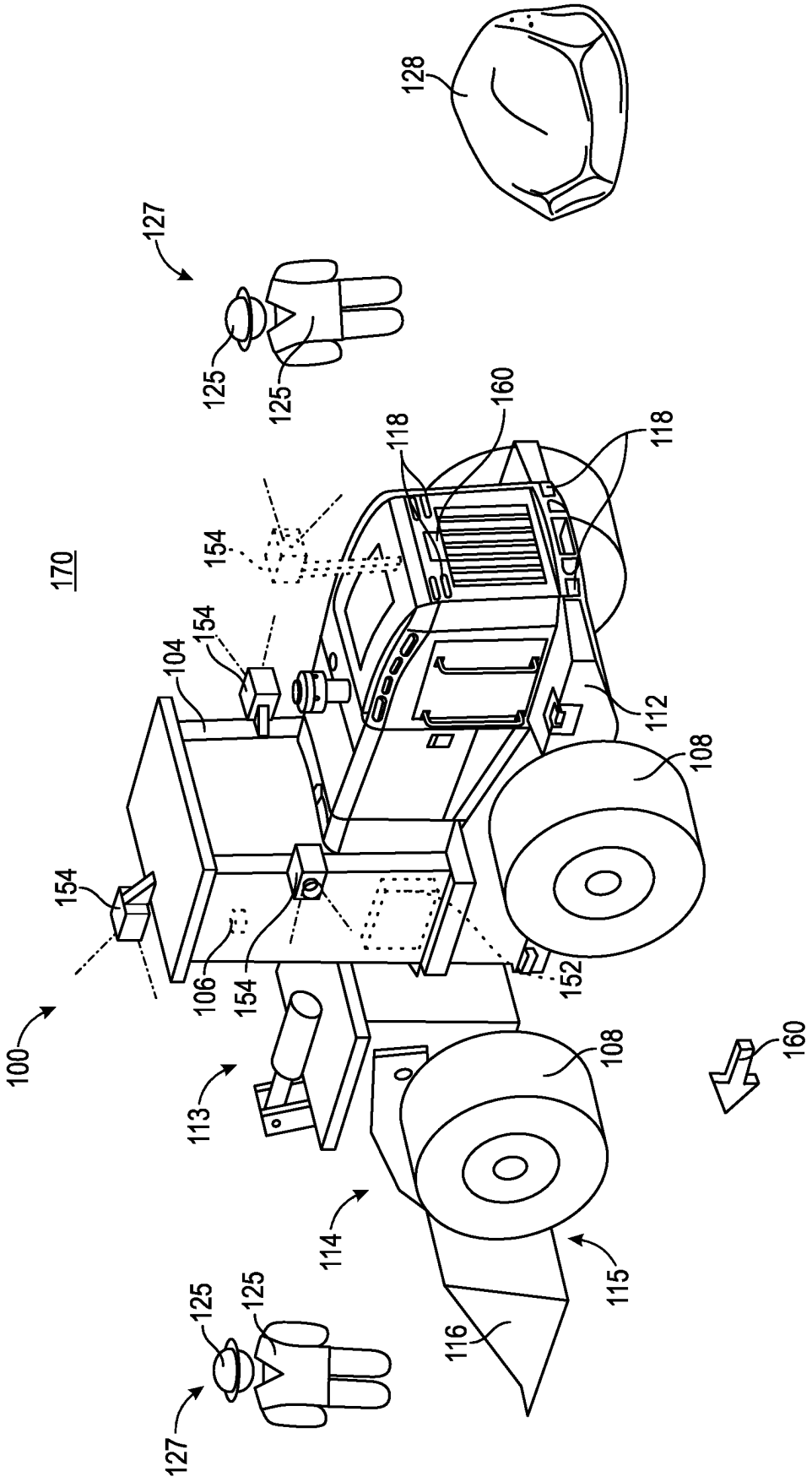
128
127
125
125
160
118
118
154
170
154
104
112
108
154
106
154
152
100
113
108
160
114
115
125
125
116
127

FIG. 1

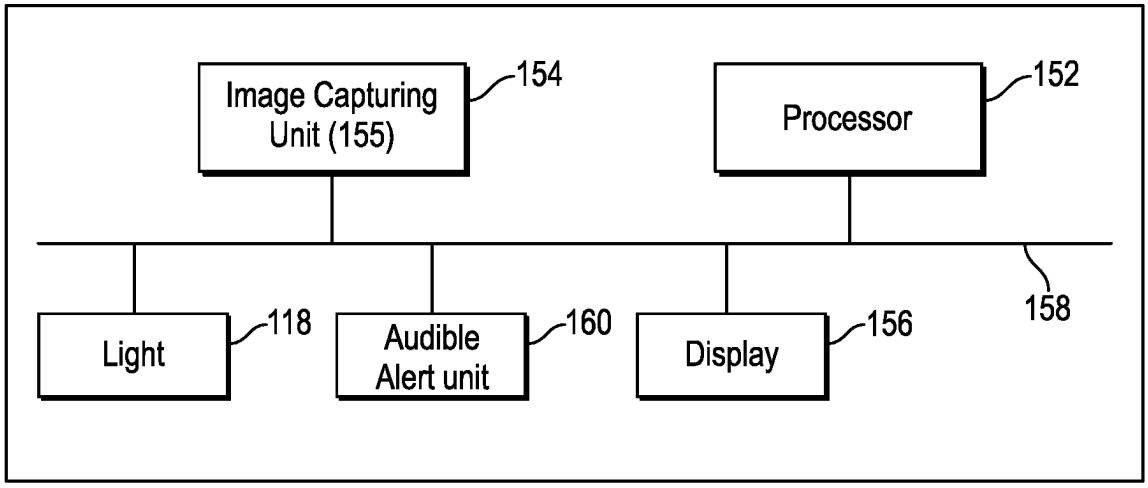
Image Capturing Unit (155)
154
Processor
152
158
Light
118
Audible Alert unit
160
Display
156

