



G00002

APPARATUS AND METHOD FOR DETECTING AND COUNTING VEHICLES

BACKGROUND OF THE INVENTION



159159

This invention relates generally to a system and a method for detecting and counting moving vehicles on a road.

Currently, there are a variety of known vehicle detection and counting systems. Commonly used sensors for vehicle detection include inductive loops, pressure sensitive strips, three-beam infrared sensors, and electromagnetic sensors. The induction loops are installed beneath the road pavement and capable of detecting vehicle presence, speed and length. The pressure sensitive strips are installed on the road surface for measuring the applied pressure exerted on the strips. Electromagnetic sensors measure the changes in the earth's magnetic field to detect vehicles. The three-beam infrared sensors are installed above ground and are made up of transmitters and receivers. The infrared sensors are adapted to generate three infra-red beams parallel to ground and orthogonal to the direction of the passing vehicle. As the vehicle passes through the beams, the sensors are adapted to detect a sequence pattern that only a vehicle will generate.

The above sensors have reliability problems because they are not able to differentiate a vehicle from other moving objects such as motorcycles and trolleys. Another shortcoming of these detection systems is that they are not able to detect vehicle tail-gating; i.e., closely spaced vehicles. They have difficulty in discriminating between one large object entering the detection area or two closely spaced smaller objects.

Video cameras have been used to identify vehicles, but they require intensive computational image processing. Furthermore, because video images are dependent on the lighting conditions and weather, they may not produce consistent results when conditions are bad. Video cameras would require external illuminating source for accurate detection. Thus, detection systems using video cameras are relatively expensive to install.

There remains a need for a detection system capable of reliably classifying and counting vehicles that can be installed at low cost. Furthermore, there is a need for a system that has the ability to detect vehicle tail-gating because this is important for accurate counting.

SUMMARY OF THE INVENTION

The present invention is directed to a system and method for detecting and counting moving vehicles on a road or at the entrance and exit junction of a building or a car park. The vehicle detection and counting system of the present invention comprises at least two ultrasonic sensors for determining the width of the moving vehicle, at least two infrared sensors for detecting incoming vehicle and direction of travel, a controller for processing the signals from the sensors and differentiating a vehicle from other moving objects, and a counter for counting the number of detected vehicles. By measuring the width of the moving vehicle, the vehicle detection and counting system is adapted to differentiate vehicles from unwanted moving objects like motorcycles and people. The system is mounted above the ground and is relatively inexpensive to install.

Another aspect of the present invention is that the vehicle detection and counting system is adaptable for detecting tailgating of a vehicle with the infrared sensors when installed at the entrance or exit of a car park with or without a barrier.

The novel features and advantages of the present invention will become more apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the schematic diagram of the vehicle detection and counting system in accordance with the preferred embodiment of the present invention.

FIG. 2 shows the top view of the installed vehicle detection and counting system.

FIG. 3 shows the side view of an arrangement in which two bars supporting the sensors used in the system are mounted to ground.

FIG. 4 shows another side view the bars shown in FIG. 3.

FIG. 5 shows the side view of an arrangement in which two bars supporting the sensors used in the system are mounted to the walls.

FIG. 6 shows a flowchart depicting the first part of the method for vehicle detecting and counting moving vehicles in accordance with the preferred embodiment of the present invention.

FIG. 7 shows a flowchart depicting the second part of the method for detecting and counting moving vehicles.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to vehicle detection and counting system that can be installed at the entrance and exit of a road or building. Referring to FIG. 1, the vehicle detection and counting system of the present invention basically comprises at least one pair of infrared sensors 1 and 2, at least one pair of ultrasonic sensors 3 and 4, a controller 5, a vehicle counter 6 and a display device 7. Infrared sensor 1 includes transmitter T1 and receiver R1. Infrared sensor 2 includes transmitter T2 and receiver R2. The infrared sensors are operable to detect the presence of a moving object in a defined zone where the infrared sensors are mounted. The controller 5 is adapted to capture the output signals from the infrared sensors 1 and 2, and trigger the ultrasonic sensors 3 and 4 to measure the width of the moving object. The controller 5 is operable to determine if the sensed object is a vehicle based on the measured width and to control the vehicle counter 6 to count the vehicle after it is classified as such. The display device 7 in communication with the controller 5 is adapted to display the results or raw data. Light emitting diodes (LEDs) 9 are provided for diagnostic and alignment purposes. The controller 5 may be linked to other controllers 8 by fieldbus.

