



(43) International Publication Date
27 September 2012 (27.09.2012)

(51) International Patent Classification:

B60R 1/00 (2006.01) *G08G 1/16* (2006.01)
G06T 1/00 (2006.01)

(21) International Application Number:

PCT/IB2012/000500

(22) International Filing Date:

15 March 2012 (15.03.2012)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2011-061317 18 March 2011 (18.03.2011) JP

(71) Applicant (for all designated States except US):

TOYOTA JIDOSHA KABUSHIKI KAISHA [JP/JP]; 1,
Toyota-cho, Toyota-shi, Aichi-ken 471-8571 (JP).

(72) Inventor; and

(75) Inventor/Applicant (for US only): FUJIYOSHI, Satoshi
[JP/JP]; c/o Toyota Jidosha Kabushiki Kaisha, of 1,
Toyota-cho, Toyota-shi, Aichi-ken 471-8571 (JP).

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

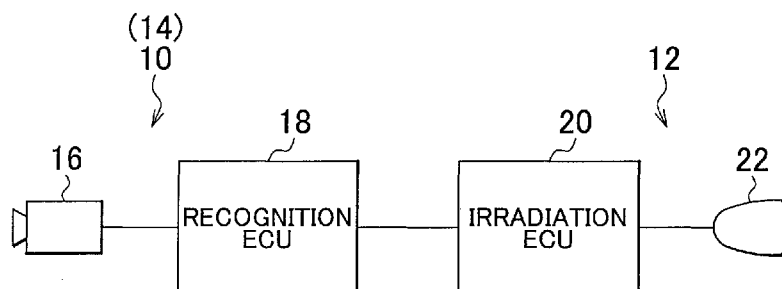
Published:

— with international search report (Art. 21(3))

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,

(54) Title: BICYCLE DETECTION SYSTEM AND IRRADIATION CONTROL SYSTEM

FIG. 1



(57) Abstract: A bicycle detection system includes: a camera that captures an area including a direction in which light is irradiated from an irradiation unit; an intensity determining unit that determines whether an intensity of light in a captured image captured by the camera falls within a predetermined range; a reciprocal movement determining unit that determines whether light in the captured image captured by the camera reciprocally moves up and down; and a bicycle determining unit that, when affirmative determination is made by the intensity determining unit and affirmative determination is made by the reciprocal movement determining unit, determines that a bicycle is present in the direction.



BICYCLE DETECTION SYSTEM AND IRRADIATION CONTROL SYSTEM

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to a bicycle detection system and an irradiation control system and, more particularly, to a bicycle detection system that detects an approaching bicycle, for example, in the nighttime or in a dark place, such as a tunnel, and an irradiation control system that executes light shielding control for limiting the
10 irradiation range of light from an irradiation unit, such as a headlamp of a vehicle, in a dark place.

2. Description of Related Art

[0002] Generally, there is known a system that detects an approaching object, such as a bicycle, that approaches a vehicle in a dark place (for example, see Japanese
15 Patent Application Publication No. 2005-6152 (JP 2005-6152 A). In this system, an approaching object emits light in a predetermined pattern, and a vehicle detects whether light in the predetermined pattern from the approaching object is included in an image captured by an imaging device in a dark place, and, when light in the predetermined
20 pattern is included in the captured image, it is determined that the approaching object is approaching the host vehicle.

[0003] However, in the above described system, the approaching object, such as a bicycle, is required to emit light in the predetermined pattern registered in the vehicle in advance, so an approaching object that emits light in a general lighting or blinking
25 manner and does not emit light in the predetermined pattern is excluded from a target to be detected by the vehicle.

SUMMARY OF THE INVENTION

CONFIRMATION COPY

[0004] The invention provides a bicycle detection system that is able to accurately detect an approaching bicycle in a dark place and an irradiation control system that employs the bicycle detection system.

[0005] A first aspect of the invention provides a bicycle detection system. The bicycle detection system includes: a camera that captures an area including a direction in which light is irradiated from an irradiation unit; an intensity determining unit that determines whether an intensity of light in a captured image captured by the camera falls within a predetermined range; a reciprocal movement determining unit that determines whether light in the captured image captured by the camera reciprocally moves up and down; and a bicycle determining unit that determines whether a bicycle is present in the direction, based on the determination made by the intensity determining unit and the determination made by the reciprocal movement determining unit.

[0006] In addition, in the bicycle detection system according to the first aspect, when affirmative determination is made by the intensity determining unit and affirmative determination is made by the reciprocal movement determining unit, the bicycle determining unit may determine that a bicycle is present in the direction.

[0007] In addition, in the bicycle detection system according to the first aspect, the bicycle determining unit may include a bicycle estimating unit that, when affirmative determination is made by the intensity determining unit, estimates that a bicycle is present in the direction, and a reliability increasing unit that, when affirmative determination is made by the reciprocal movement determining unit, increases reliability that a bicycle is present in the direction, the reliability being estimated by the bicycle estimating unit.

[0008] In addition, in the bicycle detection system according to the first aspect, the intensity determining unit may determine whether an intensity of at least one of rays of light present in the captured image captured by the camera falls within the predetermined range.

[0009] In addition, in the bicycle detection system according to the first aspect, the reciprocal movement determining unit may determine whether a pair of rays of light

present right and left in the captured image captured by the camera both reciprocally move up and down.

[0010] In addition, in the above bicycle detection system, the reciprocal movement determining unit may determine whether a pair of rays of light present right and left on both sides of the one of rays of light in the captured image captured by the camera reciprocally move up and down.

[0011] In addition, in the above bicycle detection system, the reciprocal movement determining unit may determine whether the pair of rays of light reciprocally move up and down at mutually opposite phases.

[0012] In addition, the bicycle detection system according to the first aspect may further include a color detecting unit that detects color of light in the captured image captured by the camera, the intensity determining unit may determine whether an intensity of at least one of rays of white light present in the captured image captured by the camera falls within the predetermined range, and the reciprocal movement determining unit may determine whether a pair of rays of amber light present right and left in the captured image captured by the camera reciprocally move up and down.

[0013] A second aspect of the invention provides an irradiation control system. The irradiation control system includes a light shielding control unit that, when it is determined by the bicycle determining unit of the bicycle detection system according to first aspect that a bicycle is present in the direction in which light is irradiated from the irradiation unit, executes light shielding control over the irradiation unit such that light irradiated from the irradiation unit does not illuminate the bicycle.

[0014] According to the aspects of the invention, it is possible to accurately detect an approaching bicycle in a dark place.

25

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a configuration diagram of an in-vehicle system that includes a bicycle detection system and an irradiation control system according to a first embodiment of the invention;

FIG. 2 is a flow chart of an example of control routine executed in the first embodiment;

FIG. 3 is a perspective view of a bicycle;

FIG. 4 is a view that schematically shows a state variation of light in the case where light output or reflected from the bicycle is input to a vehicle;

FIG. 5 is a view that shows a technique for changing the irradiation range of light in the irradiation control system according to the first embodiment; and

FIG. 6 is a flow chart of an example of control routine executed in a bicycle detection system and an irradiation control system according to a second embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0016] Hereinafter, a specific embodiment of a bicycle detection system and an irradiation control system according to the aspect of the invention will be described with reference to the accompanying drawings.

