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(71) Applicant: **MOVYON S.p.A.**
00159 Roma (IT)

(72) Inventor: **FABBRIZI, Emanuele**
Roma (IT)

(74) Representative: **Pietra, Giulia et al**
Marchi & Partners S.r.l.
Via Vittor Pisani, 13
20124 Milano (IT)

(54) **SYSTEM AND METHOD FOR DETECTING THE CLASS OF A
VEHICLE IN TRANSIT**

(57) A system and a method for detecting the class of a vehicle in transit along a road section are described. An image acquisition device acquires the images of the vehicle, in which the license plate (or license plates) of the vehicle is/are visible. In the acquired images the license plate is identified, its properties (shape, syntax of the license plate number, number of visible license plates of the vehicle) are determined and, if these properties uniquely indicate that the vehicle belongs to a certain class, it is concluded that the vehicle belongs to that class. If this is not the case, it is determined whether in the images acquired there are present further retroreflective elements which, according to the existing regulations, must be affixed to certain categories of vehicles (retroreflective panels for trucks or for semi-trailer trucks, etc.). Then the properties of these possible further elements are determined and, if these uniquely indicate that the vehicle belongs to a certain class, it is concluded that the vehicle belongs to that class.

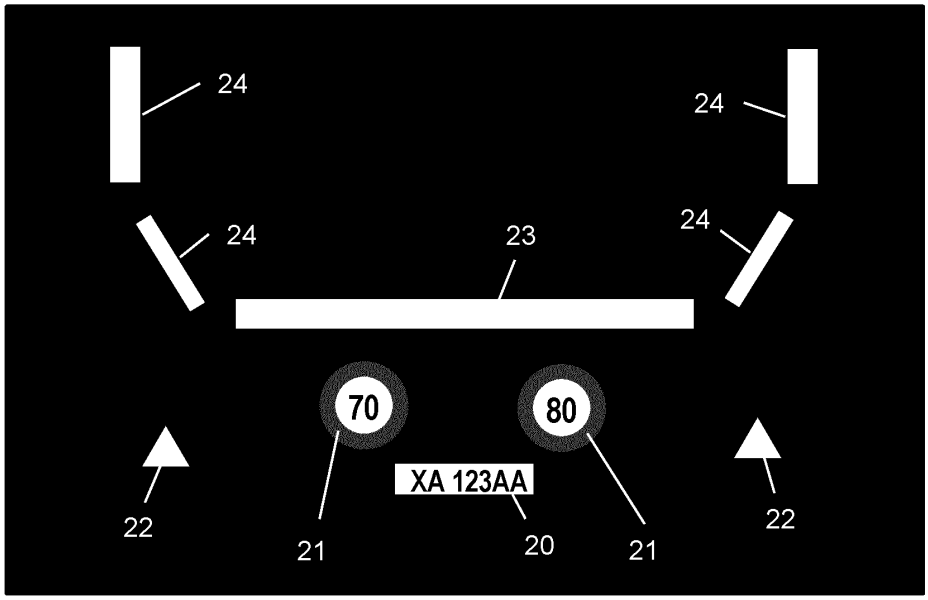

Fig. 2

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Description

Technical field

[0001] The present invention relates in general to the field of methods and systems for controlling traffic. In particular, the present invention relates to a system and a method for detecting the class of a vehicle in transit.

Background art

[0002] As is known, vehicles are classified depending on their type, their use and their weight, power and maximum speed. For example, in the countries of the European Union, the UNECE classification, which provides for the subdivision of the vehicles into different classes, is applied to vehicles. The vehicles which belong to each class are subject to different limits and obligations as regards type approval and road driving performance.

[0003] Systems which are able to automatically detect the class to which a vehicle in transit belongs are known. These systems are positioned for example at the access gates of toll road sections or at the access gates of road sections which are subject to traffic restrictions or at stations for checking the speed of vehicles in transit. Depending on the class detected for each vehicle in transit, it is thus possible to determine the toll which is due, the access right or prohibition, or the applicable speed limit.

[0004] Different types of systems for detecting the class of vehicles in transit are known. These systems in general make use of radar or laser sensors or magnetic loops which are installed in the road surface. These sensors generally acquire information about the structure of the vehicle, namely the information regarding the shape of its profile and/or the distribution of its volumes and/or the number of its axles, etc. Based on this information the class to which the vehicle belongs is then determined.

[0005] EP 2 686 841 describes a system for the classification of vehicles which provides for acquiring rear images of the vehicles and determines firstly whether it consists of a small or large vehicle, based on the width of the vehicle in relation to the width of the lane. Then it determines a more accurate classification depending on the minimum height of the vehicle in relation to the ground (clearance). In the case of vehicles which cannot be classified using the above criteria, it is envisaged applying specific rules, such as the presence of a striped panel which indicates that the vehicle belongs to the class of trucks.

[0006] US 2013/050492 A1 describes a method for classifying vehicles, which involves acquiring a 3/4 image of the front side of the vehicle in which the license plate is visible. The contour of the license plate is detected in the image and, by means of a comparison with an archive of standard license plate formats, a rule for correction of the perspective of the acquired image is determined. The rule is then applied to a portion of the image in which, in addition to the license plate, other characteristic parts of the vehicle (for example the front headlights and the front grille) are visible. Once the contours of these characteristic parts have also been identified, the vehicle class is determined based on the comparison with an archive of reference images of vehicles belonging to different classes, applying a similarity criterion.

Summary of the invention

[0007] The Applicant has noted that the known systems for detecting the class of vehicles in transit have a number of drawbacks.

[0008] In particular, the known systems which use radars, lasers or magnetic loops often are unable to perform reliable detection of the class of the vehicle, since the structural features of the vehicles which can be detected by these sensors often fall within two or more classes. This results in classification errors which may lead for example to incorrect calculation of the toll due or the applicable speed limit. This may happen, for example, in the case of commercial vans and trucks. These types of vehicles belong to two different classes, but their structural features which may be detected by the sensors of the known systems (length, shape of the profile, number of axles) may be easily confused with each other. Errors in the classification of vehicles which belong to one of the two classes may therefore occur. These errors may in turn result in incorrect determination of the applicable highway speed limit which, in the case of commercial vans, is 130 km/h, while in the case of trucks it is 100 km/h.