FIG. 2 shows the top view of the vehicle detection and counting system with a passing vehicle 18. A pair of bars 10 and 11 are installed above the ground and spaced from each other to define the detection zone. A moving vehicle or another moving object may enter the detection zone in the direction A or B. The bars 10 and 11 are arranged so that they are substantially parallel to the direction of the moving vehicles. At both ends of bar 10 are housings 12 and

13, which hold infrared transmitters T1 and T2, respectively. At both ends of bar 11 are housings 14 and 15, which hold infrared receivers R1 and R2, respectively. Ultrasonic sensor U1 is installed in the center housing 17 of bar 11, and ultrasonic sensor U2 is installed in the center housing 16 of bar 10. The distance (z) between the two infrared sensors is determined by the maximum speed of the moving object to be detected and the maximum distance between the ultrasonic sensors of about 6 meters. It has been determined that a bar length of approximately one meter long is sufficient for detecting most vehicles traveling at a speed under 30 km/hr. However, it should be pointed out that other bar lengths is possible. The bars 10 and 11 may be mounted substantially parallel to the ground via a pair of vertically grounded poles 19 and 20 as shown in FIG. 3. FIG. 4 shows another side view of one of the mounted bars, in this case bar 10. Light emitting diodes (LEDs) 9 are provided at the center of each bar as shown in FIG. 4 for diagnostic and alignment purposes. Alternatively, LEDs 9 may be mounted on the side of the each bar. When the infrared beams are not broken by a moving object and the infrared sensors are in line of sight, the LEDs will remain lighted indefinitely. When the beams are broken or the infrared sensors are out of sight, the LEDs will not be lighted up. By this arrangement, the bars 10 and 11 can be aligned easily.

As an alternative, the bars 10 and 11 may be mounted onto the walls at a distance above ground as shown in FIG. 5. The bars 10 and 11 may be installed at a distance (h) of about 0.5 to 0.7 meter above the ground surface. This height has been found to be sufficient for detecting most vehicles, particularly when the system of the present invention is used in a multi-story car park, which normally

has a height limit of about 2 meters. In the case of open car parks, there may be a need for detecting big trucks, which have a body height of more than 0.7 meter. For detecting big trucks, the system of the present invention can be modified by providing an additional, upper arrangement of infrared sensors and ultrasonic sensors above bars 10 and 11 so that the infrared beams and the ultrasonic sound waves will be generated at two different heights relative to ground. For example, two additional bars, with the same construction as bars 10 and 11, can be installed above and parallel to bars 10 and 11 to accommodate the height of trucks. In such an arrangement, the upper bars will operate in the same manner as the lower bars 10 and 11.

The infrared sensor used in the present invention is a through-beam type, which means that it needs a transmitter and a receiver. The transmitter transmits an infrared beam in a straight line to the receiver at 90° with respect to the bar. Arrows L1 and L2 in FIG. 2 depict the infrared beams generated by the infrared sensors 1 and 2. The infrared sensors are oriented to generate infrared beams that will be broken by a moving object moving in the traveling direction. Line of sight is blocked if the infrared beam is broken, i.e. interrupted, by a moving object. The ultrasonic sensors transmit a sound at 90° with respect to the bar. Even though beams L1 and L2 are shown in FIG. 2 as being perpendicular to the traveling direction of the moving vehicle, it is not necessary for the moving vehicle to be traveling perpendicular to the beams.

FIG. 6 shows a flowchart depicting the method of operating the vehicle detection and counting system shown in FIG. 2. When the system is initialized, infrared transmitter T1 transmits infrared beam L1 to receiver R1, and transmitter

T1 transmits infrared beam L2 to receiver R2, and the system is in an idle state 100. When a moving vehicle passes through the detection zone, one of infrared beam L1 and L2 will be broken first. Depending on which beam is broken first, the direction of the moving object can be determined. At step 101, the system determines whether beam L1 is broken. If yes, then the system is activated at step 102 to follow the logic that the object is possibly moving in direction A. The system determines whether the sensed object is present for a minimum time period t_1 at step 103. This is done to filter out unwanted noises that trigger the infrared sensor, e.g. people walking by, or electrical noise from the surrounding environment. The minimum time period t_1 is predetermined by assuming a maximum travel speed of the moving vehicle as it approaches the detection zone. If the system is installed at the entry or exit of a road or building, the maximum speed of the moving vehicle can be assumed to be less than 30 km/hr. If the detected time of the infrared sensor is less than the minimum time t_1 , the system goes back to idle state 100. If the detected time is greater than the minimum time t_1 , then the system proceeds to step 104 to determine whether beam L2 is broken. If beam L2 is found to be unbroken at step 104, the system checks beam L1 again at step 105 to find out if it is broken. If beam L1 is still not broken, the system returns to step 104. The checking at steps 104 and 105 goes on indefinitely until beam L1 or L2 is broken. If beam L1 is found to be broken at step 105, then the system returns to step 103. If beam L2 is found to be broken at step 104, the system confirms that the object is moving in direction A and the ultrasonic sensor U1 is activated to measure the distance y_1 at step 106, wherein y_1 is the distance between ultrasonic sensor U1 and the moving object as shown