[0017] FIG. 1 shows the configuration diagram of an in-vehicle system that includes a bicycle detection system 10 and an irradiation control system 12 according to the first embodiment of the invention. In the present embodiment, the bicycle detection system 10 is equipped for a four-wheel or two-wheel vehicle, such as an automobile and a truck. The bicycle detection system 10 detects a bicycle that is present ahead of the host vehicle and that approaches a host vehicle. The bicycle detection system 10 is included as part of an object detection system 14 equipped for the vehicle. In addition, the irradiation control system 12 is equipped for the vehicle. The irradiation control system 12 controls the irradiation range or irradiation amount of light of a headlamp, irradiated forward from the host vehicle.

[0018] The object detection system 14 that includes the bicycle detection system

10 includes a camera 16. The camera 16 is arranged at a vehicle bumper, a front grill, the stay of a rearview mirror in a vehicle cabin, or the like. The camera 16 is a photo-detection sensor that is able to capture a predetermined area spreading forward from the host vehicle. The camera 16 is not an infrared camera that senses a near
5 infrared ray. The camera 16 may be a general digital camera that senses visible light.

[0019] The object detection system 14 further includes an electronic control unit (hereinafter, referred to as recognition ECU) 18 that is mainly formed of a microcomputer. The above camera 16 is electrically connected to the recognition ECU 18. The image captured by the camera 16 is supplied to the recognition ECU 18. The recognition ECU
10 18 detects a bicycle and another vehicle, present ahead of the host vehicle, as distinguished from each other on the basis of the image captured by the camera 16 and supplied from the camera 16, as will be described in detail later. The recognition ECU 18 detects the position, including the angle and the distance, of the detected bicycle or other vehicle with respect to the host vehicle on the basis of the position of the detected
15 bicycle or other vehicle in the captured image.

[0020] The irradiation control system 12 includes an electronic control unit (hereinafter, referred to as irradiation ECU) 20 mainly formed of a microcomputer. The recognition ECU 18 is electrically connected to the irradiation ECU 20. Information about the positions of the bicycle and other vehicle, detected by the recognition ECU 18,
20 with respect to the host vehicle is supplied to the irradiation ECU 20.

[0021] Headlamps 22 are respectively arranged at the front right and front left of the vehicle body. The headlamps 22 are electrically connected to the irradiation ECU 20. The headlamps 22 irradiate visible light to the predetermined area ahead of the vehicle in accordance with a command from the irradiation ECU 20. The right and left headlamps
25 22 each are an LED light, a bulb light, or the like, that is able to change the irradiation range to which light is irradiated. The irradiation ECU 20 is able to recognize where the irradiation range of the headlamps 22 is located ahead of the host vehicle with respect to the host vehicle.

[0022] The irradiation ECU 20 issues a light emission command to the

headlamps 22, and changes the irradiation range ahead of the vehicle, to which light of the head lamps 22 is irradiated, on the basis of information about the positions of the bicycle and other vehicle, supplied from the recognition ECU 18, information about the steering angle of the vehicle, and a vehicle height position. For example, the irradiation range (direction in which each optical axis is directed in the transverse direction) of the headlamps 22 is changed such that light of the headlamps 22 is irradiated in the direction at right and left angles based on the steering angle and speed of the vehicle or the irradiation range (direction in which each optical axis is directed in the vertical direction) of the headlamps 22 is changed such that light of the headlamps 22 is irradiated in the direction at upper and lower angles based on the vehicle height position.

[0023] Next, each of the operation of the object detection system 14, including the bicycle detection system 10 according to the present embodiment, and the operation of the irradiation control system 12 will be described with reference to FIG. 2 to FIG. 5. FIG. 2 shows the flow chart of an example of control routine executed in the present embodiment. FIG. 3 shows the perspective view of a bicycle. FIG. 4 shows a view that schematically shows a state variation of light in the case where light output or reflected from the bicycle is input to the vehicle. In addition, FIG. 5 shows a view that shows a technique for changing the irradiation range of light in the irradiation control system 12 according to the present embodiment.

[0024] In the present embodiment, the vehicle automatically lights up the headlamps 22 of the host vehicle through passenger's switch operation or when it has been detected that surroundings of the host vehicle are dark at a predetermined illuminance or below. The irradiation ECU 20 issues a lighting command to the headlamps 22 when the condition for lighting up the headlamps 22 is satisfied. In this case, the headlamps 22 irradiate visible light to the predetermined area ahead of the host vehicle. When a detecting condition, such as the fact that the headlamps 22 of the vehicle are lit up in a dark place, is satisfied (affirmative determination is made in step 100 of FIG. 2), the object detection system 14 uses the camera 16 to capture an area ahead of the vehicle, at least including the direction in which visible light is irradiated from the

headlamps 22 (step 102). The image captured by the camera 16 is supplied to the recognition ECU 18.

[0025] When the above described detecting condition is satisfied, the recognition ECU 18 detects light included in the captured image on the basis of the captured image supplied from the camera 16 (step 104). Then, it is determined whether the intensity W of the detected light is higher than or equal to a first threshold $SH1$ (step 106). Note that the first threshold is, for example, the minimum luminous intensity of light that is achieved when light irradiated from the headlamps of a vehicle located a predetermined distance (for example, about 400 m) or longer from the host vehicle is input to the host vehicle. In addition, light to be detected at this time may blink at predetermined intervals. As a result of the determination, when the intensity W of light is higher than or equal to the first threshold $SH1$, it is determined that the object that is present ahead of the host vehicle and that irradiates the light is a vehicle, and then it is determined that another vehicle is present ahead of the host vehicle (step 108).

[0026] On the other hand, as a result of the determination, when the intensity W of the detected light is lower than the first threshold $SH1$, the recognition ECU 18 subsequently determines whether the intensity W of the light is higher than or equal to a second threshold $SH2$ (step 110). Note that the second threshold $SH2$ is, for example, the minimum luminous intensity of light achieved when light irradiated from the headlamp of a bicycle located a predetermined distance (for example, 75 m) or longer from the host vehicle is input to the host vehicle, and is lower than the above described first threshold $SH1$. In addition, in order to detect light irradiated from the headlamp of a bicycle, light to be determined whether the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ may be limited to the one that is located at a predetermined height (for example, about 80 cm) from the ground and that emits light within a predetermined area (for example, about $10\text{ cm}^2 \pm 3\text{ cm}^2$).

[0027] As a result of the above determination, when the intensity W of light is lower than the second threshold $SH2$, the recognition ECU 18 determines that no object that irradiates light is present ahead of the host vehicle or the object that irradiates light is

not a bicycle, and then cancels the following detecting process. On the other hand, as a result of the above determination, when the intensity W of light is higher than or equal to the second threshold $SH2$ (that is, when $SH2 \leq W < SH1$ is satisfied), it is determined that the object that is present ahead of the host vehicle and that irradiates the light is not a
5 vehicle but may be a bicycle. In addition, when such determination is made, subsequently, it is determined whether there are further other rays of light at two portions, other than the light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$, in the captured image from the camera 16 (step 112).

10 [0028] Note that two rays of light to be detected in step 112 each just need to have the intensity W of light higher than or equal to a third threshold $SH3$, and the third threshold $SH3$ may be set so as to be lower than the second threshold $SH2$. In addition, the third threshold $SH3$ is, for example, the minimum luminance intensity of light achieved when rays of reflected light that light of the headlamps 22 of the host vehicle is
15 reflected from reflectors attached to the pedals of a bicycle located a predetermined distance (for example, 75 m) or longer from the host vehicle are input to the host vehicle. In addition, two rays of light to be detected in step 112 each may be limited to the one that emits light within a predetermined area (for example, about the surface area of each of the reflectors attached to the pedals).

