TITLE OF THE INVENTION

SYSTEM FOR OPTICALLY DETECTING VEHICLES TRAVELING ALONG THE LANES OF A ROAD

BACKGROUND OF THE INVENTION

The present invention relates to a system for detecting vehicles traveling along a plurality of lanes of a toll road.

In order to collect toll automatically at a tollgate to a toll road, it is necessary to detect any vehicle coming to or passing through the tollgate.

A vehicle detecting system is known which optically detects vehicles passing along the lanes of a toll road. As shown in FIG. 1, the system comprises a gantry 2 and a plurality of optical line sensors 3a to 3g. The gantry 2 straddles the toll road 1, extending across the 3-lane toll road 1. The line sensors 3a to 3g are attached to the lower side of the gantry 2. The sensors 3a is located above the outer boundary of the lane 4a, the sensor 3c above the boundary between the lanes 4a and 4b, the sensor 3e above the boundary between the lanes 4b and 4c, and the sensor 3g above the outer boundary of the lane 4c. The sensors 3b, 3d and 3f are located above the center lines of the lanes 4a, 4b and 4c, respectively. On the surface of the road 1, the view field 3x of each line sensor overlaps half the view field 3x of either adjacent sensor.

When no vehicles are under the gantry 2, the line

sensors 3a to 3g get the linear images of the surface of the road 1 at the right angle to the direction of the lanes and convert the linear images into video signals respectively. The video signals are stored in a memory device, so that the signals may be used as reference signals. In this case, above the line sensors can use one dimensional type TV cameras, as well as projecting/receiving light type sensors emitting and scanning light beam.

In operation, the line sensors 3a to 3g get the linear images of the surface of the road 1, and convert them into video signals. These signals are compared with the reference signals to determine whether or not vehicles are on the toll road 1. Assume a vehicle 5 is on the second lane 4b as shown in FIG. 2. In this case, the signal generated by the sensor 3d located above the center line of the second lane 4b and the signals generated by the sensors 3c and 3e located on the sides of the sensor 3d are compared with the three reference signals generated by the sensors 3d, 3c and 3e. The basis of the difference between each signal and the corresponding reference signal is used to detect the vehicle 5. In FIG. 2, S1, S2 and S3 represent the diagrammatically the signal differing sections where the signals generated by the line sensors 3c, 3e and 3d differ from the corresponding reference signals, respectively. The signal the sensor 3d generates when

the vehicle 5 goes right below the sensor 3d has a signal differing section which is wider than the section representing the width of the vehicle 5. By contrast, the signals the sensors 3c and 3e generate when the vehicle 5 travels right below the sensor 3d have a signal differing section which is just about half the section representing the width of the vehicle 5. This is because the view fields 3x of the sensors 3c and 3e each overlap half the view field 3x of the sensor 3d on the surface of the road 1 and get the image of the vehicle 5 sideways. Hence, the width 6 of the vehicle 5 can be detected from a logical product of the signal differing sections S1, S2 and the signal differing section S3.

Unless the width 6 of the vehicle 5 is extremely small, it can be accurately detected a logical product of the signal differing sections S1, S2 and the section S3. Even the width of a motorcycle, which is relatively small, can be accurately detected unless the motorcycle is located right below any one of the line sensors 3a to 3g.

But the conventional vehicle-detecting system may fail to detect a motor cycle, when a motorcycle 5a is traveling, almost along the center line of the lane 4b as is illustrated in FIG. 3, or virtually along the boundary between the view fields of the line sensors 3c and 3e. If this is the case, the signal differing

section S3 of the signal generated by the sensor 3d is large, but the sections S1 and S2 are very small since the widths of signal 7 detecting a motorcycle 5a by the sensors 3c and 3e are small. Consequently, the width 6 determined by processing the signals is therefore less than the actual width of the motor cycle 5a, or the motor cycle 5a may not be detected.

The system shown in FIG. 1 may detects fallen leaves, trash or the like, which happen to be on the toll road 1. In this case, the system generates and supplies a vehicle-detection signal, though no vehicles are passing under the gantry 2. The vehicle-detecting system has but a low operating reliability.

Earth or sand may fall from a damp track onto the road 1 and may spread over the surface of the road 1. The vehicle-detecting system detects the earth or sand and generates a false vehicle-detection signal. In view of this, too, the reliability of the conventional vehicle-detecting system is insufficient.