in FIG. 2. The ultrasonic sensor U2 is also activated to measure the distance y_2 at step 107, where y_2 is the distance between ultrasonic U2 and the moving object as shown FIG. 2. In order to measure the distance (y_1 or y_2) between each ultrasonic sensor and the moving object, the controller 5 activates each ultrasonic sensor to transmit an ultrasonic signal toward the moving object. The echo of the reflected signal by the moving object is received by the ultrasonic sensor. The returned echo signal is then processed by the controller 5. At least three readings should be taken and the best average of the readings will be used.

Steps 101-107, as described above, represent the logic for detecting an object moving in direction A. The logic for detecting an object moving in direction B is represented by steps 108-114, which are the reverse of steps 101-107. If beam L1 is found to be unbroken at step 101, then the system determines whether beam L2 is broken at step 108. If yes, then the system is activated at step 109 to follow the logic that the object is possibly moving in direction B. The system determines whether the sensed object is present for a minimum time period t_1 at step 110. If the detected time is less than the minimum time t_1 , the system goes back to idle state 100. If the detected timing is greater than the minimum time t_1 , then the system proceeds to step 111 to determine whether beam L1 is broken. If beam L1 is found to be unbroken at step 111, the system checks beam L2 again at step 112 to find out if it is broken. If beam L2 is still not broken, the system returns to step 111. The checking at steps 111 and 112 goes on indefinitely until beam L1 or L2 is broken. If beam L2 is found to be broken at step 112, then the system returns to step 110. If beam L1 is found to be broken at step 111, the system confirms that the object is moving in direction B and the

ultrasonic sensor U1 is activated to measure the distance y_1 at step 113. The ultrasonic sensor U2 is activated to measure the distance y_2 at step 114.

After step 107 or 114, the system follows the flow chart shown in FIG. 7. At step 115, the object's width is computed using the formula $y_3 = d - y_1 - y_2$, where d is the distance between the ultrasonic sensors U1 and U2. The system determines whether the computed width y_3 is within a vehicle width at step 116. If y_3 is not within a vehicle width, then the system returns to idle state 100. If y_3 is a vehicle width, then the detection timing of the infrared sensors is compared with a minimum time period t_2 at step 117 to confirm a minimum length of the moving vehicle. The minimum time period t_2 is the minimum time that the two infrared sensors detect a moving vehicle. Steps 116 and 117 are carried out to filter out unwanted objects such as people or motorcycles. At step 119, beam L1 is checked to see if it is broken. If no, then the system continues to check until beam L1 is broken. If beam L1 is broken, then beam L2 is checked. If beam L2 is not broken, the system continues to check until beam L2 is broken. If L2 is broken, the vehicle counter is triggered at step 121 to count the moving object as a vehicle moving in direction A or B. Steps 119 and 120 are carried out to determine the exit of the tail of the vehicle. The system returns to idle state 100 once the vehicle is counted at step 121.

When the vehicle detection and counting system of the present invention is installed at the entrance and at the exit of a parking area, a parking zone can be created. By zoning the car park, it is possible to implement a zone-specific guidance for larger, open-air car park or multi-level car park. This arrangement would provide a cost effective parking guidance system.

One important advantage of the vehicle detection and counting system of the present invention is that it is capable of detecting vehicle tailgating, i.e., closely spaced vehicles. Because the infrared beam is narrow, it can detect a small break between two closely spaced vehicles. The system can discriminate between vehicles moving at 20 km/hr with as little as 30 mm between their bumpers. In the past, people have tried to cheat by tailgating the exiting vehicle before the barrier is closed so as to avoid paying parking fees. When the system is installed just before the exit barrier, the system will be able to detect that a vehicle has already passed the barrier, and if another vehicle is detected before the barrier is closed again, tailgating would be detected. Various actions can be implemented when tailgating is detected, e.g. logging in an alarm in the computer, capturing the tailgating vehicle on the video, or activating a sound alarm.