20 [0029] Generally, as shown in FIG. 3, a bicycle 30 has a single headlamp 32, and right and left pedals 34 and 36 respectively have reflectors 38 and 40 that reflect light. Therefore, as light is irradiated from the headlamps 22 of the vehicle present in the travelling direction of the bicycle 30 toward the front of the bicycle 30, the light is reflected by the reflectors 38 and 40 of the right and left pedals 34 and 36 of the bicycle
25 30 to generate a pair of two rays of reflected light, and the pair of two rays of reflected light return to the vehicle. In addition, the bicycle 30 generates power as the rider pushes the pedal 34 or 36, so, generally, as shown in FIG. 4, as light is continuously irradiated from the headlamps 22 of the vehicle, present in the travelling direction of the bicycle 30, toward the front of the bicycle 30, it is seen from the vehicle that light of the

headlamp 32 of the bicycle 30 is substantially immovable and, on the other hand, a pair of rays of reflected light that are present right and left (more specifically, lower right and lower left) on both sides of the light of the headlamp 32 and that are reflected from the reflectors 38 and 40 of the right and left pedals 34 and 36 of the bicycle 30 reciprocally
5 move up and down. Note that these pair of rays of reflected light reciprocally move at mutually opposite phases and at substantially constant intervals.

[0030] As a result of the determination in step 112 of FIG. 2, when no pair of rays of light, other than the light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$, are present in the
10 captured image, the recognition ECU 18 determines that no object that irradiates or reflects light is present ahead of the host vehicle or the object is not a bicycle, and then cancels the following detecting process. On the other hand, when it is determined that such a pair of rays of light are present, it is determined that light irradiated from the headlamps 22 of the host vehicle may be reflected from each of the reflectors attached to
15 the right and left pedals of the bicycle and may be returned to the host vehicle. Subsequently, it is determined whether the pair of rays of light are present on both sides of the light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ (hereinafter, referred to as center light) and reciprocally move up and down (step 114).

20 [0031] Note that reciprocal movements of a pair of rays of light, required for affirmative determination in step 114, each may be carried out at substantially constant intervals (for example, intervals of about one second and may be intervals of a predetermined range with a certain width), and may be carried out at mutually opposite phases in terms of the relationship between both the pair of rays of light. Furthermore,
25 the determination process may be made on the basis of a synthetic image obtained by synthesizing a plurality of captured images of the camera 16, obtained in a predetermined period of time.

[0032] As a result of the determination in step 114, when no pair of rays of light are present on both sides of the center light or when any one of those pair of rays of light

does not reciprocally move up and down, it is determined that the object that irradiates light, present ahead of the host vehicle, is not a bicycle, and then the following detecting process is cancelled. In addition, even when a pair of rays of light are present on both sides of the center light and do not reciprocally move up and down, the following
5 detecting process is cancelled. On the other hand, when a pair of rays of light are present on both sides of the center light and reciprocally move up and down, it is determined that the object that irradiate light, present ahead of the host vehicle, is a bicycle, and it is determined that a bicycle is present ahead of the host vehicle (step 116).

[0033] In this way, in the object detection system 14 that includes the bicycle
10 detection system 10 according to the present embodiment, when visible light is irradiated forward of the host vehicle from the headlamps 22 of the host vehicle, the camera 16 captures an area ahead of the host vehicle, at least including the direction in which the visible light is irradiated. Then, through processing the captured image of the camera 16, when light of which the intensity W is higher than or equal to the first threshold $SH1$ has
15 been detected, it is determined that another vehicle is present ahead of the host vehicle. In addition, through processing the captured image of the camera 16, when light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ has been detected and a pair of rays of reflected light that are present right and left on both sides of the center light and that reciprocally move up and down
20 have been detected, it is determined that a bicycle is present ahead of the host vehicle. That is, in order to determine that a bicycle is present ahead of the host vehicle, a set of the center light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ and a pair of rays of reflected light that are present right and left on both sides of the center light and that reciprocally move up and
25 down needs to be detected in the captured image of the camera 16.

[0034] As described above, as light is continuously irradiated toward a bicycle from the headlamps 22 of the vehicle present in the travelling direction of the bicycle, it is seen from the vehicle that light of the headlamp of the bicycle is substantially immovable and, on the other hand, a pair of rays of reflected light that are present right

and left (more specifically, lower right and lower left) on both sides of the light of the headlamp and that are reflected from the reflectors of the right and left pedals of the bicycle reciprocally move up and down. On the other hand, it is presumable that an object other than a bicycle does not provide such reciprocal movements of a pair of rays of light.

[0035] Thus, the bicycle detection system 10 according to the present embodiment is able to detect whether an object that emits light and that is present ahead of the host vehicle is a bicycle or a fixed object (such as a sign and a natural illuminant) other than a bicycle as distinguished from each other on the basis of, through processing the captured image of the camera 16, whether light (center light) of which the intensity W does not reach the first threshold $SH1$, at which an object that is present ahead of the host vehicle and that emits light may be determined to be another vehicle, but is higher than or equal to the second threshold $SH2$ has been detected and whether a pair of rays of reflected light that are present right and left on both sides of the center light and that reciprocally move up and down have been detected. Therefore, even when light that is longer in intensity than light having the intensity W , at which it may be determined that an object that is present ahead of the host vehicle and that emits light is another vehicle, is set as light to be detected in order to detect an object in the captured image of the camera 16, it is possible to prevent erroneous detection of a bicycle. In addition, when a bicycle that approaches the host vehicle is present ahead of the host vehicle in the direction in which the headlamps 22 irradiate light while the headlamps 22 of the host vehicle light up in the nighttime or in a dark place, such as a tunnel, it is possible to accurately detect the approaching bicycle.

[0036] In the present embodiment, when the recognition ECU 18 determines that another vehicle is present ahead of the host vehicle in step 108 of FIG. 2 or determines that a bicycle is present ahead of the host vehicle in step 116 of FIG. 2, the recognition ECU 18 detects the position, including the angle and the distance, of the other vehicle or the bicycle with respect to the host vehicle and supplies the position information to the irradiation ECU 20. Note that, when it is not determined that another

vehicle or a bicycle is present ahead of the host vehicle, position information is not supplied from the recognition ECU 18 to the irradiation ECU 20. When the irradiation ECU 20 is supplied with the position information of another vehicle or a bicycle with respect to the host vehicle from the recognition ECU 18, the irradiation ECU 20 executes
5 light shielding control for limiting the irradiation range, in which visible light is irradiated from the headlamps 22, on the basis of the position information (step 118 and step 120).

[0037] Specifically, as shown in FIG. 5, when the irradiation ECU 20 is not supplied with the position information of another vehicle or a bicycle with respect to the host vehicle from the recognition ECU 18, the irradiation ECU 20 does not limit the
10 irradiation range of the headlamps 22; whereas, when the irradiation ECU 20 is supplied with the position information of another vehicle or a bicycle, which has been detected to be present ahead of the host vehicle, with respect to the host vehicle from the recognition ECU 18, the irradiation ECU 20 limits the irradiation range of the headlamps 22 such that visible light from the headlamps 22 of the host vehicle do not illuminate the other vehicle
15 or the bicycle.