BRIEF SUMMARY OF THE INVENTION

The object of the present invention is to provide a vehicle-detecting system which can accurately measure the width of a vehicle, however slim the vehicle is, and which generates no false vehicle-detection signal when it detects a small thing on the road, such as a fallen leaf or trash, or a thing spread over the road, such as earth or sand, and which therefore has high

operating reliability.

The foregoing object is accomplished by providing a system for optically detecting vehicles traveling a road having a plurality lanes, the system comprising:

a gantry provide at the road so as to straddle the plurality lanes;

a plurality of optical line sensors provided on the gantry, for getting linear images of a surface of the road, the optical line sensors arranged in two rows and in a staggered pattern such that each has a view field overlapping the view filed of either adjacent optical line sensor by the sum of half the view field and a width of a motor cycle;

photoelectric sensor apparatus consisting of photo-projector elements and photo-detector elements, and having optical axes which are parallel to each other and are substantially located in the position of the view fields of the optical line sensors; and

a signal-processing section for detecting a vehicle traveling under the gantry in accordance with output signals of the optical line sensors and output signals of the photoelectric sensor apparatus, by using reference signals which the optical line sensors generate when no vehicles travel under them.

With the present invention can provide the system, wherein the signal-processing section includes means

for converting a correlation between the output signal of each optical line sensor and the corresponding reference signal into a binary signal, obtaining a logical sum of the binary signals pertaining to the optical line sensors of one row and a logical sum of the binary signals pertaining to the optical line sensors of the other row, obtaining a logical produce of the two logical sums, and determining, from the logical product, whether a vehicle is traveling under the gantry.

With the present invention can provide the system, wherein the signal-processing section includes means for converting a correlation between the output signal of each optical line sensor and the corresponding reference signal into a binary signal, obtaining a logical sum of the binary signals pertaining to the optical line sensors of one row and a logical sum of the binary signals pertaining to the optical line sensors of the other row, for obtaining a logical produce of the two logical sums, thereby generating a vehicle detection signal, and detecting a vehicle on the basis of the vehicle detection signal and vehicle detection signals generated by the photoelectric sensors.

With the present invention can provide the system, wherein the signal-processing section includes means for updating the reference signals to the output

signals of the optical line sensors, which indicate that no vehicles are traveling under the gantry.

With the present invention can provide the system, further comprising a ticket-issuing machine for issuing a toll ticket when the signal-processing section detects a vehicle traveling under the gantry.

Additional object and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The object and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a diagram showing a conventional vehicle-detecting system;

FIG. 2 is a diagram explaining how the system of FIG. 1 detects a vehicle traveling on a lane of a toll road;

FIG. 3 is a diagram explaining how the system of FIG. 1 detects a motorcycle traveling on the lane;

FIG. 4 is a plan view of a vehicle-detecting system according to an embodiment of the present invention;

FIG. 5A is a front view of the system shown in FIG. 4;

FIG. 5B is a side view of the system illustrated in FIG. 4;

FIG. 6 is a block diagram depicting the signal-processing system incorporated in the vehicle-detecting system of FIG. 4;

FIG. 7 is a flow chart explaining the operation of the system shown in FIG. 4; and

FIG. 8 is a diagram explaining how the system of FIG. 4 measure the width of a motorcycle traveling on a lane of a toll road.

DETAILED DESCRIPTION OF THE INVENTION

A vehicle-detecting apparatus according to the present invention will be described, with reference to the accompanying drawings.

As shown in FIGS. 4, 5A and 5B, the vehicle-detecting system comprises a gantry 2, seven optical line sensors 3a to 3g, a photo-projector 8a having a plurality of photo-projector elements of photoelectric sensor 30a, 30b, 30c, 30d, 30e, 30f, 30g and 30h and a photo-detector 8b having a plurality of photo-detector

elements of photoelectric sensor 31a, 31b, 31c and 31d, 31e, 31f, 31g and 31h. The gantry 2 straddles a 3-lanes toll road 1, extending across the road 1. Above photo-projector 8a and photo-detector 8b constitute a photoelectric sensor apparatus 8.

As shown in FIG. 4 which is a plan view, the line sensors 3a, 3c, 3e and 3g are attached to one side of the gantry 2, while the line sensors 3b, 3d and 3f are coupled to the same side of the gantry 2 by the supports 9a, 9b and 9c. The sensors 3b, 3d and 3f are positioned in front of the sensors 3a, 3c, 3e and 3g, spaced apart therefrom by a distance d. Hence, the optical line sensors 3a to 3g are arranged in a staggered pattern as the system is viewed from above.