FIG . 2

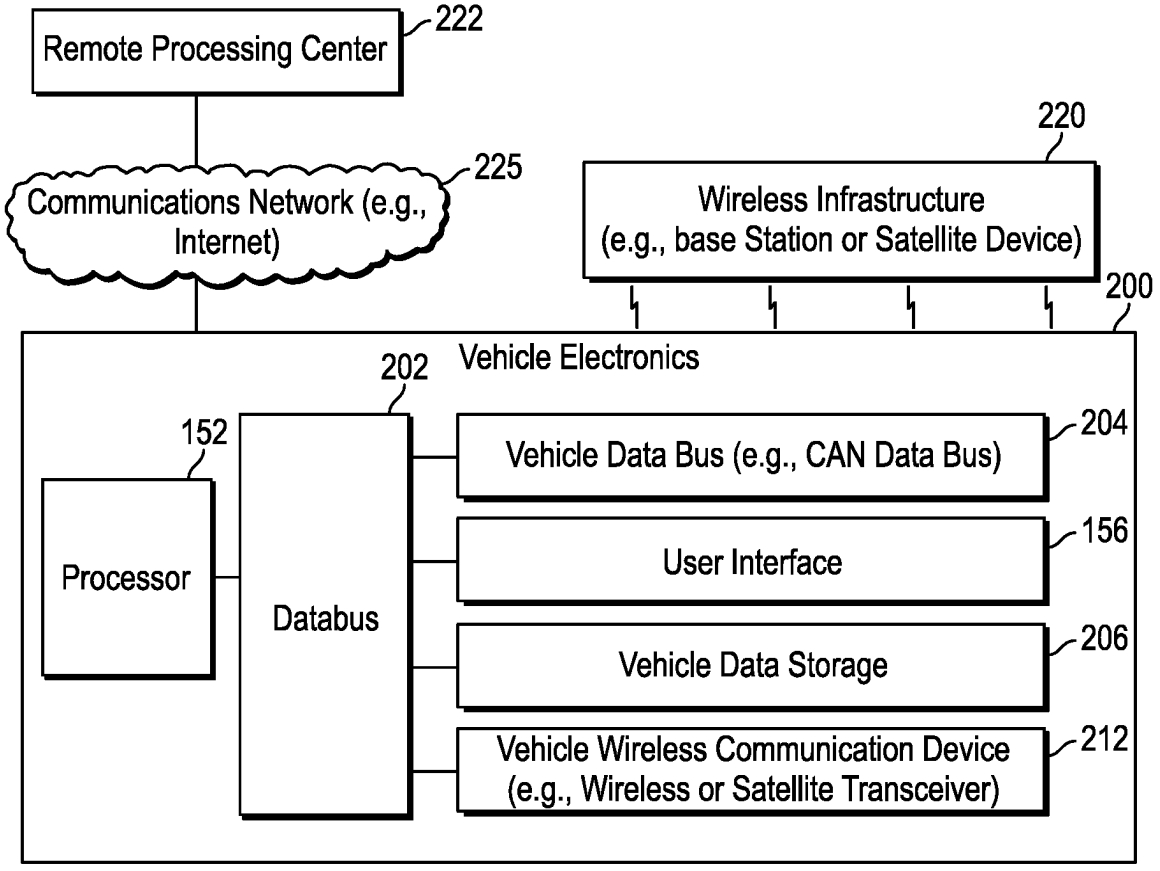
Remote Processing Center
222
Communications Network (e.g., Internet)
225
220
Wireless Infrastructure (e.g., base Station or Satellite Device)
200
Vehicle Electronics
202
152
Processor
Databus
Vehicle Data Bus (e.g., CAN Data Bus)
204
User Interface
156
Vehicle Data Storage
206
Vehicle Wireless Communication Device (e.g., Wireless or Satellite Transceiver)
212

FIG . 3

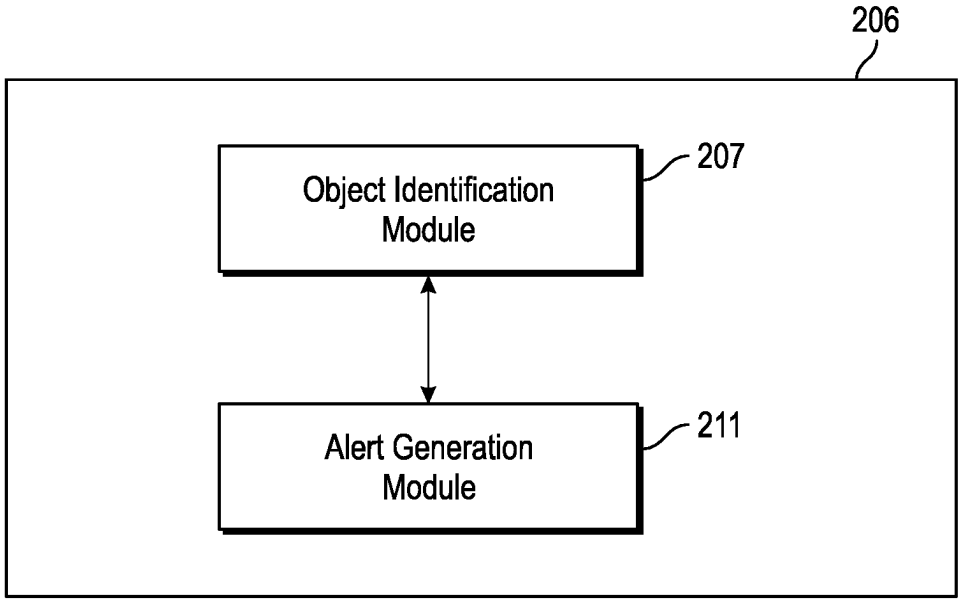
206
Object Identification Module
207
Alert Generation Module
211

FIG . 4

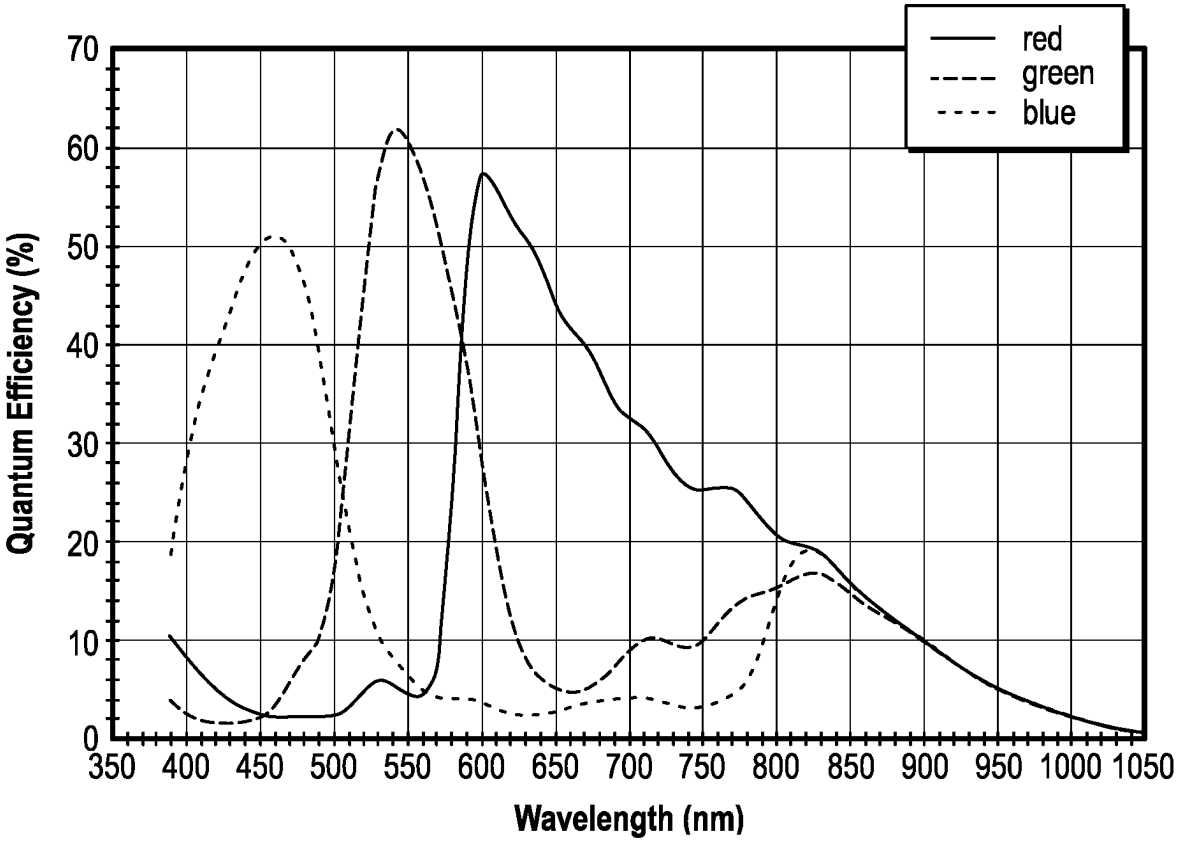
red
green
blue
Quantum Efficiency (%)
0
10
20
30
40
50
60
70
350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050
Wavelength (nm)