[0038] In such light shielding control, when another vehicle or a bicycle is present ahead of the host vehicle, visible light is irradiated while avoiding the area in which the other vehicle or the bicycle is present within all the area ahead of the host vehicle in which visible light is normally irradiated from the headlamps 22 of the host
20 vehicle, so a passenger of the other vehicle or a rider of the bicycle ahead of the host vehicle is prevented from experiencing glare. Thus, the irradiation control system 12 according to the present embodiment is able to, when the host vehicle runs in the nighttime or in a dark place, such as a tunnel, avoid interference with running of another vehicle or a bicycle ahead of the host vehicle due to light irradiated from the headlamps
25 22 of the host vehicle, so it is possible to improve safety running of each of vehicles and bicycles on a road.

[0039] Note that, in the above described first embodiment, the headlamps 22 correspond to a "irradiation unit" according to the aspect of the invention, determining whether the intensity W of light detected by the recognition ECU 18 is higher than or

equal to the second threshold SH2 and is lower than the first threshold SH1 by the recognition ECU 18 corresponds to an "intensity determining unit" according to the aspect of the invention, executing the process of step 114 in the routine shown in FIG. 2 by the recognition ECU 18 corresponds to a "reciprocal movement determining unit"

5 according to the aspect of the invention, executing the process of step 116 by the recognition ECU 18 corresponds to a "bicycle determining unit" according to the aspect of the invention, executing light shielding control for limiting the irradiation range in which visible light is irradiated from the headlamps 22 by the irradiation ECU 20 on the basis of the position information of another vehicle or a bicycle, supplied from the

10 recognition ECU 18, corresponds to a "light shielding control unit" according to the aspect of the invention.

[0040] Incidentally, in the above first embodiment, when a set of the center light of which the intensity W is higher than or equal to the second threshold SH2 and is lower than the first threshold SH1 and a pair of rays of reflected light that are present right and

15 left on both sides of the center light and that reciprocally move up and down have been detected in the captured image of the camera 16, it is determined that a bicycle is present ahead of the host vehicle; instead, when a multiple sets of the center light and a pair of rays of reflected light have been detected in the captured image of the camera 16, it may be determined that a plurality of bicycles are present ahead of the host vehicle.

20 [0041] In addition, in the above first embodiment, the recognition ECU 18 does not recognize the color of light included in the captured image from the camera 16. However, generally, the headlamp of a bicycle emits white light, and the reflectors of the pedals emit amber light. Then, when the recognition ECU 18 has detected light in the captured image, the recognition ECU 18 may further recognize the color of the detected

25 light and then may determine that an object that is present ahead of the host vehicle and that emits light is a bicycle when the intensity W of one of rays of white light among all the detected rays of light is higher than or equal to the second threshold SH2 and is lower than the first threshold SH1 and a pair of rays of amber light that are present right and left on both sides of the white light reciprocally move up and down. According to the above

alternative embodiment, it is possible to further accurately detect a bicycle that approaches the host vehicle in a dark place.

[0042] In addition, in the above described first embodiment, the recognition ECU 18 initially determines whether the intensity W of light in the captured image from the camera 16 is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$, after that, when affirmative determination is made, determines whether a pair of rays of light other than the center light are present, and, furthermore, when affirmative determination is made, determines whether the pair of those rays of light are present right and left on both sides of the center light and reciprocally move up and down. By so doing, it is determined whether a bicycle that approaches the host vehicle is present ahead of the host vehicle. However, the sequence of the above determinations for determining whether a bicycle is present is not limited to the above. For example, it is applicable that it is determined whether a pair of rays of light are present right and left in the captured image of the camera 16 and it is determined whether the pair of rays of light reciprocally move up and down and then, when affirmative determination is made, it is determined whether light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ is present between the pair of those rays of light to thereby determine whether a bicycle that approaches the host vehicle is present ahead of the host vehicle.

[0043] In the above described embodiment, through processing the captured image from the camera 16, when center light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ has been detected and a pair of rays of reflected light that are present right and left on both sides of the center light and that reciprocally move up and down have been detected, it is determined that the object that is present ahead of the host vehicle and that emits light is a bicycle. In contrast to this, in a second embodiment of the invention, through processing the captured image of the camera 16, when center light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ has been detected, it is estimated that the object that is present ahead of the

host vehicle and that emits light is a bicycle and, in addition, the reliability of determining that the object that is present ahead of the host vehicle and that emits light is a bicycle is increased when a pair of rays of reflected light that are present right and left on both sides of the center light and that reciprocally move up and down have been
5 detected, while the reliability is decreased when such a pair of rays of reflected light have not been detected.

[0044] The system according to the second embodiment of the invention is implemented by causing the recognition ECU 18 of the object detection system 14 and the irradiation ECU 20 of the irradiation control system 12 to execute the routine shown
10 in FIG. 6 instead of the routine shown in FIG. 2. FIG. 6 shows the flow chart of an example of control routine executed in the present embodiment. Note that, in the routine shown in FIG. 6, like reference signs denote steps that execute similar processes to those of the processes shown in FIG. 2, and the description thereof is omitted or simplified.

15 [0045] In the present embodiment, as a result of determining in step 106 whether the intensity W of light detected through processing the captured image of the camera 16 is higher than or equal to the first threshold $SH1$, when affirmative determination is made, the recognition ECU 18 determines that another vehicle is present ahead of the host vehicle (step 108). On the other hand, when negative determination is
20 made, it is determined whether the intensity W of the light is higher than or equal to the second threshold $SH2$ (step 110).

[0046] As a result of determination in step 110, when the intensity W of light is lower than the second threshold $SH2$, the recognition ECU 18 determines that no object that irradiates or reflects light is present ahead of the host vehicle or an object is not a
25 bicycle, and then cancels the following detecting process. On the other hand, as a result of the above determination, when the intensity W of light is higher than or equal to the second threshold $SH2$ (that is, when $SH2 \leq W < SH1$ is satisfied), it is estimated that the object that is present ahead of the host vehicle and that irradiates or reflects the light is
... not a vehicle but may be a bicycle (step 200), and, in addition, it is determined whether

further other two rays of light at two portions, other than the light of which the intensity W is higher than or equal to the second threshold SH2 and is lower than the first threshold SH1, are present in the captured image from the camera 16 (step 112).

[0047] As a result of the determination in step 112, when a pair of rays of light, other than the light of which the intensity W is higher than or equal to the second threshold SH2 and is lower than the first threshold SH1, are present in the captured image, the recognition ECU 18 subsequently determines whether the pair of rays of light are present right and left on both sides of the light (hereinafter, referred to as center light) of which the intensity W is higher than or equal to the second threshold SH2 and is lower than the first threshold SH1 and that reciprocally move up and down (step 114).

[0048] As a result of determination in step 114, when the pair of rays of light are present right and left on both sides of the center light and that reciprocally move up and down, the recognition ECU 18 increases the reliability (probability) of determining that the object that is present ahead of the host vehicle is a bicycle (step 202). For example, when the reliability of estimating in step 200 that the object present ahead of the host vehicle is a bicycle is 50%, the reliability of determining that the object is a bicycle as a result of the process of step 202 is 75%.