As shown in FIG. 5A which is a front view, the sensor 3a is located above the outer boundary of the lane 4a, the sensor 3c above the boundary between the lanes 4a and 4b, the sensor 3e above the boundary between the lanes 4b and 4c, and the sensor 3g above the outer boundary of the lane 4c. The sensors 3b, 3d and 3f are located above the center lines of the lanes 4a, 4b and 4c, respectively. On the surface of the road 1, the view field 3x of each line sensor overlaps that of either adjacent line sensor by the sum of half the view field 3x and the width of a motor cycle.

As FIG. 5A shows, the photo-projector 8a is provided at one side of the road 1, and the

photo-detector 8b at the other side of the road 1. Each photo-projector elements 30a, 30b, 30c, 30d, 30e, 30f, 30g and 30h opposes one photo-detector elements 31a, 31b, 31c, 31d, 31e, 31f, 31g and 31h, across the lanes 4a, 4b and 4c. The elements 30a, 30b, 30c, 30d, 30e, 30f, 30g and 30h emit light beams 8x toward the photo-detector elements 31a, 31b, 31c, 31d, 31e, 31f, 31g and 31h, respectively. The light beams 8x intersect with the optical axes of the optical line sensors 3a to 3g.

As illustrated in FIG. 5B, the photo-projector elements 30a to 30h of the photo-projector 8a are arranged in two columns, one aligned with the optical axes of the sensors 3a, 3c, 3e and 3g, and the other aligned with the optical axes of the sensors 3b, 3d and 3f. The photo-detector elements 31a, 31b, 31c, 31d, 31e, 31f, 31g and 31h are arranged in the same way as the photo-projector elements 30a, 30b, 30c, 30d, 30e, 30f, 30g and 30h. Since the elements 30a to 30h and 31a to 31h are arranged in vertical columns, they serve to detect the bumpers of a car and the rearview mirrors of a heavy-duty vehicle.

As shown in FIG. 6, the optical line sensors 3a to 3g and the photoelectric sensor apparatus 8, comprising of a photo-projector 8a and a photo-detector 8b, are connected to a signal-processing section 21, which is connected to a ticket-issuing machine 22 installed at a

tollgate. The section 21 processes the signals generated by the sensors, generating data representing the image of the vehicle 5a. The data is supplied to the ticket machine 22. The machine 22 prints a ticket on the basis of the data and issues the ticket.

How the vehicle-detecting system described above operates will be described with reference to the flow chart of FIG. 7.

At the start-up of system, the optical line sensors 3a to 3g get linear images of the surface of the toll road 1 just under of them. The video signals of above linear images represent the condition of the road 1 when no vehicles are traveling in the view fields of all the line sensors 3a to 3g. The video signals are supplied to the signal-processing section 21 and stored therein as reference signals (Step A1).

Once the system is put into service, the optical line sensors 3a to 3g get the linear images of the surface of the road 1 and vehicles, if any, passing under the line sensors 3a to 3g. The video signals are supplied to the signal-processing section 21 (Step A2). The section 21 compares the signals with the reference signals, thereby obtaining the correlation between each video signal and the reference signal generated by the same line sensor (Step A3).

Further, the correlation between each video signal and the reference signal is compared with a

predetermined threshold value. The correlation is converted to a binary signal "1" if it is less than the threshold value, and converted to a binary signal "0" if it is equal to or greater than the threshold value (Step A4). The threshold value has been determined from two factors. The first factor is the stability of the video signals representing the condition of the road 1, and the second factor is the change which each video signal undergoes when a vehicle passes under the line sensor.

Next, a logical sum of four binary signals pertaining to the video signals generated by the line sensors 3a, 3c, 3e and 3g is obtained (Step A5). Further, a logical sum of three binary signals pertaining to the video signals generated by the line sensors 3b, 3d and 3f is obtained (Step A6).