FIG . 5

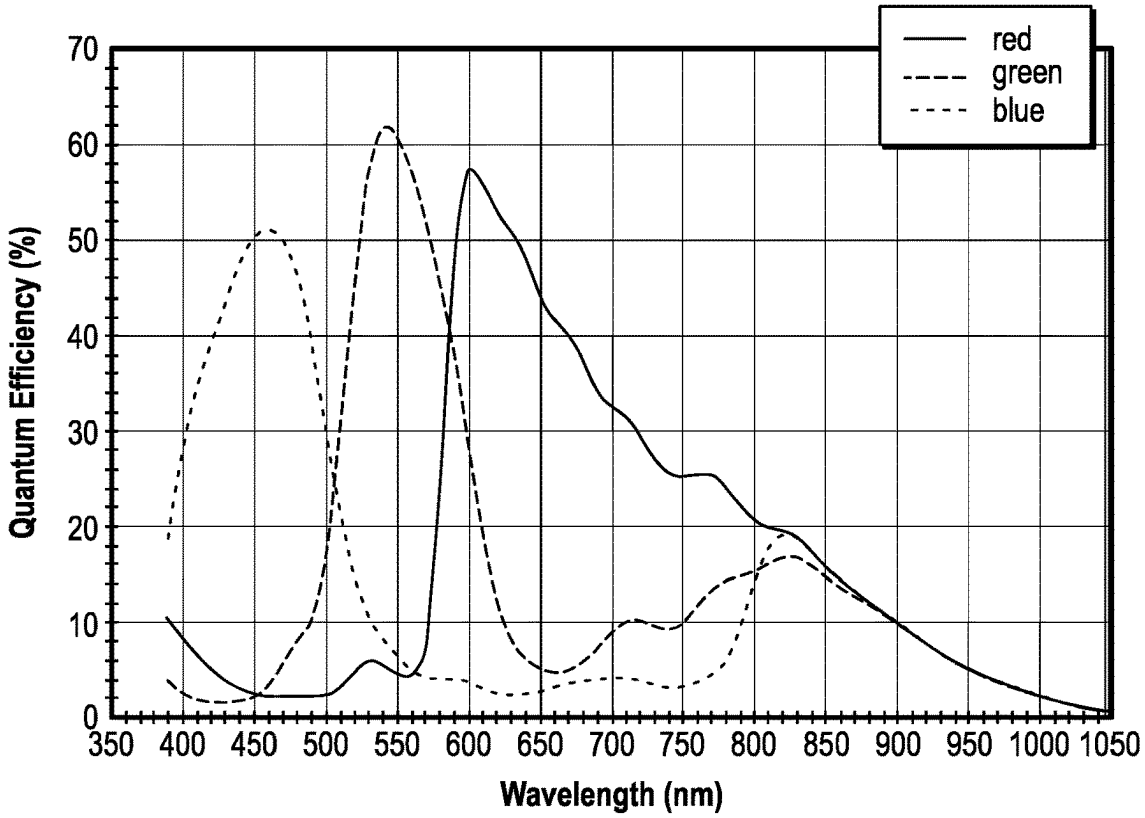
red
green
blue
Quantum Efficiency (%)
0
10
20
30
40
50
60
70
350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050
Wavelength (nm)

FIG . 6

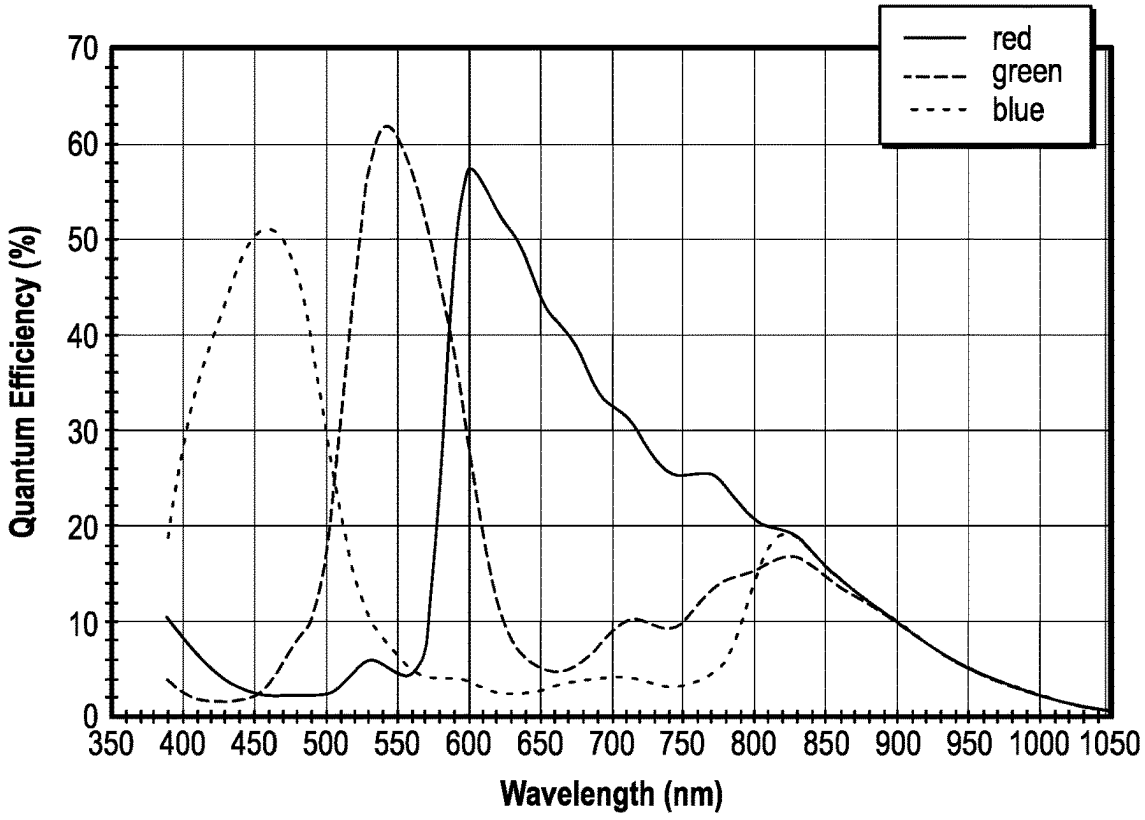
red
green
blue
Quantum Efficiency (%)
0
10
20
30
40
50
60
70
350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050
Wavelength (nm)