[0049] On the other hand, when it is determined in step 112 that no pair of rays of light, other than light of which the intensity W is higher than or equal to the second threshold SH2 and is lower than the first threshold SH1, are present in the captured image or when it is determined in step 114 that the pair of rays of light are not present right and left on both sides of the center light or any one of the pair of rays of light does not reciprocally move up and down, the reliability (probability) of determining that the object present ahead of the host vehicle is a bicycle is decreased (step 204). For example, when the reliability of estimating in step 200 that the object present ahead of the host vehicle is a bicycle is 50%, the reliability of determining that the object is a bicycle as a result of the process of step 204 is 25%. On the other hand, when the pair of rays of light are present right and left on both sides of the center light and do not reciprocally move up and down, the reliability (probability) may be decreased as in the case of the

above; instead, the degree of decreasing the reliability may be lower than that of the above and, in addition, the reliability of estimation may be directly used.

[0050] In this way, in the object detection system 14 that includes the bicycle detection system 10 according to the present embodiment, through processing the captured image of the camera 16, when light of which the intensity W is higher than or equal to the first threshold $SH1$ has been detected, it is determined that another vehicle is present ahead of the host vehicle. In addition, through processing the captured image of the camera 16, when the center light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ has been detected, it is estimated that a bicycle may be present ahead of the host vehicle and, in addition, when a pair of rays of reflected light that are present right and left on both sides of the center light and that reciprocally move up and down have been detected, the reliability of determining that the object present ahead of the host vehicle is a bicycle is increased, and, on the other hand, when such a pair of rays of light have not been detected, the reliability is decreased. That is, when a set of the center light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ and a pair of rays of reflected light that are present right and left on both sides of the center light and that reciprocally move up and down have been detected in the captured image of the camera 16, the reliability of determining that the object present ahead of the host vehicle is a bicycle is increased, and, on the other hand, when a pair of rays of reflected light have not been detected even when the center light has been detected, the reliability is decreased.

[0051] Thus, with the bicycle detection system 10 according to the present embodiment, through processing the captured image of the camera 16, when light (center light) of which the intensity W does not reach the first threshold $SH1$, at which it may be determined that an object that is present ahead of the host vehicle and that emits light is another vehicle, but is higher than or equal to the second threshold $SH2$ has been detected, the reliability of determining that the object that is present ahead of the host vehicle and that emits light is a bicycle may be changed on the basis of whether a pair of rays of

reflected light that are present right and left on both sides of the center light and that reciprocally move up and down have been detected.

[0052] In the present embodiment, when the recognition ECU 18 determines in step 108 that another vehicle is present ahead of the host vehicle or increases the reliability of determining that a bicycle is present ahead of the host vehicle in step 202, the recognition ECU 18 detects the position, including the angle and the distance, of the other vehicle or the estimated bicycle with respect to the host vehicle and supplies the position information to the irradiation ECU 20. When the irradiation ECU 20 is supplied with the position information of the other vehicle or the estimated bicycle from the recognition ECU 18, the irradiation ECU 20 executes light shielding control as usual for limiting the irradiation range in which visible light is irradiated from the headlamps 22 on the basis of the position information (step 118 and step 206). Specifically, the irradiation range of the headlamps 22 is limited such that visible light from the headlamps 22 of the host vehicle does not illuminate the other vehicle or the estimated bicycle, which has been detected ahead of the host vehicle and of which the position information is supplied.

[0053] On the other hand, when the recognition ECU 18 decreases the reliability of determining that a bicycle is present ahead of the host vehicle in step 204, the recognition ECU 18 detects the position, including the angle and the distance, of the estimated bicycle with respect to the host vehicle, and supplies the position information to the irradiation ECU 20. When the irradiation ECU 20 is supplied with the position information of the estimated bicycle from the recognition ECU 18, the irradiation ECU 20 executes light shielding control for limiting the irradiation range in which visible light is irradiated from the headlamps 22 on the basis of the position information in a limited manner (step 208). Specifically, the irradiation range of the headlamps 22 is limited such that the range in which visible light from the headlamps 22 of the host vehicle does not illuminate the estimated bicycle, which has been detected ahead of the host vehicle and of which the position information is supplied, is limited to part of the irradiation range.

[0054] In such light shielding control, visible light is irradiated while avoiding the area in which the other vehicle or the estimated bicycle having a high determination reliability is present within all the area ahead of the host vehicle, to which visible light is normally irradiated from the headlamps 22 of the host vehicle, so a passenger of the other vehicle or a rider of the bicycle ahead of the host vehicle is prevented from experiencing glare. Thus, the irradiation control system 12 according to the present embodiment is able to, when the host vehicle runs in the nighttime or in a dark place, such as a tunnel, avoid interference with running of another vehicle or a bicycle ahead of the host vehicle due to light irradiated from the headlamps 22 of the host vehicle, so it is possible to improve safety running of each of vehicles and bicycles on a road.

[0055] In addition, in the above light shielding control, visible light is irradiated while avoiding part of the area in which an estimated bicycle having a low determination reliability is present within all the area ahead of the host vehicle, to which visible light is normally irradiated from the headlamps 22 of the host vehicle, so a passenger of the other vehicle or a rider of the bicycle ahead of the host vehicle is prevented from experiencing glare, and the influence at the time when the estimated bicycle having a low determination reliability is actually not a bicycle is minimized. Thus, when the host vehicle runs in the nighttime or in a dark place, such as a tunnel, it is possible to prevent interference with running of a bicycle ahead of the host vehicle due to light irradiated from the headlamps 22 of the host vehicle, so it is possible to improve safety running of each of vehicles, including the host vehicle, and bicycles on a road.

[0056] An aspect according to the above second embodiment provides a bicycle detection system. The bicycle detection system includes: a camera that captures an area including a direction in which light is irradiated from an irradiation unit; an intensity determining unit that determines whether an intensity of light in a captured image captured by the camera falls within a predetermined range; a bicycle estimating unit that, when affirmative determination is made by the intensity determining unit, estimates that a bicycle is present in the direction; a reciprocal movement determining unit that determines whether light in the captured image captured by the camera reciprocally

moves up and down; and a reliability increasing unit that, when affirmative determination is made by the reciprocal movement determining unit, increases reliability that a bicycle is present in the direction, estimated by the bicycle estimating unit.

[0057] In the bicycle detection system, the intensity determining unit may
5 determine whether the intensity of at least one of rays of light present in the captured image captured by the camera falls within the predetermined range.

[0058] In addition, in the above described bicycle detection system, the reciprocal movement determining unit may determine whether a pair of rays of light present right and left in the captured image captured by the camera reciprocally move up
10 and down.

[0059] In addition, in the above described bicycle detection system, the reciprocal movement determining unit may determine whether a pair of rays of light present right and left on both sides of the at least one of rays of light in the captured image captured by the camera reciprocally move up and down.

15 [0060] In addition, in the above described bicycle detection system, the reciprocal movement determining unit may determine whether the pair of rays of light reciprocally move up and down at mutually opposite phases.

[0061] In addition, the above described bicycle detection system may further include a color detecting unit that detects color of light in the captured image captured by
20 the camera, the intensity determining unit may determine whether an intensity of at least one of rays of white light present in the captured image captured by the camera falls within the predetermined range, and the reciprocal movement determining unit may determine whether a pair of rays of amber light present on both sides in the captured image captured by the camera reciprocally move up and down.

25 [0062] Note that, in the above described second embodiment, executing the process of step 200 in the routine shown in FIG. 6 by the recognition ECU 18 corresponds to the above described "bicycle estimating unit", and executing the process of step 202 by the recognition ECU 18 corresponds to the above described "reliability increasing unit".