Assume a motor cycle 5a travels along the center line of the second lane 4b, entering the overlapping parts of the view fields of the line sensors 3c, 3d and 3e, as is illustrated in FIG. 8. In this case, the video signal generated by the optical line sensor 3d has a signal differing section, i.e. region of the above binary signal "1", S3. The section S3 represents a width greater than the width of the motor cycle 5a. This is because the line sensor 3d is located right above the motor cycle 5a. Meanwhile, the video signals generated by the line sensors 3c and 3e have signal

differing sections, i.e. regions of the above binary signal "1", S1 and S2 shown in FIG. 8. As comparison between FIG. 8 and FIG. 3 may reveal, the sections S1 and S2 are greater than the sections S1 and S2 of the signals generated in the conventional vehicle-detecting system. This is because the view fields 3x of the line sensors 3c and 3e overlap that of the line sensor 3d by the width of the motor cycle 5a on the surface of the toll road 1. On the road surface, the right edge of the view field of the sensor 3c and the left edge of the view field of the sensor 3e are almost aligned with the right and left sides of the motor cycle 5a, respectively.

Hence, when the signal-processing section 21 obtains a logical sum of video signals of line sensor 3c and 3d, there will be detected a region of "1" which has a width corresponding to the width of the motor cycle 5a and which momentarily exists in the view fields of the optical line sensors 3c and 3e.

Then, a logical product of the logical sums obtained in Steps A5 and A6 is obtained (Step A7). As a result, the width 6 and position of the vehicle (i.e., motor cycle 5a) can be accurately measured by the result of step A7.

As shown in FIG. 4, the line sensors 3b, 3d and 3f are spaced from the line sensors 3a, 3c, 3e and 3g by a distance d, by means of the supports 9a, 9b and 9c.

Therefore, that part of the video signal which represents a fallen leaf, trash or the like lying in only one side of the field of above adjacent groups of the sensors will be canceled out by obtaining the logical product of the logical sums acquired in Steps A5 and A6. Thus, the vehicle will be detected with accuracy.

The distance d may be much shorter than the length of the vehicle 5 or the motor cycle 5a. Then, the vehicle or motor cycle passing under the gantry 2 will exist, though momentarily, in the view fields of any two adjacent line sensors (e.g., sensors 3a and 3b, sensors 3b and 3c, and so on). The video signals generated by the two adjacent line sensors will not be canceled when the logical product of the logical sums acquired in Steps A5 and A6 is obtained.

If no region of "1" is detected as the result of logical calculation in the above Step A7, it is determined that no vehicles are traveling on the lane 4a, 4b or 4c (Step 8). If this case, i.e. NO in Step A8, the operation goes to Step A9. In Step A9 the reference signals are updated (Step A9). The operation then returns to Step A2.

If YES in Step A8, that is, if a region of "1" is detected, it is determined that a vehicle may be traveling under the line sensors or something may spread over the road 1. In this case, the operation

goes to Step A10. In Step A10, signals of the photoelectric sensor apparatus 8 are checked. More specifically, if all photo-detector elements 31a, 31b, 31c, 31d, 31e, 31f and 31g receive the light beams 8x, it is determined nothing exists under the line sensors to intercept the light beams 8x. If one of photo-detector elements 31a, 31b, 31c, 31d, 31e, 31f and 31g do not receive the light beams 8x, it is determined a vehicle 5 exits under the line sensors, intercepting at least one light beams 8x (Step A10).

If NO in Step A10, that is, if the photoelectric sensor apparatus 8 detects no vehicle, the operation goes to Step A11. In Step A11, it is determined that the region of "1" detected by the line sensors 3a to 3g is something fallen and spreading on the toll road 1, and the reference signals are updated. The operation then returns to Step A2.

If YES in Step A10, that is, if the photoelectric sensor apparatus 8 detects a vehicle 5, the operation goes to Step A12. In Step A12, the signal-processing section 21 supplies a signal indicating the entry of the vehicle 5, to the ticket-issuing machine 22 installed at the tollgate. In this case, the reference signals are not updated. If the reference signals are updated, there will arise the possibility that a vehicle may not be detected in the subsequent processing of video signals.

Upon receipt the signal from the signal-processing section 21, the ticket-issuing machine 22 issues a ticket to the driver of the vehicle 5 detected in Step A10. The vehicle 5 can therefore pass through the tollgate.