[0009] With regard to the system described in EP 2 686 841 an accurate determination of the width of the vehicle and its minimum height in relation to the ground requires a complex geometric calibration of the apparatus used to acquire the images of the vehicles. Furthermore, in order to be able to determine correctly the side edges and bottom edges of the vehicle, the whole rear shape of the vehicle must be recorded in the images, said operation being particularly complex in particular in the case of multiple lanes situated alongside each other, where the vehicles may pass over any point of the roadway and therefore be located only partially within the viewing range of each of the system telecameras. The angle of acquisition of the images is also limited, since the determination of the width of the vehicle and its minimum height in relation to the ground become less accurate if the images are taken from too high up or too far on one side. Moreover, in poor visibility conditions (heavy rain or at nighttime) it may happen that the edges of the vehicle are not clearly visible or not visible at all in the image, something which does not allow the system to perform any classification. The classification system may therefore not be very reliable.

[0010] As regards the system described in US 2013/050492 A1, it requires to determine with precision the contours of the license plate, of the vehicle and of other characteristic parts of the vehicle , something which requires that the license plate and the other characteristic

parts of the vehicle should not too small in the image and moreover that the perspective of the image acquired should be precisely corrected. Moreover, in this case also, in the event of poor visibility conditions (heavy rain or at nighttime), it may happen that the edges of the vehicle and of the other characteristic parts of the vehicle are not clearly visible or not visible at all in the image, something which does not allow the system to perform a correct classification.

[0011] An object of the present invention is to provide a system and a method for detecting the class of a vehicle in transit which are able to overcome the aforementioned drawbacks.

[0012] In particular, an object of the present invention is to provide a system and a method for detecting the class of a vehicle in transit are more reliable, namely which are subject to a significantly limited risk of classification errors.

[0013] The Applicant has realized that the shape of the license plate and the syntax of the license plate vary depending on the type of vehicle. For example, in the case of Italian motorcycles and mopeds the license plate has a square shape, while the license plate number has a syntax of the type "AA12345" and "X12345", respectively, and is arranged in two rows. In motor vehicles, instead, the license plate is rectangular, while the license plate number has a syntax of the type "AA 123AA" and is arranged in a single row. In the case also of trailers (for motor cars, trailer trucks and semi-trailer trucks) the license plate is rectangular; in the case of trailers subsequent to 2001, the syntax of the license plate number is similar to that of vehicles, but the first letter is always "X", while for trailers prior to 2011 the syntax of the license plate number is of the type "AA123456". In the case of all-terrain vehicles, instead, the license plate has a square shape and the syntax of the license plate is similar to that of motor cars, but the first letter is always "Z". And so on. Moreover, in the case where a trailer is present (namely in the case where the vehicle is a vehicle assembly composed of two units, i.e. tractor unit and the trailer), the vehicle comprises two license plates (one for each unit).

[0014] The Applicant has realized that, since there are significant differences between one class and another, the license plates of the vehicles may be used to provide a system which is able to detect in a particularly reliable manner the classes to which the vehicles in transit belong.

[0015] In particular, according to embodiments of the present invention, a system for detecting the class of a vehicle in transit is provided, said system comprising an image acquisition device suitable for acquiring one or more images of the vehicle, in which at least one portion of the surface of the vehicle provided with at least one license plate of the vehicle is visible. The system also comprises a data processing unit which identifies in the acquired image the at least one license plate present and determines one or more properties thereof. On the basis of the properties of the license plate identified in the acquired image, the data processing unit of the system then determines the class to which the vehicle belongs.

[0016] In the present description and the claims, the expression "license plate property" will indicate its shape, the syntax of the license plate number shown on it or the number of vehicle license plates which are visible in the image. The "license plate property" is therefore a property of the license plate per se, and not of the license plate in relation to other elements present in the images (such as its distance from the edge of the vehicle or the road surface).

[0017] The system for detecting the class of a vehicle in transit according to embodiments of the present invention is advantageously more reliable than the known systems.

[0018] The license plate, which has a retroreflective background on which the alphanumeric characters which form the license plate number are written, is indeed visible and identifiable in the images with a particularly high degree of reliability (in particular in the case of infrared images). In particular, the license plate properties which vary between one class and another (and which therefore allow one class to be distinguished from another class) are identifiable in the images with a particularly high degree of reliability. In this way, advantageously, the risk of incorrect classification of the vehicle is reduced significantly, especially in the case of vehicles which with the known detection systems fall within two or more classes.

[0019] On the other hand, since the classification is based on properties of the license plate per se (and not of the license plate in relation to other elements present in the image, for example its distance from the bottom edge of the vehicle and/or the ground), calibration of the image acquisition device is not required. The acquisition angle is moreover a less critical parameter, such that the image acquisition device may be positioned along the side of the carriageway so as to acquire 3/4 images of the vehicles, or on an arch or flyover above the carriageway, without this affecting the accuracy of determination of the license plate properties and therefore of the class to which the vehicle belongs.

[0020] Furthermore, the determination of the license plate properties according to the present invention does not require particularly precise correction of the perspective of the image acquired. More specifically, the determination of the syntax of the license plate number and/or of the number of license plates visible in the image may be performed with a certain degree of reliability also where the correction of the perspective of the acquired image is not particularly accurate or is not even possible. On the other hand, the determination of the shape of the license plate according to the present invention consists in calculating the height to width ratio (or the reciprocal ratio), said calculation - differently from, for example, the exact determination of the positions of the corners of the license plate or its contour - being able to be performed in a reliable manner also where correction of the per-

spective of the acquired image is not particularly accurate or is not even possible.

[0021] According to a first aspect, a system for detecting the class of a vehicle in transit along a road section is provided, the system comprising:

- an image acquisition device located along the road section, the image acquisition device being configured to acquire at least one image of the vehicle, at least one license plate of the vehicle being visible in the at least one image; and
- a data processing unit cooperating with the image acquisition device, the data processing unit being configured to identify said at least one license plate in said at least one image, to determine at least one property of said at least one license plate and, if said at least one license plate uniquely indicates that the vehicle belongs to a class, to determine that the vehicle belongs to said class.

[0022] Preferably, the image acquisition device comprises an infrared image acquisition device and said at least one image of the vehicle comprises at least one infrared image of the vehicle.

[0023] Preferably, said at least one image of the vehicle comprises at least one rear image of the vehicle.

[0024] Preferably, said at least one rear image of the vehicle is acquired at an angle with respect to the direction of travel of the vehicle, in the horizontal plane, of between 0° and 40°.