FIG . 7

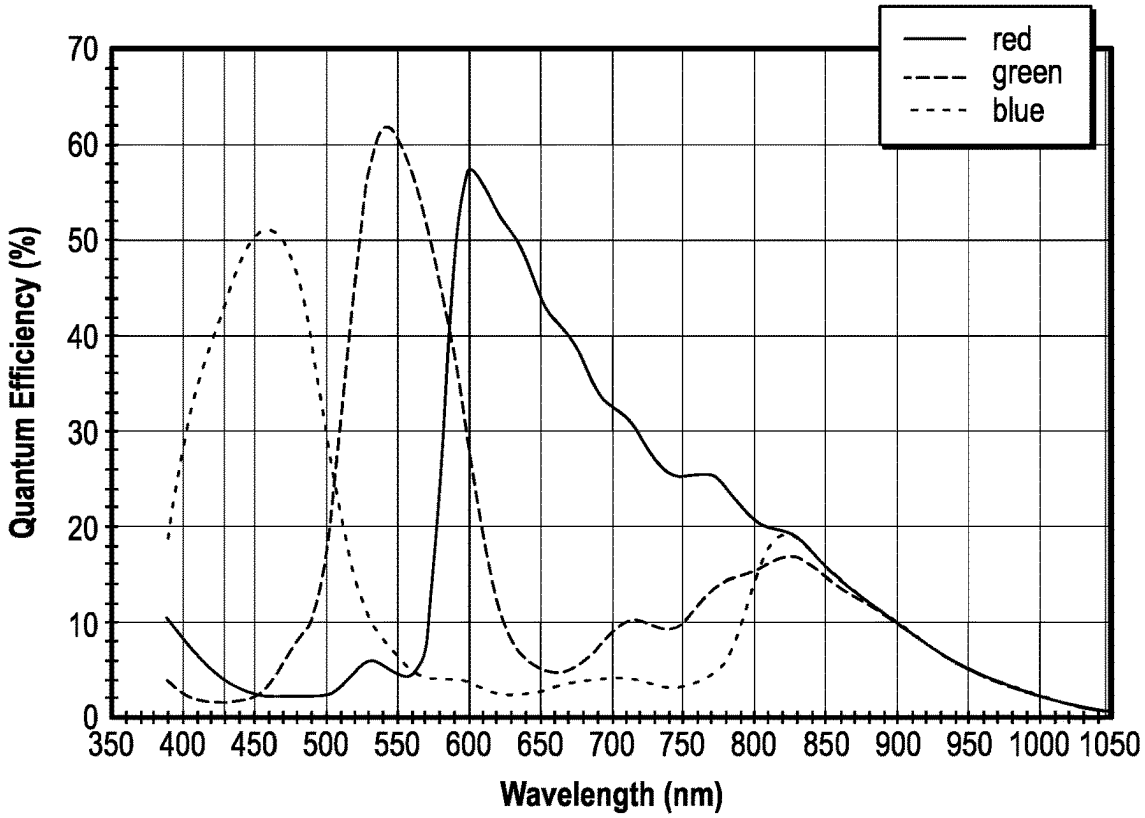
red
green
blue
Quantum Efficiency (%)
0
10
20
30
40
50
60
70
350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050
Wavelength (nm)

FIG . 8

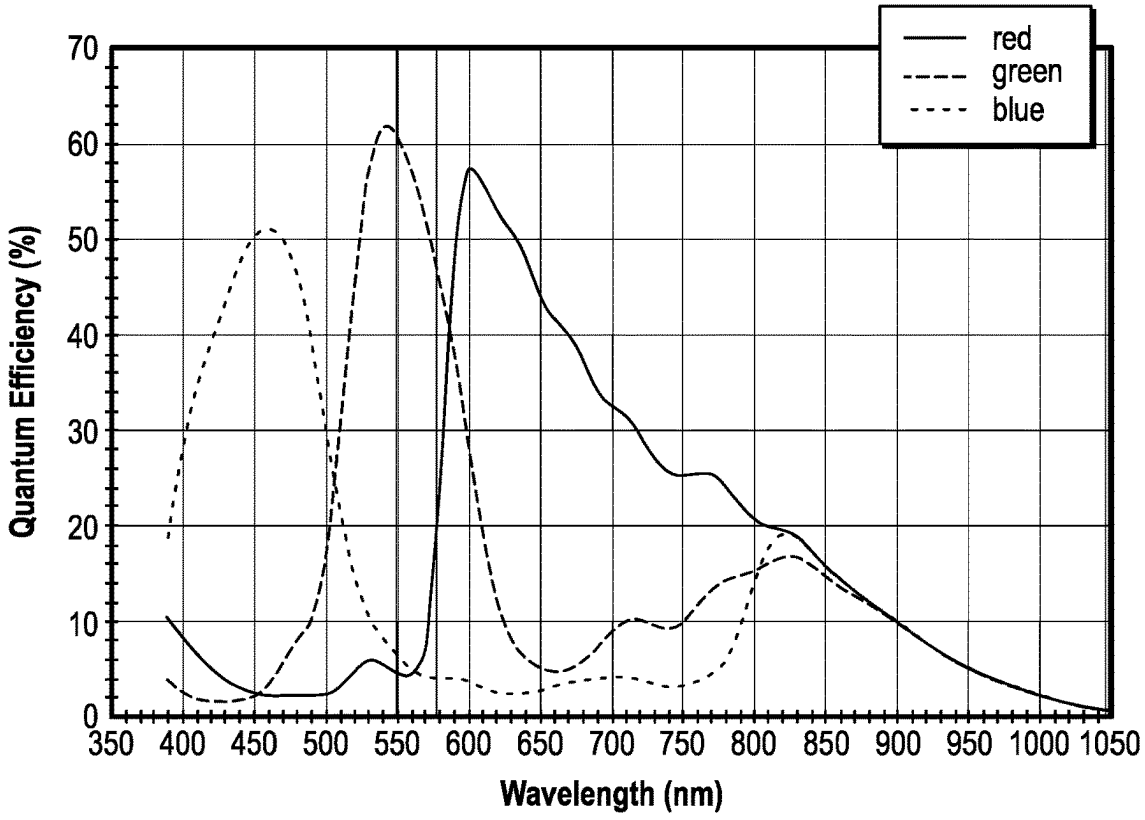
red
green
blue
Quantum Efficiency (%)
0
10
20
30
40
50
60
70
350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050
Wavelength (nm)

FIG . 9

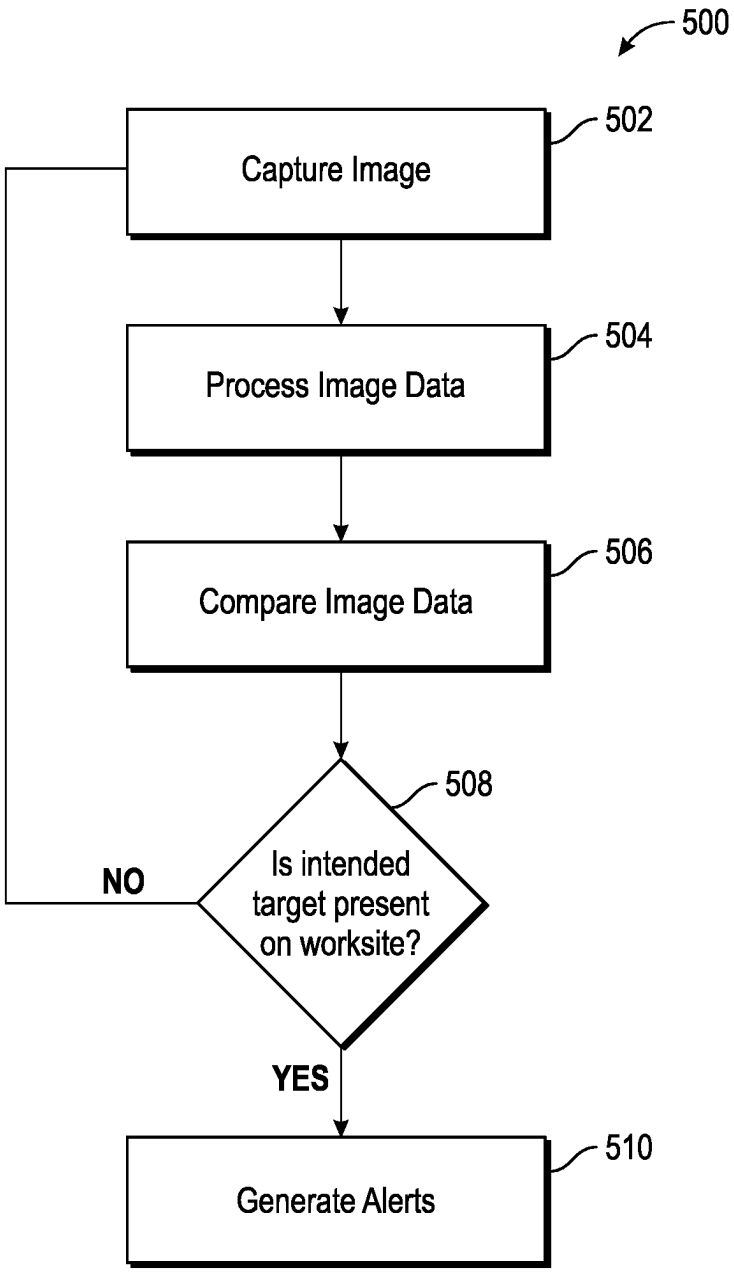
500
Capture Image
502
Process Image Data
504
Compare Image Data
506
Is intended target present on worksite?
508
NO
YES
Generate Alerts
510

FIG . 10

PEDESTRIAN WARNING WITH LIGHT SPECTRUM THAT DOES NOT AFFECT CAMERA BASED OBJECT DETECTION AT NIGHT

FIELD OF THE DISCLOSURE

The present disclosure relates generally to a pedestrian warning system, and, more particularly, to a warning system and method for alerting a pedestrian near a vehicle which does not affect camera based object detection of any sensors on the vehicle.