[0063] Incidentally, in the above described second embodiment, when an object

that irradiates light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ is present ahead of the host vehicle, the reliability of determining that the object present ahead of the host vehicle is a bicycle may be changed on the basis of whether a pair of rays of reflected light that are present right and left on both sides of the light and that reciprocally move up and down are present, and, when a plurality of objects that irradiate light having the above intensity W are present, the reliability of determining that the object is a bicycle may be changed for each of the objects on the basis of whether a pair of rays of light that are present right and left on both sides of the corresponding light and that reciprocally move up and down are present.

[0064] In addition, in the above described second embodiment, the recognition ECU 18 does not recognize the color of light included in the captured image of the camera 16, when the recognition ECU 18 has detected light in the captured image, the recognition ECU 18 may further recognize the color of the detected light, and then, when the intensity W of one of rays of white light among all the detected rays of light is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$, the recognition ECU 18 may estimate that the object present ahead of the host vehicle is a bicycle, and may change the reliability of determining that the object present ahead of the host vehicle is a bicycle on the basis of whether a pair of rays of amber light are present right and left on both sides of the one of rays of white light and reciprocally move up and down. According to the above alternative embodiment, the reliability of determining that the object present ahead of the host vehicle is a bicycle on the basis of the intensity of light included in the captured image of the camera 16 may be changed where appropriate on the basis of whether the pair of rays of light are present and move up and down.

[0065] In addition, in the above described second embodiment, when the recognition ECU 18 has detected that the intensity W of light in the captured image of the camera 16 is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$, the recognition ECU 18 estimates that the object present ahead of the host

vehicle is a bicycle and may determine whether a pair of rays of light other than the center light are present, and, when affirmative determination is made, the recognition ECU 18 determines whether the pair of rays of light are present right and left on both sides of the center light and reciprocally move up and down to thereby change the reliability of determining that the object present ahead of the host vehicle is a bicycle. Instead, the sequence of the above described processes to estimate that the object is a bicycle and change the reliability is not limited to the above sequence. For example, when the recognition ECU 18 has detected that a pair of rays of light are present right and left in the captured image of the camera 16 and reciprocally move up and down, the recognition ECU 18 may estimate that the object present ahead of the host vehicle is a bicycle, and may determine whether light of which the intensity W is higher than or equal to the second threshold $SH2$ and is lower than the first threshold $SH1$ is present between the pair of rays of light to thereby change the reliability of determining that the object present ahead of the host vehicle is a bicycle.

[0066] Incidentally, in the above described first and second embodiments, when another vehicle or a bicycle present ahead of the host vehicle has been detected, the irradiation range of light from the headlamps 22 is limited such that the other vehicle or the bicycle does not fall within the irradiation range. Then, limiting the irradiation range may be, for example, changing from high-beam irradiation to low-beam irradiation or, instead of limiting the irradiation range, the amount of irradiating visible light from the headlamps 22 to the other vehicle or the bicycle present ahead of the host vehicle may be reduced.

[0067] In addition, when another vehicle or a bicycle present ahead of the host vehicle has been detected, light shielding control for limiting the irradiation range of light from the headlamps 22 is executed. Then, when a bicycle present ahead of the host vehicle has been detected, alarm control for waking a driver of the host vehicle to pay attention to the bicycle with an alarm or vibrations.

CLAIMS:

1. A bicycle detection system comprising:
 - a camera that captures an area including a direction in which light is irradiated from an irradiation unit;
 - an intensity determining unit that determines whether an intensity of light in a captured image captured by the camera falls within a predetermined range;
 - a reciprocal movement determining unit that determines whether light in the captured image captured by the camera reciprocally moves up and down; and
 - a bicycle determining unit that determines whether a bicycle is present in the direction, based on the determination made by the intensity determining unit and the determination made by the reciprocal movement determining unit.
2. The bicycle detection system according to claim 1, wherein when affirmative determination is made by the intensity determining unit and affirmative determination is made by the reciprocal movement determining unit, the bicycle determining unit determines that a bicycle is present in the direction.
3. The bicycle detection system according to claim 1, wherein the bicycle determining unit includes a bicycle estimating unit that, when affirmative determination is made by the intensity determining unit, estimates that a bicycle is present in the direction, and a reliability increasing unit that, when affirmative determination is made by the reciprocal movement determining unit, increases reliability that a bicycle is present in the direction, the reliability being estimated by the bicycle estimating unit.
4. The bicycle detection system according to any one of claims 1 to 3, wherein the intensity determining unit determines whether an intensity of at least one of rays of light present in the captured image captured by the camera falls within the predetermined

range.

5. The bicycle detection system according to any one of claims 1 to 4, wherein the reciprocal movement determining unit determines whether a pair of rays of light present right and left in the captured image captured by the camera reciprocally move up and down.

6. The bicycle detection system according to claim 4, wherein the reciprocal movement determining unit determines whether a pair of rays of light present right and left on both sides of the one of rays of light in the captured image captured by the camera reciprocally move up and down.

7. The bicycle detection system according to claim 5 or 6, wherein the reciprocal movement determining unit determines whether the pair of rays of light reciprocally move up and down at mutually opposite phases.

8. The bicycle detection system according to any one of claims 1 to 7, further comprising a color detecting unit that detects color of light in the captured image captured by the camera, wherein

the intensity determining unit determines whether an intensity of at least one of rays of white light present in the captured image captured by the camera falls within the predetermined range, and

the reciprocal movement determining unit determines whether a pair of rays of amber light present right and left in the captured image captured by the camera reciprocally move up and down.

9. An irradiation control system comprising a light shielding control unit that, when it is determined by the bicycle determining unit of the bicycle detection system according to any one of claims 1 to 8 that a bicycle is present in the direction in which

light is irradiated from the irradiation unit, executes light shielding control over the irradiation unit such that light irradiated from the irradiation unit does not illuminate the bicycle.