[0025] Preferably, said at least one property of said at least one license plate comprises at least one of the following: shape of said at least one license plate, syntax of a license plate number shown on said at least one license plate, and number of license plates visible in said at least one image.

[0026] Preferably, determining the shape of the license plate comprises measuring the height and width of the license plate in the at least one image of the vehicle and calculating the ratio between height and width or the reciprocal ratio.

[0027] Preferably, said data processing unit is also configured, if said at least one property of said at least one license plate does not uniquely indicate that the vehicle belongs to any class, to determine whether at least one further retroreflective element present on the surface of the vehicle is visible in said at least one image.

[0028] Preferably, the at least one further retroreflective element is present on a rear surface of the vehicle.

[0029] Preferably, said at least one further retroreflective element comprises one or more of the following: rectangular retroreflective panel for trucks, rectangular retroreflective panel for trucks or trailer trucks, retroreflective label indicating the applicable speed limit, retroreflective triangles for trailers, set of retroreflective strips defining the rear shape of the vehicle.

[0030] Preferably, the data processing unit is configured to determine at least one property of said at least one further retroreflective element and, if said at least one property of said at least one further retroreflective element uniquely indicated that the vehicle belongs to a class, determining that the vehicle belongs to this class.

[0031] Preferably, said at least one property of said at least one further retroreflective element comprises at least one of the following: absence/presence of said at least one further retroreflective element and, if present, shape of said at least one further retroreflective element, presence of a drawing, pattern or writing on said at least one further retroreflective element.

[0032] Preferably, the system also comprises a sensor configured to acquire information about the shape of the profile of the vehicle and/or length of the vehicle and/or number of axles of the vehicle and/or position of the axles of the vehicle, the data processing unit being configured to first determine the class to which the vehicle belongs on the basis of the information acquired by the sensor, and to confirm the class to which the vehicle belongs on the basis of said at least one property of said at least one license plate.

[0033] Preferably, said sensor comprises a radar sensor and/or a laser sensor and/or a magnetic loop sensor.

[0034] Preferably, the image acquisition device and the data processing unit are comprised in a detection station located along said road section.

[0035] According to one embodiment, the data processing unit is incorporated in the image acquisition device.

[0036] According to a second aspect, the present invention provides a method for detecting the class of a vehicle in transit along a road section, the method comprising:

- by means of an image acquisition device located along the road section, acquiring at least one image of the vehicle, at least one license plate of the vehicle being visible in said at least one image; and
- by means of a data processing unit cooperating with the image acquisition device, identifying said at least one license plate in said at least one image, determining at least one property of said at least one license plate and, if said at least property of said at least one license plate uniquely indicates that the vehicle belongs to a class, determining that the vehicle belongs to said class.

Brief description of the drawings

[0037] The present invention will become clearer from the following detailed description, provided by way of a non-limiting example, to be read with reference to the accompanying drawings, in which:

- Figure 1 shows in schematic form a system for detecting the class of a vehicle in transit, according to an embodiment of the present invention;
- Figure 2 shows an exemplary infrared image of a

vehicle in transit, acquired by the system of Figure 1;

- Figure 3 shows a flow chart illustrating the operation of the system shown in Figure 1, according to an embodiment of the present invention; and
- Figure 4 is a flow chart showing an example of implementation of some of the steps of the flow diagram shown in Figure 3.

Detailed description of embodiments of the invention

[0038] Figure 1 shows in schematic form a system 100 for detecting the class of a vehicle 10 in transit, according to an embodiment of the present invention.

[0039] The system 100 preferably comprises at least one class detection station 1 located along a road section 2 along which the vehicle 10 is in transit. For example, the class detection station 1 may be situated at a gate (e.g. entry or exit gate or intermediate gate) of a toll road section, or at a gate (entry or exit gate) of a road section subject to traffic restrictions, or at a station for recording the instantaneous and/or average speed of passing vehicles, located along road section 2.

[0040] The system 100 may comprise a plurality of class detection stations similar to the station 1, distributed along the road section 2. For example, in the case where the road section is subject to tolls, a class detection station may be provided at each entry gate and/or at each exit gate of the road section. In the case where the road section 2 has several lanes, a single detection station 1 may be provided for all the lanes, or a class detection station similar to the station 1 may be provided for each lane or only for the lane reserved for the transit of the types of vehicles which are of interest for detection of their class.

[0041] The class detection station 1 preferably comprises at least one image acquisition device 3. According to a preferred embodiment, the image acquisition device 3 is an infrared image acquisition device. The device 3 for example may comprise an infrared video camera or an infrared photo camera. For example, the Applicant has carried out some tests using the infrared camera Vega Basic produced by the company Tattile which has its head office in Mairano (Brescia, Italy).

[0042] Preferably, the class detection station 1 also comprises a data processing unit 4. The data processing unit 4 may be electrically connected to the device 3 as shown in Figure 1 or may be incorporated in the said device 3.

[0043] According to a particularly advantageous embodiment, the class detection station 1 also comprises at least one sensor 5 suitable for detecting information about the structure of the vehicle 10. Said sensor 5 may for example comprise a radar sensor or laser sensor or a magnetic loop sensor suitable for acquiring information on the shape of the profile of the vehicle 10 and/or the number of vehicle axles.

[0044] Optionally, the system 100 may also comprise a server 6 located in a position remote from the class detection station 1. Preferably, the class detection station 1 is connected to the server 6, for example via a communications network 7. The connection between the class detection station 1 and the communications network 7 may be of any known type, for example a mobile, W-Fi or cable connection (Ethernet, etc.).

[0045] Preferably, the image acquisition device 3 is configured, upon passing of the vehicle 10, to acquire one or more images of the vehicle 10 in which at least one portion of the surface of the vehicle 10 is visible, on which at least one retroreflective element, in particular at least one license plate of the vehicle, is present. If the image acquisition device 3 is an infrared image acquisition device, the one or more images of the vehicle 10 acquired are infrared images.