The present invention provides a vehicle detection and counting system that is accurate and simple to install. Because the system of the present invention is easier to install than conventional detection systems, the cost of installation is thereby reduced.

Although the present invention has been described herein with specificity, it is not confined to the details and drawings described above but may be modified within the scope of the appended claims.

CLAIMS

1. A system for detecting and counting vehicles that are moving through a detection zone in a traveling direction, said system comprising:

at least two infrared sensors for detecting the presence of an incoming moving object and the direction of travel, the infrared sensors being mounted above ground and spaced along the traveling direction within the detection zone;

at least two ultrasonic sensors for determining the width of the moving object, the ultrasonic sensors being mounted above ground and within the detection zone;

a controller coupled to the infrared sensors and the ultrasonic sensors for processing the signals received from the sensors and differentiating a moving vehicle from other moving objects; and

a counter for counting the number of detected vehicles.

2. The system of claim 1, wherein the infrared sensors are oriented to generate infrared beams that will be interrupted by the passage of the moving object traveling through the detection zone.

3. The system of claim 2, wherein the infrared sensors are oriented to generate infrared beams that are substantially perpendicular to the traveling direction of the moving object.

4. The system of claim 1, wherein each infrared sensor comprises a transmitter and a receiver, the transmitter being operable to transmit an infrared beam in a straight line to the receiver.

5. The system of claim 1, wherein the ultrasonic sensors are positioned so as to transmit sound wave toward the moving object as it moves through the detection zone and to receive the reflections of the sound from the moving object.
6. The system of claim 5, wherein at least two ultrasonic sensors are positioned on opposite sides of the detection zone so that they will transmit sound waves toward the moving object in opposite direction to each other.
7. The system of claim 4, further comprising:
- (a) a first bar supporting
 - a first housing at one and a second housings at the other end, each of said first and second housings containing one of the infrared transmitters, and
 - a third housing between the first and second housings, said third housing containing one of the ultrasonic sensors; and
 - (b) a second bar supporting
 - a fourth housing at one end and a fifth housing at the other end, each of said fourth and fifth housings containing one of the infrared receivers, and
 - a sixth housing between the fourth and fifth housings, said sixth housing containing one of the ultrasonic sensors;
- wherein the first and second bars are mounted substantially parallel to the direction of travel and at a spaced distance from each other.
8. The system of claim 7, wherein each of the first and second bars is mounted at a distance above ground on a pole having a height equal to said distance.

9. The system of claim 7, wherein each of the first and second bars is mounted on a wall at a distance above ground.

10. The system of claim 1, wherein the infrared sensors and the ultrasonic sensors are arranged at different heights so that the system can detect trucks as well as other vehicles.

11. A method for detecting and counting vehicles that are moving through a detection zone in a traveling direction, said method comprising:

(a) projecting at least two infrared beams across the detection zone so that the beams will be broken by the passage of an object moving through the detection zone, the beams being spaced along the travel direction of the moving object;

(b) detecting the presence of a moving object in the detection zone based on the length of time during which the beams are broken;

(c) determining the direction of travel based on the sequence in which the beams are broken;

(d) transmitting ultrasonic sound waves towards opposite sides of the moving object and receiving the reflections of the ultrasonic sound wave;

(e) calculating the width of the moving object based on the timing of the reflections;

(f) determining whether the length of time for the broken beams and the width of the moving object satisfy the criteria for a moving vehicle;

(g) counting the moving object as a moving vehicle if said criteria are met.

12. The method of claim 11, wherein steps (d) and (e) are repeated several times so that several width measurements are taken, then the average of the width measurements is calculated.

13. The method of claim 11, wherein at least two infrared beams are projected, one beam at each end of the detection zone, whereby a moving vehicle passing through the detection zone will interrupt one of the beams at the end before interrupting the one at the other end.

14. The method of claim 11, wherein the ultrasonic sound waves are transmitted by at least two ultrasonic sensors located on opposite sides of the detection zone, said at least two ultrasonic sensors being oriented so that ultrasonic sound waves will be transmitted in a direction substantially perpendicular to the direction of travel.

15. The method of claim 11, wherein the infrared beams are projected at different heights relative to ground so that the presence of moving trucks as well as other vehicles can be detected.