Thus, any vehicle that travels under the gantry 2 can be detected as a solid body having a width, length and height which are greater than the values determined by the positions of the optical line sensors 3a to 3g and the positions of the photoelectric sensor apparatus 8, in detail, photo-projector and detector elements 30a to 30g and 31a to 31g. Even a vehicle having a small width, such as a motor cycle, can be detected, and its width can be accurately measured. If small things such as a fallen leaf or trash happen to be on the road 1, they would not be detected as vehicles. Further, sand or earth spreading, covering an area on the road 1, would not be detected as a vehicle. The vehicle-detecting system can operate reliably, detecting vehicle traveling under the gantry 2 with high accuracy.

As has been described, the view field 3x of each line sensor overlaps that of either adjacent line sensor by the sum of half the view filed 3x and the width of a motor cycle, on the surface of the toll road 1. Hence, when a narrow vehicle such as a motor cycle passes right below a line sensor, entering the overlapping parts of the view fields of the two

immediately adjacent line sensors, the adjacent line sensors generate video signals which have sufficiently wide signal differing sections. The system can accurately and reliably determine the position and width of the vehicle, from a logical product of the three video signals which are generated by, respectively, the line sensor located right above the vehicle, the line sensor located at an upper-left position, and the line sensor located at an upper-right position.

Moreover, since the line sensors 3b, 3d and 3f are positioned in front of the line sensors 3a, 3c, 3e and 3g and spaced therefrom by the distance d, anything shorter than the distance d is never detected as a vehicle. The system would not detect a small thing like trash as a vehicle at all.

As indicated above, the light beams which the photo-projector elements emit toward the photo-detector elements intersect with the optical axes of the optical line sensors. Comprised of the photo-projector 8a with plurality of photo-projector elements and photo-detector 8b with plurality of photo-detector elements, the photoelectric sensors apparatus 8 can detect the height of any object that is found to be a vehicle by means of the optical line sensors. If the height is less than a motor cycle or a car, that object is determined to be a thing fallen onto the road, such as sand or earth. This serves to increase the operating

reliability of the vehicle-detecting system.

As described above, the present invention can provide a vehicle-detecting system which can detect an solid object as a vehicle if the object has a width, length and height, all greater than the values determined by the positions of the optical line sensors and the positions of the photoelectric sensor apparatus, i.e. photo-projector elements and photo-detector elements, and which can therefore detect vehicles with high accuracy and reliability.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalent.

CLAIMS

1. A system for optically detecting vehicles traveling a road having a plurality lanes, said system comprising:

a gantry provide at the road so as to straddle the plurality lanes;

a plurality of optical line sensors provided on said gantry, for getting linear images of a surface of the road, said optical line sensors arranged in two rows and in a staggered pattern such that each has a view field overlapping the view filed of either adjacent optical line sensor by the sum of half the view field and a width of a motor cycle;

photoelectric sensor apparatus consisting of photo-projector elements and photo-detector elements, and having optical axes which are parallel to each other and are substantially located in the position of the view fields of said optical line sensors; and

a signal-processing section for detecting a vehicle traveling under said gantry in accordance with output signals of said optical line sensors and output signals of said photoelectric sensor apparatus, by using reference signals which said optical line sensors generate when no vehicles travel under them.

2. A system according to claim 1, wherein said signal-processing section includes means for converting a correlation between the output signal of each optical

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line sensor and the corresponding reference signal into a binary signal, obtaining a logical sum of the binary signals pertaining to the optical line sensors of one row and a logical sum of the binary signals pertaining to the optical line sensors of the other row, obtaining a logical produce of the two logical sums, and determining, from the logical product, whether a vehicle is traveling under said gantry.

3. A system according to claim 1, wherein said signal-processing section includes means for converting a correlation between the output signal of each optical line sensor and the corresponding reference signal into a binary signal, obtaining a logical sum of the binary signals pertaining to the optical line sensors of one row and a logical sum of the binary signals pertaining to the optical line sensors of the other row, for obtaining a logical produce of the two logical sums, thereby generating a vehicle detection signal, and detecting a vehicle on the basis of the vehicle detection signal and vehicle detection signals generated by said photoelectric sensors.

4. A system according to claim 1, wherein said signal-processing section includes means for updating the reference signals to the output signals of said optical line sensors, which indicate that no vehicles are traveling under said gantry.

5. A system according to claim 1, further

comprising a ticket-issuing machine for issuing a toll ticket when said signal-processing section detects a vehicle traveling under said gantry.

6. A system for optically detecting vehicles traveling along the lanes of a road, substantially as hereinbefore described with reference to FIGS. 4 to 8 of the accompanying drawings.