[0046] In addition to the license plate (or license plates, in the case of vehicles with a trailer), in accordance with the regulations laid down by the Highway Code, some types of vehicles (such as buses, trucks, trailer trucks and semi-trailer trucks) have further retroreflective elements fixed to their surface (in particular to their rear surface). These further retroreflective elements have different properties (namely shape, colors or writing), depending on the type of vehicle. For example, in addition to the license plate, on the rear surface of buses, trucks, trailer trucks and semi-trailer trucks there are also present circular shaped retroreflective labels showing the applicable speed limit. In addition to these, also rectangular retroreflective (and fluorescent) panels with yellow/red diagonal stripes are also fixed to the rear surface. The trailers of trailer trucks and semi-trailer trucks are also provided with rectangular panels which are retroreflective (and fluorescent), but yellow colored with a red edge, while the trailers are provided with retroreflective triangles. In general, goods transport vehicles are also provided with retroreflective strips which define the rear shape thereof. Any further retroreflective elements, if present, are also preferably visible in the at least one image acquired by the device 3.

[0047] In general, the further retroreflective elements are present only on the rear surface of the vehicles. The at least one image acquired by the device 3 is preferably therefore a rear image of the vehicle 10. This rear image is preferably acquired at an angle with respect to the direction of travel of the vehicle 10, in the horizontal plane, which varies between 0° (front view of the rear surface of the vehicle 10) and 40°, more preferably between 0° and 20°. The angle of acquisition with respect to the direction of travel of the vehicle 10 in the vertical plane preferably is comprised between 10° and 40°. In order to allow the device 3 to acquire a rear image of the vehicle 10 in these conditions, the device 3 is preferably positioned above the lane along which the vehicle 10 is passing.

[0048] Optionally, the class detection station 1 may also comprise a transit sensor (not shown in Figure 1) which is able to detect passing of the vehicle 10 and, in

response to this detection, to send to the device 3 an activation signal, in response to which the device 3 acquires one or more rear images of the vehicle 10.

[0049] Figure 2 is a schematic representation of an exemplary infrared rear image acquired by the device 3, assuming by way of a non-limiting example that the vehicle 10 is a trailer truck or a semi-trailer truck.

[0050] As shown in Figure 2, the image 11 shows, on a black background, a plurality of retroreflective elements fixed onto the rear surface of the vehicle 10. Said plurality of retroreflective elements comprises a single license plate 20 in which the license plate number "XA 123AA" is visible, and further retroreflective elements in addition to the license plate, namely: two retroreflective circular labels 21 which show two speed limits applicable to the vehicle 10 (70 km/h and 80 km/h, which are applicable on freeways and highways, respectively), two retroreflective triangles 22, a rectangular retroreflective panel 23 without diagonal stripes, and four retroreflective strips 24 which define the rear shape of the vehicle 20. Should the vehicle 10 be of another type (for example a motor car, a motorcycle, a bus or a truck), the retroreflective elements present in the image would be different and would have properties different from those shown in Figure 2. In the case of a motor car, for example, the only retroreflective element present would be the license plate and the license plate number would not start with the letter "X". In the case of a motorcycle or a moped, the license plate would have a different shape (square, not rectangular) and the license plate number would be arranged in two rows. In the case of a bus, the only further retroreflective elements in addition to the license plate would be the labels which indicate the applicable speed limits (which limits moreover would be different from those indicated by the labels 21). In the case of a truck, the license plate number would not start with the letter "X" and the rectangular retroreflective panel 23 would have diagonal stripes.

[0051] Since they exhibit remarkable differences from one class to another, the license plate (or license plates) and any further retroreflective elements present on the surface (in particular on the rear surface) of the vehicle 10 and visible in the at least one image acquired by the device 3 are advantageously used by the system 100 to the detect the class to which the vehicle 10 belongs.

[0052] This detection according to an embodiment of the present invention will now be described with reference to the flow chart of Figure 3.

[0053] According to an embodiment of the present invention, during a first step 300 the data processing unit 4 preferably receives from the device 3 at least one infrared image of the vehicle 10, in which the license plate (or license plates) of the vehicle 10 and any further additional retroreflective elements (labels, panels, etc., depending on the type of vehicle, as described above) are visible.

[0054] At step 300 the data processing unit 4 may receive from the device 3 also other information relating to the vehicle 10, such as its position on the carriageway (namely the lane along which the vehicle 10 is travelling, in the case of several lanes). Optionally, in step 300 the data processing unit 4 may receive from the device 3 also the license plate number of the vehicle 10. For this purpose, the device 3 is preferably provided with its own processor able to apply to the at least one infrared image acquired a processing algorithm able to identify the license plate number in the image and convert it into a sequence of alphanumeric characters (OCR algorithm). Alternatively, the reading of the license plate number from the at least one infrared image acquired may be performed by the data processing unit 4.

[0055] According to a preferred embodiment, the data processing unit 4 also receives from the sensor 5 information about the structure of the vehicle 10, for example about the shape of its profile and/or the number of its axles (step 301).

[0056] At step 301, the data processing unit 4 may receive from the sensor 5 also other information about the vehicle 10, for example its speed at the moment when it passes by the class detection station 1.

[0057] According to a preferred embodiment, the data processing unit 4 firstly applies to the information received from the sensor 5 a classification algorithm for performing a first determination of the class to which the vehicle 10 belongs (step 302). For example, in the case where the sensor 5 is a radar, the classification algorithm applied at step 302 may perform determination of the class based on the length of the vehicle 10; if instead the sensor 5 comprises magnetic loops, the algorithm determines the class based on the number and the position of the axles of the vehicle 10; if instead the sensor 5 comprises a laser, the algorithm determines the class of the vehicle based on the shape of its profile (for example its side, top or side/top profile). Preferably, the output of the algorithm applied at step 302 is a class CL* (step 303) chosen from a predefined number of classes. By way of example, the predefined set of classes may be that shown in the table hereinbelow.

Class	Description
A	Motor cars and vans < 3.5 t
B	Motor cars and vans < 3.5 t + trailer
C	Trucks > 3.5 t
D	Trailer trucks and semi-trailer trucks > 3.5 t
E	Buses
G	Motorcycles and mopeds
F	Other/not classifiable

[0058] Assuming therefore that the vehicle 10 is for example a trailer truck, the classification algorithm applied to step 302 - if it functions correctly - will determine that the vehicle 10 belongs to the class CL*=D.

[0059] Therefore, once the initial determination of the class CL* of the vehicle 10 has been performed, the data processing unit 4 preferably performs a check of the class CL* determined at step 302, based on the properties of the retroreflective elements contained in the at least one image acquired by the device 3.