BACKGROUND OF THE DISCLOSURE

In industrial applications, worksite safety procedures are important to ensure the safety of pedestrians, operators, workmen, and other personnel located in the worksite. Generally, for safety purposes, when pedestrians are located in a worksite, alarms on the work vehicle are triggered to alert an operator that non-authorized persons or pedestrians are in the work zone and may be hazardous. These alarms are intended to alert the operator who must then take action to avoid the pedestrian or remove the pedestrian from the work zone. These steps that the operator must take reduce the productivity of the operator and the overall work that is being done in the work zone since the operator must stop work to take action.

To address such concerns, some conventional approaches employ the use of strobe lights to flash at the non-authorized persons or pedestrians that are in the work zone. Other conventional approaches include audible alarms to alert the non-authorized persons that are in the work zone. Drawbacks to such approaches include ineffective notification to the pedestrians as many pedestrians simply ignore the strobe light and take no action to leave the work zone. These pedestrians have become de-sensitized to the back-up alarms or similar audio alarms. An additional drawback is during night when various image sensors on the work vehicle are used to detect objects or view the work zone itself, the strobe lights interfere with the imaging being performed by these image sensors.

As such, there is a need in the art for an improved pedestrian warning system that provides increased visibility and alerts to the pedestrian but does not interfere with camera or other image based object detection at night.

SUMMARY

According to one embodiment of the present disclosure, a pedestrian warning system for a work vehicle at a worksite, the pedestrian warning system comprising: a sensor system configured to capture images of an identified target located at the worksite, the sensor system operably coupled to the work vehicle; an electronic data processor communicatively coupled to the sensor system, the electronic data processor comprising a non-transitory computer readable storage medium having machine readable instructions that, when executed by the electronic data processor, cause the electronic data processor to: determine whether the identified target from the captured image is an intended target based on one or more identifying characteristics associated with the identified target; wherein when the intended target is identified, generate an alert directed to the intended target that includes the electronic data processor is further configured to generate a control signal to operate one or more lights mounted on the work vehicle, wherein the one or more lights are configured to operate in one or more light spectrum ranges that is not visible by the sensor system.

In one example, the sensor system comprises a plurality of imaging devices operably coupled to the work vehicle, wherein the plurality of imaging devices are configured to capture monocular or stereographic images or videos of identified targets located at the worksite.

In one example, the sensor system comprises one or more filters that block light from the light spectrum range that the one or more lights are configured to operate in.

In one example, the one or more filters block light at wavelengths greater than about 650 nm, and the one or more lights operate at wavelengths greater than about 650 nm.

In one example, the one or more filters block light at wavelengths greater than about 600 nm, and the one or more lights operate at wavelengths greater than about 600 nm.

In one example, the one or more filters block light at wavelengths greater than about 600 nm and less than about 425 nm, and the one or more lights operate at wavelengths greater than about 600 nm and less than about 425 nm.

In one example, the one or more filters block light at wavelengths greater than about 650 nm and block light between approximately 550 nm and 575 nm, and the one or more lights operate at wavelengths greater than about 650 nm and block light between approximately 550 nm and 575 nm.

In one example, the electronic data processor is further configured to generate a control signal to operate the one or more lights in an intermittent operation towards the intended target.

In one example, the electronic data processor is further configured to generate a control signal to operate an audible alert unit towards the intended target.

In one example, wherein the sensor system comprises one or more of a thermal imager, a near infrared imaging device, a short waved infrared device, a light detection and ranging device, a radar device, an ultrasonic device, and/or a scanner operably coupled to the work vehicle.

In one example, wherein the one or more identifying characteristics for the identified target being a person include apparel, wearable devices, and/or facial recognition features stored in a database accessible by the electronic data processor.

According to another embodiment of the present disclosure, a method for warning an intended target on a worksite having a work vehicle thereon, the method comprising: capturing, via a sensor system, one or more images of an identified target located at the worksite; determining, via an electronic data processor communicatively coupled to the sensor system, the electronic data processor comprising a non-transitory computer readable storage medium having machine readable instructions, whether the identified target from the captured image is an intended target based on one or more identifying characteristics associated with the identified target; and wherein when the intended target is identified, generating an alert directed to the intended target that includes the electronic data processor operating one or more lights mounted on the work vehicle in one or more light spectrum ranges that is not visible by the sensor system.

In one example of this embodiment, the capturing images of persons comprises capturing monocular or stereographic images or videos of persons by a plurality of imaging devices.

In one example of this embodiment, the generating an alert comprises activating a strobe light on the work vehicle or triggering a sound file towards the identified target to notify the identified target is located on the worksite.

In one example of this embodiment, the sensor system includes one or more filters that block light from the light spectrum range that the one or more lights are configured to operate in.

In one example of this embodiment, the one or more filters block light at wavelengths greater than about 650 nm, and the one or more lights operate at wavelengths greater than about nm.

In one example of this embodiment, the one or more filters block light at wavelengths greater than about 600 nm, and the one or more lights operate at wavelengths greater than about 600 nm.

In one example of this embodiment, the one or more filters block light at wavelengths greater than about 600 nm and less than about 425 nm, and the one or more lights operate at wavelengths greater than about 600 nm and less than about 425 nm.

In one example of this embodiment, the one or more filters block light at wavelengths greater than about 650 nm and block light between approximately 550 nm and 575 nm, and the one or more lights operate at wavelengths greater than about 650 nm and block light between 9 approximately 550 nm and 575 nm.

In one example of this embodiment, further comprising: generating an audible alert, via an audible alert unit, towards the intended target.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description of the drawings refers to the accompanying figures in which:

FIG. **1** is an illustration of a work vehicle including a pedestrian warning system according to an embodiment;

FIG. **2** is a block diagram of the pedestrian warning system according to an embodiment;

FIG. **3** is a block diagram of a vehicle electronics unit and a remote processing center according to an embodiment;

FIG. **4** is a block diagram of a vehicle data storage device according to an embodiment;

FIG. **5** illustrates a quantum efficiency chart for an imaging device of the work vehicle of FIG. **1** that illustrates red, green, and blue color channels and the corresponding wavelength (nm) of each of those colored lights that are visible to the imaging device;

FIG. **6** illustrates wavelengths that blocked by one or more optical filters associated with the imaging device of FIG. **5**;

FIG. **7** illustrates wavelengths that blocked by one or more optical filters associated with the imaging device of FIG. **5**;

FIG. **8** illustrates wavelengths that blocked by one or more optical filters associated with the imaging device of FIG. **5**;

FIG. **9** illustrates wavelengths that blocked by one or more optical filters associated with the imaging device of FIGS. **5**; and

FIG. **10** is a flow diagram of a method for identifying persons located in a worksite and warning these persons.

Like reference numerals are used to indicate like elements throughout the several figures.

DETAILED DESCRIPTION

The embodiments of the present disclosure described below are not intended to be exhaustive or to limit the disclosure to the precise forms in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may appreciate and understand the principles and practices of the present disclosure.