FIG. 1

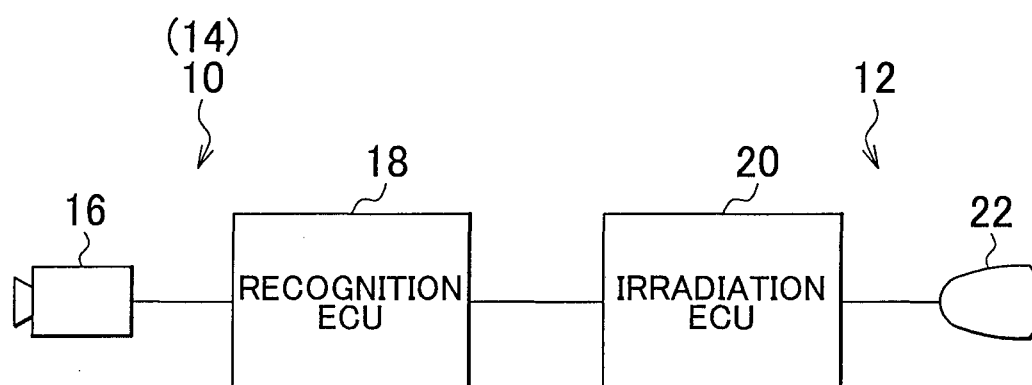


FIG. 2

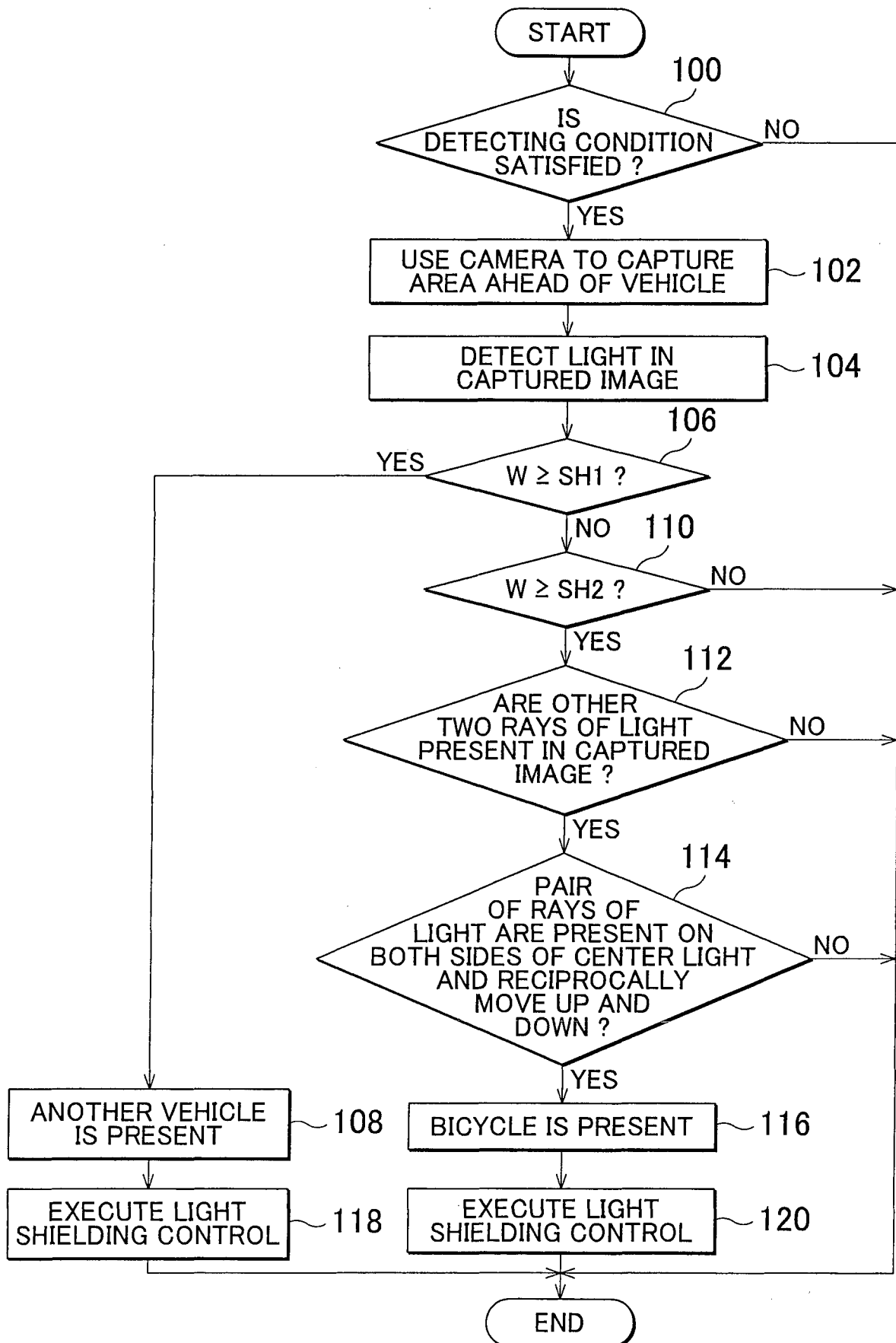


FIG. 3

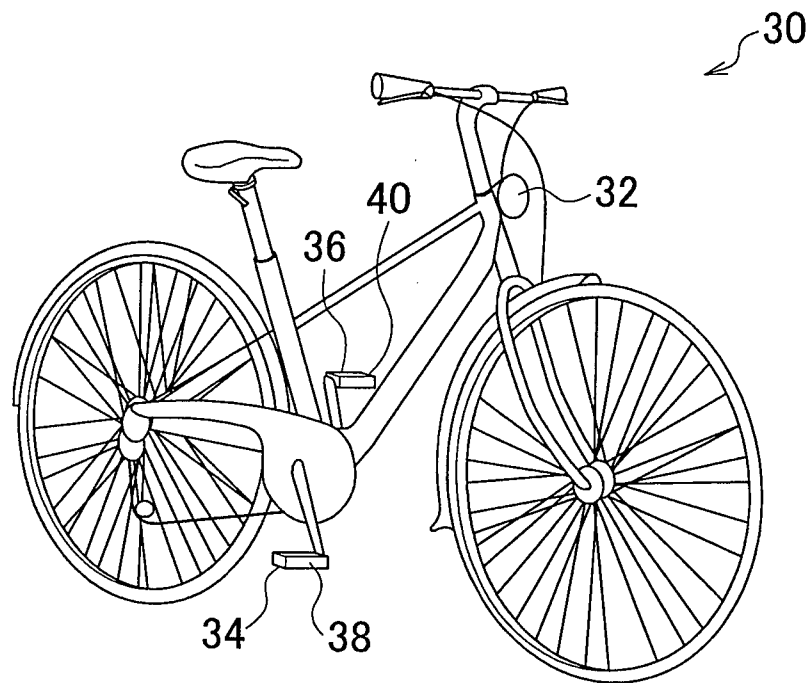


FIG. 4

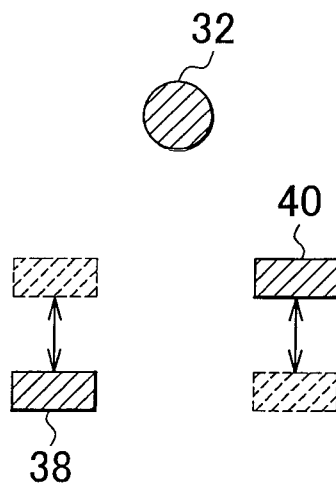


FIG. 5

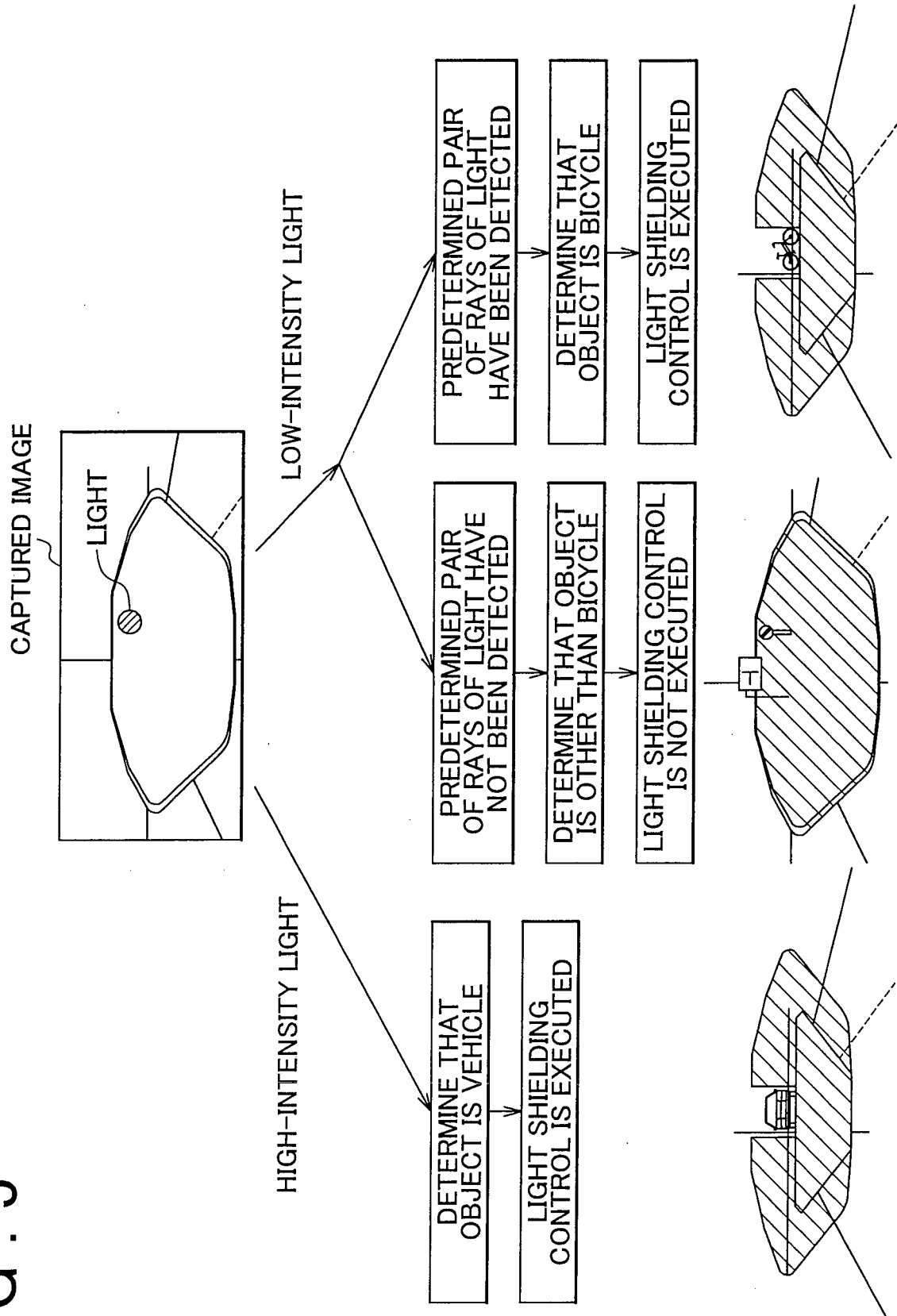
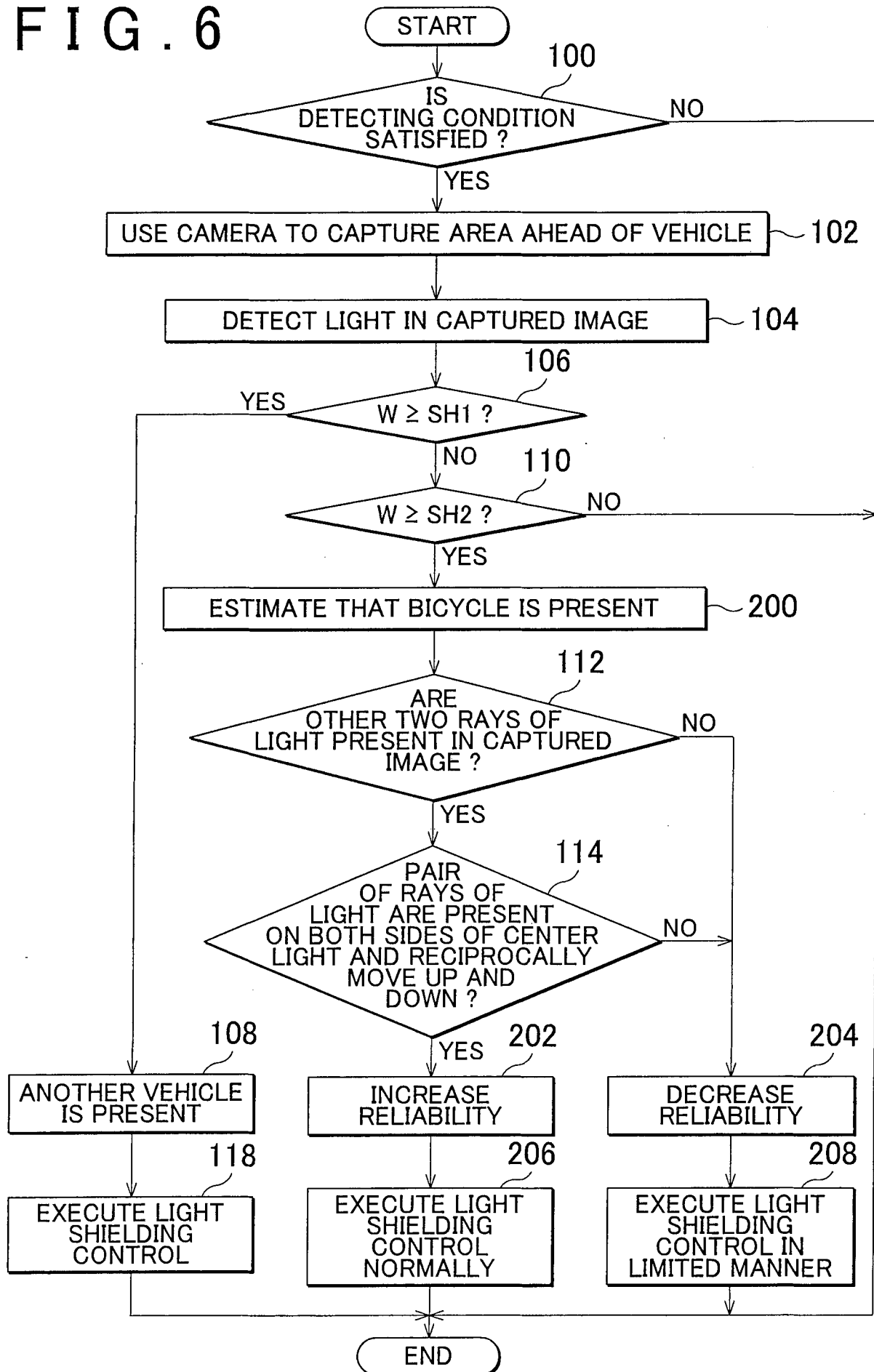


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/000500

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60R1/00 G06T1/00 G08G1/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60R G06T G08G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011/027907 A1 (HONDA MOTOR CO LTD [JP]; YOKOCHI YUJI [JP]; EGUCHI ATSUSHIRO [JP]; NEGO) 10 March 2011 (2011-03-10)	1-7
A	the whole document	8,9
	figure 3	

A	EP 1 830 321 A2 (HITACHI LTD [JP]) 5 September 2007 (2007-09-05)	1-9
	the whole document	
	figure 4a	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 May 2012

Date of mailing of the international search report

11/06/2012

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Gaillard, Alain

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2012/000500

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2011027907 A1	10-03-2011	CN 102473281 A	23-05-2012
		EP 2465092 A1	20-06-2012
		WO 2011027907 A1	10-03-2011

EP 1830321 A2	05-09-2007	EP 1830321 A2	05-09-2007
		JP 2007235642 A	13-09-2007
		US 2007206833 A1	06-09-2007