[0060] In particular, the data processing unit 4 preferably first of all determines in the at least one infrared image of the vehicle 10 acquired by the device 3 at least one property of the at least one license plate of the vehicle 10 (step 304). Said at least one property in particular comprises at least one of the following: the shape of the license plate, the syntax of the license plate number shown on it, and the number of license plates of the vehicle 10 which are visible in the image. The recognition of these properties of the license plate is performed by applying image processing algorithms which are known per se.

[0061] If the at least one license plate property determined at step 304 is uniquely compatible with a class CL** chosen from the predefined number of classes indicated above (step 305), the data processing unit 4 preferably concludes that the vehicle 10 belongs to class CL**, regardless of the class CL* determined at steps 302-303 (step 306). The class CL** may therefore be the same as the class CL*, or different.

[0062] The license plate properties may be considered by the data processing unit 4 in a certain hierarchical order.

[0063] For example, with reference to the flow chart shown in Figure 4, the data processing unit 4 may initially consider the shape of the license plate (step 400). Specifically, at step 400 the data processing unit 4 determines whether the shape of the license plate is square or rectangular. For this purpose, the data processing unit 4 preferably measures the height and the width of the license plate in the acquired image and calculates the height to width ratio (or the reciprocal width to height ratio). A ratio close to 1 indicates a square shape, while a ratio different from 1 indicates a rectangular shape. The calculation of the ratio may be carried out on the height and width measured directly in pixels in the acquired image, without any rule for correction of the perspective being applied to the image.

[0064] If the data processing unit 4 determines that the shape of the license plate is square, it is not possible to determine uniquely the class of the vehicle 10 on the basis of the shape alone of the license plate, because the square shape of the license plate is common both to motorcycles and mopeds (class G) and to some vehicle in class A (in particular all-terrain vehicles).

[0065] In this case, the data processing unit 4 may therefore for example then proceed to consider the syntax of the license plate number (step 401). If the syntax is for example of the type "AA12345" or "X12345", the data processing unit 4 may conclude that the vehicle 10 belongs to the class CL**=G of motorcycles and mopeds, since the square shape of the license plate and the syntax of the license plate number of the type "AA12345" or "X12345" are exclusively properties of the license plates of motorcycles and mopeds. If, instead, the syntax is of the type "ZA 123AA", the data processing unit 4 may conclude that the vehicle belongs to the class CL**=A, since the square shape of the license plate and the license plate number which starts with the letter "Z" are exclusively properties of the license plates of all-terrain vehicles, which belong to class A.

[0066] Also in the case where the license plate is rectangular, it is not possible to determine uniquely the class of the vehicle 10 on the basis of the shape alone of the license plate, because the rectangular shape is common to the classes A, B, C, D and E.

[0067] In this case also, the data processing unit 4 may therefore for example then proceed to consider the syntax of the license plate number (step 402). A syntax of the type "XA 123AA" or "AA123456" allows the identification of trailers, but does not distinguish between class B (light vehicles with trailer) and class D (heavy vehicles with trailer). A syntax of the type "AA 123AA" is instead common to vehicles of class A, C and E and therefore in this case also it is not possible to determine uniquely the class on the basis of the syntax alone of the license plate number.

[0068] Still with reference to Figure 4, in the case of a syntax of the type "XA 123AA" or "AA123456", in order to distinguish between the classes B and D, the data processing unit 4 may for example consider the number of license plates (step 403). In the case where the vehicle 10 belongs to the class CL**=B, in the images acquired two license plates (that of the motor car or van and that of the trailer) are indeed typically visible. In the case where instead the vehicle 10 belongs to class CL**=D, in the images acquired in general a single license plate (namely that of the trailer) is visible since the license plate of the tractor unit is obscured by the trailer and therefore it is not visible in the at least one image of the vehicle 10.

[0069] Considering again the flow diagram of Figure 3, if therefore the license plate properties as a whole are uniquely compatible with a single class CL**, the data processing unit 4 concludes that the vehicle 10 belongs to this class, even if the class CL* determined by the classification algorithm is different.

[0070] If, instead, the license plate properties determined at step 304 do not indicate uniquely that the vehicle 10 belongs to a class (for example, a single rectangular-shaped license plate with number plate syntax of the type "AA 123AA", i.e. license plate properties which are common to the classes A, C and E, or the vehicle 10 has a license plate number with a syntax different from the expected syntaxes, for example because it has been registered in another country or because it has a non-standard license plate), the data processing unit 4 preferably determines the properties of the further retroreflective elements which may be present in the at least one acquired image (step 307). These properties comprise firstly the presence or the absence of these elements and,

in the case where they are present, their shape and any drawings or patterns or writing on them.

[0071] If the properties of any further retroreflective element (or of any further retroreflective elements) determined in step 307 are uniquely compatible with a class CL** chosen from the predefined number of classes indicated above (step 308), the data processing unit 4 preferably concludes that the vehicle 10 belongs to class CL**, regardless of the class CL* determined at steps 302-303 (step 306). Any classes not compatible with the license plate properties determined at step 304 are preferably excluded from this choice. The class CL** may therefore be the same as the class CL*, or different.

[0072] For example, with reference to the flow chart in Figure 4, in order to distinguish between the classes B and D, as an alternative to or in addition to the determination of the number of visible license plates, the data processing unit 4 may consider whether there are present further retroreflective elements (step 404), in particular a rectangular retroreflective panel for trailer trucks and semi-trailer trucks (without diagonal stripes) and/or retroreflective strips which define the rear shape of the vehicle 10. If these further retroreflective elements in addition to the license plate are present, the data processing unit 4 may conclude that the vehicle 10 belongs to class CL**=D, while if they are absent it may conclude that the vehicle belongs to class CL**=B.

[0073] Also in order to distinguish between the classes A, C and E, the data processing unit 4 may consider whether further retroreflective elements in addition to the license plate are present (step 405). In the absence of further retroreflective elements, the data processing unit 4 may conclude that the vehicle 10 belongs to the class CL**=A of motor cars and vans < 3.5 t, since the absence of further retroreflective elements is compatible uniquely only with this class, from among the possible classes (i.e. those which are compatible with the license plate properties).

[0074] In the case where, instead, there is present at least one further retroreflective element, the data processing unit 4 preferably then considers which type of element is involved (step 406).