Referring to FIGS. **1** and **2**, a work vehicle **100** having a pedestrian warning system **150** is shown according to one embodiment. The pedestrian warning system **150** monitors the activity of persons located within a worksite **170**. Although the work vehicle **100** is shown as including a construction vehicle (e.g., a loader) in FIG. **1**, it should be noted that, in other embodiments, the work vehicle **100** can vary according to application and/or specification requirements. For example, in other embodiments, the work vehicle **100** can include forestry, agricultural, or turf vehicles, with embodiments discussed herein being merely for exemplary purposes to aid in an understanding of the present disclosure.

The work vehicle **100** can comprise a frame **112** and an operator cab **104** supported by wheels **108**. A boom assembly **114** can be coupled to the frame **112** and can extend in length between a proximal end **113** and a distal end **115**. An implement **116** can be coupled to the boom assembly **114** at its distal end **115** and can comprise a conventional loader bucket as shown. It should be noted, however, that FIG. **1** is but one embodiment and, in other embodiments, the implement **116** may include a ripper, hammer, or fork, for example. One or more lights **118** can be attached to the work vehicle **100** and in particular the one or more lights **118** may be mounted on the frame **112**. The one or more lights **118** are configured to operate in one or more light spectrum ranges that does not interfere or interrupt operation of a sensor system **154** as described below. The one or more lights **118** may be mounted on other locations of the work vehicle **100**. An audible alert unit **160** can be attached to the work vehicle **100** and in particular the audible alert unit **160** may be mounted on the frame **112**.

As illustrated in FIG. **2**, the pedestrian warning system **150** can comprise a sensor system **154** communicatively coupled to an electronic data processor **152**, a user interface **156** via a communication bus **158**, the one or more lights **118**, and the audible alert unit **160**. In some embodiments, the sensor system **154** can comprise a plurality of imaging devices **155** mounted to a frame of the work vehicle **100** in various locations to capture peripheral imaging data of the worksite **170** in which the work vehicle **100** is operating in. For example, the imaging device **155** can be mounted to a front portion of the work vehicle **100** to capture images of surroundings and persons **125** arranged forward or to the side of the work vehicle **100**. The imaging device **155** can have a wide field of view that spans approximately 90 to 180 degrees along a center axis of the device or a supporting structure attached thereto within a defined range. In other embodiments, the imaging device **155** may be optionally mounted to a rear of the work vehicle **100** to capture images of persons or other objects arranged in a rear field of view. In other alternative embodiments, the imaging device **155** can include a network of wired or wirelessly connected imaging devices **155** arranged on a plurality of work vehicles, and/or located remotely at various locations throughout the worksite **170**.

Although in FIG. **1**, the imaging devices **155** are shown as including cameras such as stereo cameras, it should be noted that, in other embodiments, the imaging devices **155** may also include, without limitation, thermal imagers, infrared imaging devices, near infrared imaging (NIR) devices, short waved infrared (SWIR) devices, light detection and ranging devices (LIDAR), radar devices, ultrasonic devices, scanners, other suitable sensing devices, or combinations thereof. For example, as will be discussed herein, the

imaging device **155** can comprise a plurality of stereo cameras that capture 2D or 3D images of the persons **127** or aerial sensing devices such as drones having one or more cameras attached thereto that capture aerial views of the worksite **170**. Furthermore, NIR and SWIR cameras are not able to leverage light from the lamps that are on the machine because the lamps typically only emit visible light. Therefore, NIR and SWIR camera systems may require their own illumination sources that are coupled to the camera and pulsed synchronously with the image capture.

The electronic data processor **152** can be arranged locally as part of a vehicle electronics unit **200** (FIG. **3**) or remotely at a remote processing center **222**. In various embodiments, the electronic data processor **152** can comprise a microprocessor, a microcontroller, a central processing unit, a programmable logic array, a programmable logic controller, an application specific integrated circuit, a logic circuit, an arithmetic logic unit, a graphics processing unit (GPU), field programmable gate arrays (FPGAs), or other suitable programmable circuitry that is adapted to perform data processing and/or system control operations. For example, the electronic data processor **152** can process image and classification data associated with persons located in the worksite **170** and provide alerts to those persons that are not authorized is detected.

As will be appreciated by those skilled in the art, FIGS. **1** and **2** are provided for illustrative and exemplary purposes only and are in no way intended to limit the present disclosure or its applications. In other embodiments, the arrangement and/or structural configuration of pedestrian warning system **150** can vary. For example, in some embodiments, the pedestrian warning system **150** can comprise additional sensors or may be configured to monitor activity at multiple worksites or for a fleet of work vehicles.

Referring now to FIG. **3**, as previously discussed, the electronic data processor **152** can be arranged in the vehicle electronics unit **200** and can be configured to process images captured by the imaging device **155**. For example, the electronic data processor **152** can be configured to execute a plurality of instructions stored on a vehicle data storage device **206** to identify persons, vehicles, animals, and/or other objects arranged in the images. In addition to the electronic data processor **152**, the vehicle electronics unit **200** can comprise the vehicle data storage device **206**, a vehicle wireless communications device **212**, an operator interface (i.e., display **106**), and a vehicle data bus **204** each communicatively interfaced with a main data bus **202**.

As depicted, the various devices (i.e., vehicle data storage device **206**, vehicle wireless communications device **212**, user interface **106**, and vehicle data bus **204**) may communicate information, e.g., signals such as image data over the main data bus **202** to the electronic data processor **152**. In other embodiments, the electronic data processor **152** can manage the transfer of data to and from a remote processing system **222** via a network **225** and wireless infrastructure **220**. For example, the electronic data processor **152** can collect and process the image data from the main data bus **202** for transmission to or from the processing center **222**.

The vehicle data storage device **206** stores information and data for access by the electronic data processor **152** or the vehicle data bus **204**. The vehicle data storage device **206** may comprise electronic memory, nonvolatile random-access memory, an optical storage device, a magnetic storage device, or another device for storing and accessing electronic data on any recordable, rewritable, or readable electronic, optical, or magnetic storage medium. Additionally, the vehicle data storage device **206** may include one or more software modules or data structures that record, and store data collected by the imaging device **155** or other network devices coupled to or capable of communicating with the vehicle data bus **204**. For example, in some embodiments, the one or more software modules and/or data structures can comprise an object identification module **207** and an alert generation module **211**, and as will be discussed with reference to FIG. **4**.

Referring now to FIG. **4**, a block diagram of the vehicle data storage device **206** is shown according an embodiment. As discussed with reference to FIG. **3**, the electronic data processor **152** can be configured to communicate with the vehicle data storage device **206** to access each of the modules stored therein. The vehicle data storage device **206** can comprise computer executable code that is used to implement the object identification module **207** and alert generation module **211**. The term module as used herein may include a hardware and/or software system that operates to perform one or more functions. Each module can be realized in a variety of suitable configurations and should not be limited to any particular implementation exemplified herein, unless such limitations are expressly called out. Moreover, in the various embodiments described herein, each module corresponds to a defined functionality; however, it should be understood that in other embodiments, each functionality may be distributed to more than one module, or multiple defined functionalities may be implemented by a single module that performs those multiple functions.

The object identification module **207** can identify persons **127**, objects **128**, other vehicles (not illustrated) that may have humans inside them, and/or animals (not illustrated) located at the worksite **170**. These persons **127**, vehicles, and/or animals should not be on the worksite **170** and are therefore an intended target of the alert generation module **211**. The object identification module **207** can identify objects **128** that may include rocks, boulders, or other ground objects that may not be intended targets of the alert generation module **211**.