[0075] If, for example, in the at least one acquired image there is at least one rectangular panel for trucks (with diagonal stripes), the data processing unit 4 may conclude that the vehicle 10 belongs to class CL**=C. If, instead, there is no rectangular panel present, the data processing unit 4 may conclude that the vehicle 10 belongs to the class CL**=E of buses. The data processing unit 4 could confirm that the vehicle 10 belongs to class CL**=E for example by checking that, in addition to the license plate, one or more retroreflective labels which indicate a speed limit are present in the at least one infrared image.

[0076] According to another example, not shown in the non-limiting exemplary flow chart of Fig. 4, the data processing unit 4 may determine that the vehicle 10 belongs to class B or D if retroreflective triangles for trailers are present in the acquired image. This conclusion may be combined with that based on the syntax of the license plate (step 402) so that - for example - it is possible to determine the presence of a trailer (and therefore that the vehicle 10 belongs to class B or D) even in the case where the syntax of the license plate number is not the expected syntax "XA 123AA" or "AA123456".

[0077] Considering again the flow diagram of Figure 3, if the properties of any further retroreflective element (or any further retroreflective elements) determined at step 307 are not uniquely compatible with one of the possible classes, the data processing unit 4 preferably confirms that the vehicle 10 belongs to class CL* determined at steps 302-303.

[0078] For example, if the license plate number starts with the letter "X" (something which limits the choice of the class CL** to classes B and D only), at step 307, the data processing unit 4 could determine that, in addition to the license plate, a rectangular retroreflective panel for trucks (i.e. with slanting stripes) is present. This may happen for example in the case where the vehicle 10 is a truck with a non-standard license plate (namely with a license plate which starts with the letter "X", despite the fact that it is a syntax which is reserved for trailers), or in the case where it is a trailer truck which onto which a retroreflective panel for trucks has been mistakenly affixed. Since this panel uniquely indicates a vehicle of class C of trucks, which however is not among the possible classes (i.e. those compatible with the license plate properties), the data processing unit 4 concludes that it is not possible to determine the class of the vehicle 10 on the basis of the properties of the license plate and the further retroreflective elements visible in the at least one infrared image acquired. The data processing unit 4 therefore considers valid the result determined by the classification algorithm at steps 302-303.

[0079] In general, in the case where the properties of the license plate and of any further retroreflective elements do not allow the data processing unit 4 to reach a unique determination of the class to which the vehicle 10 belongs, according to the embodiment shown in Figure 3, the class CL* determined by the classification algorithm is confirmed.

[0080] According to advantageous embodiments, the data processing unit 4 may also use other information in order to determine the class of the vehicle 10 and/or to exclude the classes which are not possible. Said information for example comprises the speed of the vehicle 10 received at step 301 and/or the lane in which the transit of the vehicle 10 was detected, received at step 300.

[0081] If, for example, the data processing unit 4 determines that the speed of the vehicle 10 detected is greater than a certain maximum threshold plausible for heavy vehicles (i.e. those weighing more than 3.5 t) and/or that the vehicle 10 is in transit along a lane which is prohibited for heavy vehicles (namely vehicles weighing more than 3.5 t), it preferably may exclude from the possible classes the heavy vehicle classes, i.e. classes

C, D and E. The plausible maximum threshold may be for example equal to the applicable speed limit increased by a certain percentage (for example, 70%). If, for example, the limit is 80 km/h, the plausible maximum threshold may be 136 km/h. The search for the class CL** with which the properties of license plate and/or of any further retroreflective elements are uniquely compatible is thus limited to only the remaining classes.

[0082] The system 100 is advantageously more reliable than the known systems.

[0083] The license plate (or plates) and any further retroreflective elements are indeed visible and may be identified in the images of the vehicle 10 with a particularly high degree of reliability, especially if these images are infrared images. In particular, the properties of the license plate and of any further retroreflective elements which vary between one class and another (and which therefore allow one class to be distinguished from another class) are identifiable in the images of the vehicle 10 with a particularly high degree of reliability. In this way, advantageously, the risk of an incorrect classification of the vehicle 10 is significantly reduced, especially in the case where determination of the class CL* of the vehicle 10 by means of the classification algorithm applied at the step 302 borders on two or more classes. For example, in the case where the vehicle 10 is a commercial van, a known system could mistakenly classify it in class C associated with trucks, and not in class A to which it actually belongs, since a commercial van and a truck have similar structural features. The system 100 according to the present invention instead provides the correct classification since, owing to the absence of rear panels and the absence of circular labels which show a speed limit of 80 or 100 km/h, it is possible to determine in a unique manner that it is a vehicle belonging to class A.

[0084] Furthermore, since the classification is based on properties of the license plate (and any further retroreflective elements) per se, and not on the properties of these retroreflective elements in relation to other elements present in the image (for example the distance of the license plate from the bottom edge of the vehicle and/or the ground), calibration of the image acquisition device 3 is not required. The acquisition angle is moreover a less critical parameter, such that the image acquisition device 3 may be positioned along the side of the carriageway so as to acquire 3/4 images of the vehicle 10, or on an arch or flyover above the carriageway, without this affecting the accuracy of determination of the license plate properties and any further retroreflective elements and therefore the class to which the vehicle 10 belongs.

[0085] Furthermore, advantageously, particularly accurate correction of the perspective of the image acquired does not have to be carried out. More specifically, the determination of the syntax of the license plate number and/or of the number of license plates visible in the image may be performed by the data processing unit 4 with a certain degree of reliability also where the correction of the perspective of the image acquired by the image acquisition device 3 is not particularly accurate or is not even possible. On the other hand, the determination of the shape of the license plate consists in calculating the height to width ratio (or the reciprocal ratio) (step 400), said calculation - differently from, for example, the exact determination of the positions of the corners of the license plate or its contour - being able to be performed in a reliable manner by the data processing unit 4 also where correction of the perspective of the acquired image is not particularly accurate or is not even possible.

[0086] It should be noted that in the flow chart of Figure 4 exclusively the properties of the license plates and of the further retroreflective element, as laid down by the existing regulations in Italy, have been taken into consideration. The present invention is however applicable also for the classification of vehicles registered in other countries. In this case, the properties of the license plates (in particular, the possible syntaxes of the license plate numbers for the various types of vehicles) and of the further retroreflective elements may be at least partly different from those considered in the exemplary flow chart shown in Figure 4.

[0087] Although in the above description it has been assumed that the determination of the class is performed by the data processing unit 4 included in the class detection station 1, this is not limiting. According to other embodiments, the data processing unit which performs the class determination may be situated in the server 6. In this case, the at least one infrared image detected by the device 3 and, where appropriate, the information acquired by the sensors 5 is sent by means of the network 7 to the server 6. In the case where the system 100 comprises a plurality of detection stations 1 and the vehicle 10 passes by more than one station, the determination of the class may be carried out by only one of the stations which the vehicle 10 has passed by.

[0088] Furthermore, as described above, the presence of the sensor 5 is optional, as is likewise optional the execution of steps 301-302-303 of the algorithm shown in Figure 3. In the case where these steps have been omitted, the determination of the class to which the vehicle 10 belongs is based exclusively on the properties of the license plate and of any further retroreflective elements visible in the at least one acquired image of the vehicle 10. In this case, if the data processing unit 4 is unable to determine uniquely the class of the vehicle 10 on the basis of the properties alone of the at least one license plate and of any further retroreflective elements, it preferably concludes that the vehicle 10 belongs to class CL**=F of non-classifiable vehicles. Further checks will therefore be carried on the vehicle 10, depending on the purpose of the class detection operation.

[0089] The class detection may be carried out for all the vehicles in transit along the road section 2, are only for some of them.

[0090] For example, in the case where the class detection system 100 is used to assist a violation detection

system, the detection of the class may be excluded for vehicles which are clearly not committing a violation (for example, vehicles which do not exceed the speed limit permitted for the category of vehicles with a lower limit) or only for those vehicles travelling in a certain lane.

[0091] Instead of or in combination therewith, the detection of the class on the basis of the properties of the license plate and of any further retroreflective elements may be performed only in the case where the class CL* determined by the classification algorithm is of a certain type. For example, the detection of the class based on the properties of the license plates and of any further retroreflective elements could be carried out only if the class CL* is a class such that the classification algorithm is not particularly reliable (for example classes A and C which, as described above, in the case of commercial vehicles, are easily confused with each other).

[0092] In any case, carrying out detection of the class on the basis of the properties of the license plate and of any further retroreflective elements only for some of the vehicles in transit is advantageous in terms of efficiency of use the computational resources available in the data processing unit 4.

[0093] As regards the determination of the properties of the labels which indicate the applicable speed limit, according to an advantageous variant, the data processing unit 4 may also read the speed limit shown on them. In this way, the class detection system 100 may be used to assist a system for detecting speed limit violations. This is particularly advantageous especially in the case where the speed limit is different for the different types of vehicles. For example, along an Italian highway with a general speed limit of 130 km/h, motor cars and motorcycles may travel at a speed of up to 130 km/h, while trucks with a gross vehicle weight of more than 12 t may only travel at a speed of up to 80 km/h, while buses with a gross vehicle weight of more than 5 t may only travel at a speed of up to 100 km/h.

[0094] This makes it particularly difficult to determine the speed limit which is actually applicable to a vehicle, because this depends on the gross vehicle weight and not on its shape. The class detected by the known systems (which, as discussed above, detect the vehicle class on the basis of its shape, distribution of the volumes and/or number of axles) therefore often does not allow the correct applicable speed limit to be associated with the vehicle. These errors may be partly corrected for example by interrogating external databases(for example the database of the Driver and Vehicle Licensing Centre). Said interrogations however may not be performed on a large scale for systems which deal with a huge amount of traffic (various millions of vehicles passing during the day).

[0095] The automatic reading of the speed limit shown on the retroreflective labels by the data processing unit 4 is able to overcome these drawbacks and determine the correct applicable speed limit substantially for all the passing vehicles. The labels which show the speed limit are in fact obligatory according to the highway code and therefore all legally compliant vehicles travelling on the roadway networks must have them (including foreign vehicles). The automatic reading of the speed limits shown on the labels may therefore be carried on all the passing vehicles.

[0096] Access to external data banks is consequently carried out only by way of confirmation when a possible violation has been identified, thus significantly reducing the number of interrogation operations and increasing the performance of the system for detecting speed limit violations.

Claims

1. System (100) for detecting the class of a vehicle (10) in transit along a road section (2), said system (100) comprising:

   - an image acquisition device (3) located along said road section (2), said image acquisition device (3) being configured to acquire at least one image of said vehicle (10), at least one license plate (20) of said vehicle (10) being visible in said at least one image; and
   - a data processing unit (4, 6) cooperating with said image acquisition device (3), said data processing unit (4) being configured to identify said at least one license plate (20) in said at least one image, to determine at least one property of said at least one license plate (20) and, if said at least one property of said at least one license plate (20) uniquely indicates that said vehicle (10) belongs to a class (CL**), to determine that said vehicle (10) belongs to said class (CL**).

2. System (100) according to claim 1, wherein said image acquisition device (3) comprises an infrared image acquisition device and wherein said at least one image of said vehicle (10) comprises at least one infrared image of said vehicle (10).

3. System (100) according to claim 1 or 2, wherein said at least one image of said vehicle (10) comprises at least one rear image of said vehicle (10).

4. System (100) according to claim 3, wherein said at least one rear image of said vehicle (10) is acquired at an angle with respect to the direction of travel of said vehicle (10), in the horizontal plane, of between 0° and 40°.

5. System (100) according to any one of the preceding claims, wherein said at least one property of said at least one license plate (20) comprises at least one of the following: shape of said at least one license plate (20), syntax of a license plate number shown

on said at least one license plate (20) and number of license plates of said vehicle (10) which are visible in said at least one image.

6. System (100) according to any one of the preceding claims, wherein said data processing unit (4) is further configured, if said at least one property of said at least one license plate (20) does not uniquely indicate that said vehicle (10) belongs to any class, to determine whether at least one further retroreflective element (21, 22, 23, 24) present on the surface of said vehicle (10) is visible in said at least one image.

7. System (100) according to claim 6, wherein said at least one further retroreflective element (21, 22, 23, 24) is present on a rear surface of said vehicle (10).

8. System (100) according to claim 6 or 7, wherein said at least one further retroreflective element (21, 22, 23, 24) comprises one or more of the following: rectangular retroreflective panel for trucks, rectangular retroreflective panel for trailer trucks or semi-trailer trucks, retroreflective label indicating an applicable speed limit, retroreflective triangles for trailers, set of retroreflective strips defining the rear shape of said vehicle (10).