To identify persons **127** captured in the image by the imaging device **155**, the object identification module **207** can comparatively analyze identifying characteristics **125** such as apparel, wearable devices, and/or facial recognition features with those stored in a database. For example, the object identification module **207** can analyze apparel items such as protective wear (e.g., hats or eyewear), uniforms, or color-coded protective vests, or facial recognition features such as the shape, size, and/or relative arrangement of the eyes, nose, mouth, and face to identify persons **127**. In other embodiments, to identify persons **127** captured in the image by the imaging device **155**, the object identification module **207** relies on other sensor technologies. For instance, machine learning techniques can be applied to radar making use of doppler information to better identify persons **127**.

Additionally, a variety of wearable devices including, without limitation, headsets, speech generating devices, wearable fabrics, wrist or hand devices (e.g., smart watches), smart eyewear, Bluetooth-enabled devices, GPS tracking devices, other suitable communication devices can be used to identify the persons **127**. For example, personnel such as site managers may be required to use unique headsets or speech generating devices such as handheld transceivers to communicate with and/or to alert laborers, spotters, or other personnel located offsite.

To identify animals captured in the image by the imaging device **155**, the object identification module **207** can comparatively analyze identifying characteristics **125** such as shape, size, or other recognition features with those stored in

a database. To identify vehicles captured in the image by the imaging device **155**, the object identification module **207** can comparatively analyze identifying characteristics **125** such as shape, size, or other recognition features with those stored in a database.

The alert generation module **211** can communicate with the object identification module **207** to generate a plurality of alerts associated with the persons **127** from the object identification module **207** that are intended targets of the alert generation module **211**. For example, the alert generation module **211** can generate alerts that can include, without limitation, visual alerts, audible alerts, or combinations thereof. For example, the alert generation module **211** can generate visual or audible alerts such as strobe lights or sirens, that trigger when persons **127** are detected as the intended target. The alert generation module **211** will not communicate with the object identification module **207** nor generate any alerts when an object **128** is identified.

The alert generation module **211** can generate alerts via the one or more lights **118** or the audible alert unit **160** that are directed to the persons **127**, vehicle, or animal described above. The one or more lights **118** are configured to operate in one or more light spectrum ranges that does not interfere or interrupt operation of the imaging device **155** such that the images captured by the imaging device **155** are not altered by the operation of the one or more lights **118**. Alternatively, or additionally, the imaging device **155** is configured to operate such as with a filter or other mechanism to block the light from the one or more lights **118** from interfering with the operation of the imaging device **155** such that the images captured by the imaging device **155** are not altered by the operation of the one or more lights **118**. For example in one embodiment, the one or more lights **118** can be brake lights associated with the work vehicle **170**. Alternatively, or additionally, the one or more lights **118** can include additional lights such as strobe lights, flood lights, spot lights, and/or laser lights, to name a few types of lights that can be operated in certain wavelengths that do not interfere with the imaging device **155** such that the images captured by the imaging device **155** are not altered by the operation of the one or more lights **118**. As described further below, the imaging device **155** can include one or more filters that correspond to the wavelength of light that illuminates from the one or more lights **118**.

FIG. **5** illustrates a quantum efficiency chart for the imaging device **155** that shows red, green, and blue color channels and the corresponding wavelength (nm) of each of those colored lights that are visible to the imaging device **155** and will be captured in images.

In one embodiment, the imaging device **155** can include an optical filter that blocks light at wavelengths greater than about 650 nm as illustrated in FIG. **6**. In this same embodiment, the one or more lights **118** are configured to operate at wavelengths greater than about 650 nm so that the person **127** can visually see the one or more lights **118** however operation of the imaging device **155** is not affected such that any images captured while the one or more lights **118** are operational are not affected by the one or more lights **118**.

In another embodiment, the imaging device **155** can include an optical filter that blocks light at wavelengths greater than about 600 nm or 625 nm as illustrated in FIG. **7**. In this same embodiment, the one or more lights **118** are configured to operate at wavelengths greater than about 600 nm or 625 nm so that the person **127** can visually see the one or more lights **118** however operation of the imaging device **155** is not affected such that any images captured while the one or more lights **118** are operational are not affected by the one or more lights **118**. By shifting the blocking filter down to about 600 nm or 625 nm may provide additional extra visible light spectrum to the person **127** to make the light easier for the person **127** to see.

In yet another embodiment, the imaging device **155** can include two optical filters that together block light at wavelengths greater than about 600 nm and less than 425 nm as illustrated in FIG. **8**. In this same embodiment, the one or more lights **118** are configured to operate at wavelengths greater than about 600 nm so that the person **127** can visually see the one or more lights **118** that appear red however operation of the imaging device **155** is not affected such that any images captured while the one or more lights **118** are operational are not affected by the one or more lights **118**. The one or more lights **118** are configured to operate at wavelengths less than about 425 nm so that the person **127** can visually see the one or more lights **118** that appear violet however operation of the imaging device **155** is not affected such that any images captured while the one or more lights **118** are operational are not affected by the one or more lights **118**.

In yet another embodiment, the imaging device **155** can include a plurality of optical filters that together block light at wavelengths greater than about 650 nm and light between approximately 550 nm and 575 nm as illustrated in FIG. **9**. In this same embodiment, the one or more lights **118** are configured to operate at wavelengths greater than about 650 nm so that the person **127** can visually see the one or more lights **118** that appear red however operation of the imaging device **155** is not affected such that any images captured while the one or more lights **118** are operational are not affected by the one or more lights **118**. The one or more lights **118** can also be configured to operate at wavelengths between approximately 550 nm and 575 nm so that the person **127** can visually see the one or more lights **118** that appear green or yellow-green however operation of the imaging device **155** is not affected such that any images captured while the one or more lights **118** are operational are not affected by the one or more lights **118**. In this embodiment, the one or more lights **118** are configured to operate at wavelengths greater than about 650 nm and between approximately 550 nm and 575 nm.

Operation of the one or more lights **118** towards the intended target can be done as a strobing or other intermittent operation to get the attention of the intended target as identified from the object identification module **211**. It has been found that this operation of strobing or other intermittent operation of the one or more lights **118** at specific wavelengths is unique especially in situations where the intended targets have been de-sensitized to backup alarms or similar audio alarms. One issue with strobing any type of light near the imaging device **155** is that it could potentially interfere with night time performance of the imaging device **155**. However, strobing the one or more lights **118** at a specific wavelength in the spectrum where the imaging device **155** is not designed to see or capture images will not interfere with the night time performance of the imaging device **155**. As described above, the imaging device **155** can include an optical filter or other mechanism to filter out the wavelength in the spectrum that the one or more lights **118** are operating at. Described previously is the operating ranges of the one or more lights **118** and corresponding optical filters of the imaging device **155** to enable strobing or other intermittent operation of the one or more lights **118** to gain the attention of the intended target. These operating

ranges of the one or more lights **118** will get the pedestrian or intended target's attention, while being ignored by the imaging device **155**.

Operation of the audible alert unit **160** towards the intended target can be done as described previously towards the intended target as identified from the object identification module **211** to **6** get their attention. Operation of the one or more lights **118** and the audible alert unit **160** can be done together or sequentially or some combination of operation towards the intended target to get their attention.

In operation, referring now to FIG. **10**, a flow diagram of a method **500** for warning one or more intended targets located in the worksite **170** is shown. At **502**, the imaging device **155** can be configured to manually or automatically span a defined range within, e.g., a 90 to 180° radius to capture images of persons **127** located in the worksite **170**. In one embodiment, the defined range is directed rearwardly of the vehicle **100**. In another embodiment, the defined range is directed forwardly of the vehicle **100**. In other embodiments, the defined range is directed to the sides of the work vehicle **100** and any of the front and rear directions of the work vehicle **100**. For manual operations, an operator can input an initiation command via the user interface **156** to activate the imaging device **155**. In other embodiments, such as when the system is in automatic mode, the imaging device **155** can be configured to receive an initiation bit or handshake from the electronic data processor **152** upon vehicle startup to begin capturing image data. This, in turn, also adjusts the field of view based on a detected scenery or surroundings.

Once the images are captured at **502**, the image data is transmitted to the electronic data processor **152** for processing at **504**. As discussed with reference to FIG. **4**, each of the modules (i.e., the object identification module **207** and the alert generation module **211**) can be configured to implement various functionalities and interface with one another to determine whether the persons **127** are located in the worksite **170** as intended targets, and if the persons **127** are intended targets then send an alert to the persons **127**.

At **506**, a comparative analysis of the captured image and stored reference data is performed by the electronic data processor **152** to identify persons **127** or objects **128** located in the image. In some embodiments, the object identification module **207** can identify other classes such as additional vehicles, animals, or other attributes, wherein these classes should not be on the worksite **170**. The object identification module **207** may also utilize machine learning or other data processing techniques to fuse the image data with other sensor data for a more comprehensive perception feature set.

At **508**, the electronic data processor **152** determines whether persons **127** are present on the worksite **170** and therefore are intended targets. In some embodiments, the electronic data processor **152** determines whether other classes such as additional vehicles or animals are present on the worksite **170** and therefore are intended targets. If there are no intended targets, then the method **500** continues to step **502**. If there are intended targets, then the method **500** for warning persons **127** located in the worksite **170** continues to step **510**.

At **510**, the alert generation module **211** can communicate with the object identification module **207** to generate one or more alerts in response to intended targets detected around the work vehicle **100**. For example, the alert generation module **211** can associate a first type of alert in response to persons **127** being identified as the intended target. As another example, the alert generation module **211** can associate a second type of alert in response to a vehicle being identified as the intended target. As yet another example, the alert generation module **211** can associate a third type of alert in response to animals being identified as the intended target. The first, second, or third group of alerts can include, without limitation, visual alerts, audible alerts, or combinations thereof. The first, second, or third group of alerts can each be a unique audible or visual alert for each specific class. For example, the persons **127** may receive a visual alert whereas the vehicle and/or animal may receive an audible alert. For example, in some embodiments, audible alerts can include beeps, tones, or alarms, or verbal notifications that are activated when an intended target is detected. Audible alerts can also include subtle "reminder" tones or notifications that are activated. Visual alerts such as intense strobe lights can be activated in response to a detected intended target presence.

Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein is a pedestrian warning system and method. The pedestrian warning system and method are particularly advantageous in that it provides real-time monitoring of an industrial worksite by generating alerts and warnings when unauthorized persons, vehicles, and/or animals are located in around the work vehicle.

While this disclosure has been described with respect to at least one embodiment, the present disclosure can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the disclosure using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this disclosure pertains.

The invention claimed is:

1. A pedestrian warning system for a work vehicle at a worksite, the pedestrian warning system comprising:

a sensor system that captures images of an identified target located at the worksite, the sensor system operably coupled to the work vehicle;

an electronic data processor communicatively coupled to the sensor system, the electronic data processor comprising a non-transitory computer readable storage medium having machine readable instructions that, when executed by the electronic data processor, cause the electronic data processor to:

determine whether the identified target from the captured image is an intended target based on one or more identifying characteristics associated with the identified target;

determine whether the identified target from the captured image is an unintended target being free of the one or more identifying characteristics associated with the intended target;

wherein when the intended target is identified, generate an alert directed to the intended target that includes the electronic data processor generating a control signal to operate one or more lights mounted on the work vehicle, wherein the one or more lights operate in one or more light spectrum ranges that is not detected by the sensor system; and

wherein when the unintended target is identified, the electronic data processor ceases operation of the one or more lights mounted on the work vehicle.

2. The pedestrian warning system of claim **1**, wherein the sensor system comprises a plurality of imaging devices operably coupled to the work vehicle, wherein the plurality

of imaging devices are configured to capture monocular or stereographic images or videos of identified targets located at the worksite.

3. The pedestrian warning system of claim **1**, wherein the sensor system comprises one or more filters that block light from the light spectrum range that the one or more lights are configured to operate in.

4. The pedestrian warning system of claim **3**, wherein the unintended target includes a rock.

5. The pedestrian warning system of claim **3**, wherein the one or more filters block light at wavelengths greater than 600 nm, and the one or more lights operate at wavelengths greater than 600 nm.

6. The pedestrian warning system of claim **3**, wherein the one or more filters block light at wavelengths greater than 600 nm and less than 425 nm, and the one or more lights operate at wavelengths greater than 600 nm and less than 425 nm.

7. The pedestrian warning system of claim **3**, wherein the one or more filters block light at wavelengths greater than 650 nm and block light between 550 nm and 575 nm, and the one or more lights operate at wavelengths greater than 650 nm and block light between 550 nm and 575 nm.

8. The pedestrian warning system of claim **1**, wherein the electronic data processor generates a control signal to operate the one or more lights in an intermittent operation towards the intended target.

9. The pedestrian warning system of claim **1**, wherein the electronic data processor generates a control signal to operate an audible alert unit towards the intended target.

10. The pedestrian warning system of claim **1**, wherein the sensor system comprises one or more of a thermal imager, a near infrared imaging device, a short waved infrared device, a light detection and ranging device, a radar device, an ultrasonic device, and/or a scanner operably coupled to the work vehicle.

11. The pedestrian warning system of claim **1**, wherein the one or more identifying characteristics for the identified target being a person include apparel, wearable devices, and/or facial recognition features stored in a database accessible by the electronic data processor.

12. A method for warning an intended target on a worksite having a work vehicle thereon, the method comprising:

capturing, via a sensor system, one or more images of an identified target located at the worksite;

determining, via an electronic data processor communicatively coupled to the sensor system, the electronic data processor comprising a non-transitory computer readable storage medium having machine readable instructions, whether the identified target from the captured image is an intended target based on one or more identifying characteristics associated with the identified target;

wherein when the intended target is identified, generating an alert directed to the intended target that includes the electronic data processor operating one or more lights mounted on the work vehicle in one or more light spectrum ranges that is not detected by the sensor system;

determining, via the electronic data processor communicatively coupled to the sensor system, whether the identified target from the captured image is an unintended target being free of the one or more identifying characteristics associated with the intended target; and

wherein when the unintended target is identified, the electronic data processor ceases operation of the one or more lights mounted on the work vehicle.

13. The method of claim **12**, wherein capturing images of persons comprises capturing monocular or stereographic images or videos of persons by a plurality of imaging devices.

14. The method of claim **12**, wherein generating an alert comprises activating a strobe light on the work vehicle or triggering a sound file towards the identified target to notify the identified target is located on the worksite.

15. The method of claim **12**, wherein the sensor system includes one or more filters that block light from the light spectrum range that the one or more lights are configured to operate in.

16. The method of claim **15**, wherein the one or more filters block light at wavelengths greater than 650 nm, and the one or more lights operate at wavelengths greater than 650 nm.

17. The method of claim **15**, wherein the one or more filters block light at wavelengths greater than 600 nm, and the one or more lights operate at wavelengths greater than 600 nm.

18. The method of claim **15**, wherein the one or more filters block light at wavelengths greater than 600 nm and less than 425 nm, and the one or more lights operate at wavelengths greater than 600 nm and less than 425 nm.

19. The method of claim **15**, wherein the one or more filters block light at wavelengths greater than 650 nm and block light between 550 nm and 575 nm, and the one or more lights operate at wavelengths greater than 650 nm and block light between 550 nm and 575 nm.

20. The method of claim **12**, further comprising:

generating an audible alert, via an audible alert unit, towards the intended target.

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