9. System (100) according to any one of claims 6 to 8, wherein said data processing unit (4) is configured to determine at least one property of said at least one further retroreflective element (21, 22, 23, 24) and, if said at least one property of said at least one further retroreflective element (21, 22, 23, 24) uniquely indicates that said vehicle (10) belongs to a class (CL**), to determine that said vehicle (10) belongs to said class (CL**).

10. System (100) according to claim 9, wherein said at least one property of said at least one further retroreflective element (21, 22, 23, 24) comprises at least one of the following: absence/presence of said at least one further retroreflective element (21, 22, 23, 24) and, if present, shape of said at least one further retroreflective element (21, 22, 23, 24), presence of a drawing, pattern or writing on said at least one further retroreflective element (21, 22, 23, 24).

11. System (100) according to any one of the preceding claims, further comprising a sensor (5) configured to acquire information about the shape of the profile of said vehicle (10) and/or length of said vehicle (10) and/or number of axles of said vehicle (10) and/or position of said axles of said vehicle (10), said data processing unit (4, 6) being configured to first determine the class (CL*) to which said vehicle (10) belongs on the basis of said information acquired by said sensor (5), and to confirm said class to which said vehicle (10) belongs on the basis of said at least one property of said at least one license plate (20).

12. System (100) according to claim 11, wherein said sensor (5) comprises a radar sensor and/or a laser sensor and/or a magnetic loop sensor.

13. System (100) according to any one of the preceding claims, wherein said image acquisition device (3) and said data processing unit (4) are comprised in a detection station (1) located along said road section (2).

14. System (100) according to claim 13, wherein said data processing unit (4) is incorporated in said image acquisition device (3).

15. Method for detecting the class of a vehicle (10) in transit along a road section (2), said method comprising:

- by means of an image acquisition device (3) located along said road section (2), acquiring at least one image of said vehicle (10), at least one license plate (20) of said vehicle (10) being visible in said at least one image; and
- by means of a data processing unit (4, 6) cooperating with said image acquisition device (3), identifying said at least one license plate (20) in said at least one image, determining at least one property of said at least one license plate (20) and, if said at least one property of said at least one license plate (20) uniquely indicates that said vehicle (10) belongs to a class (CL**), determining that said vehicle (10) belongs to said class (CL**).

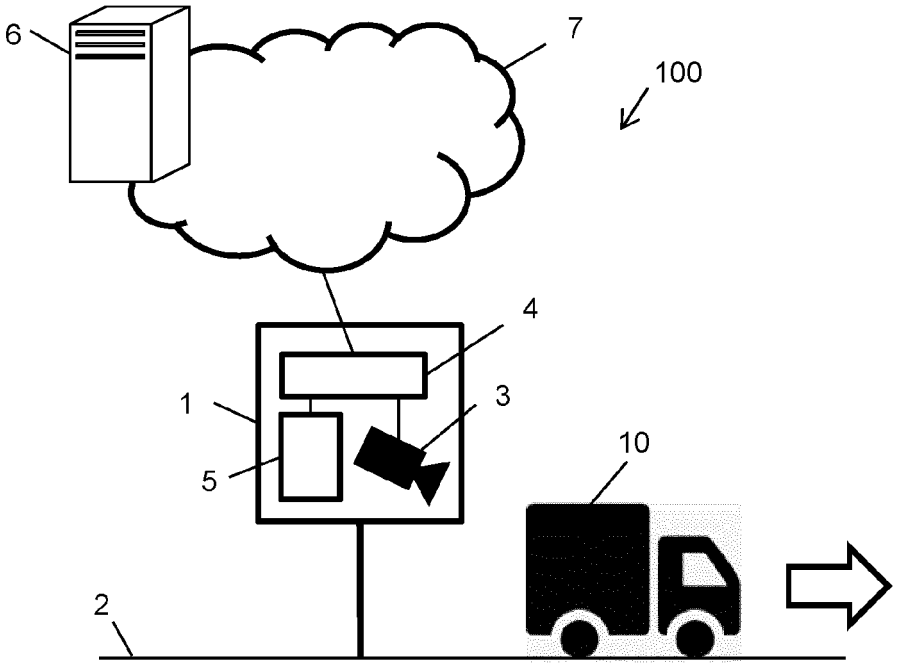

Fig. 1

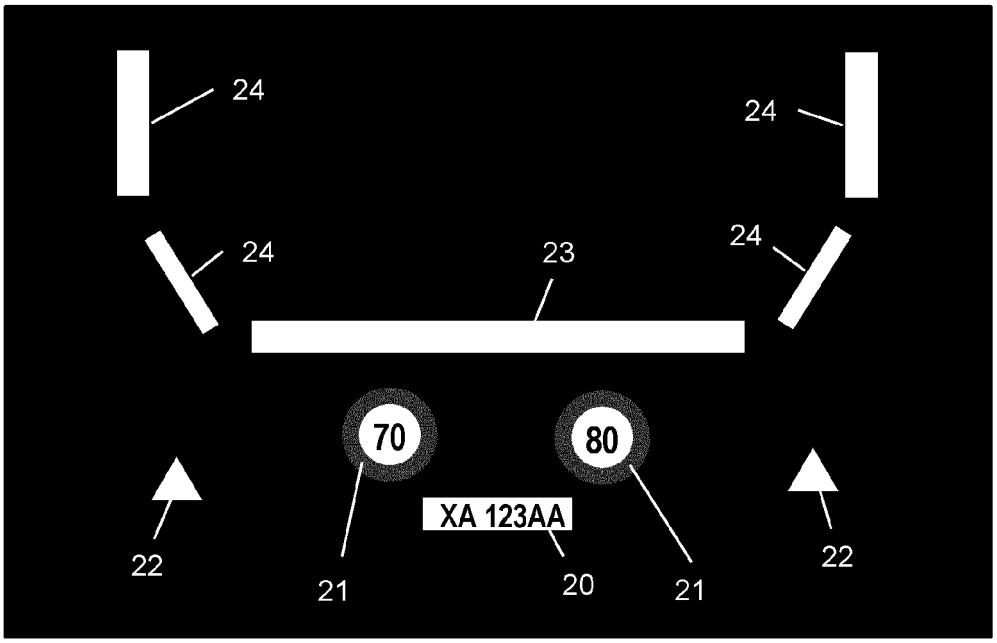

Fig. 2

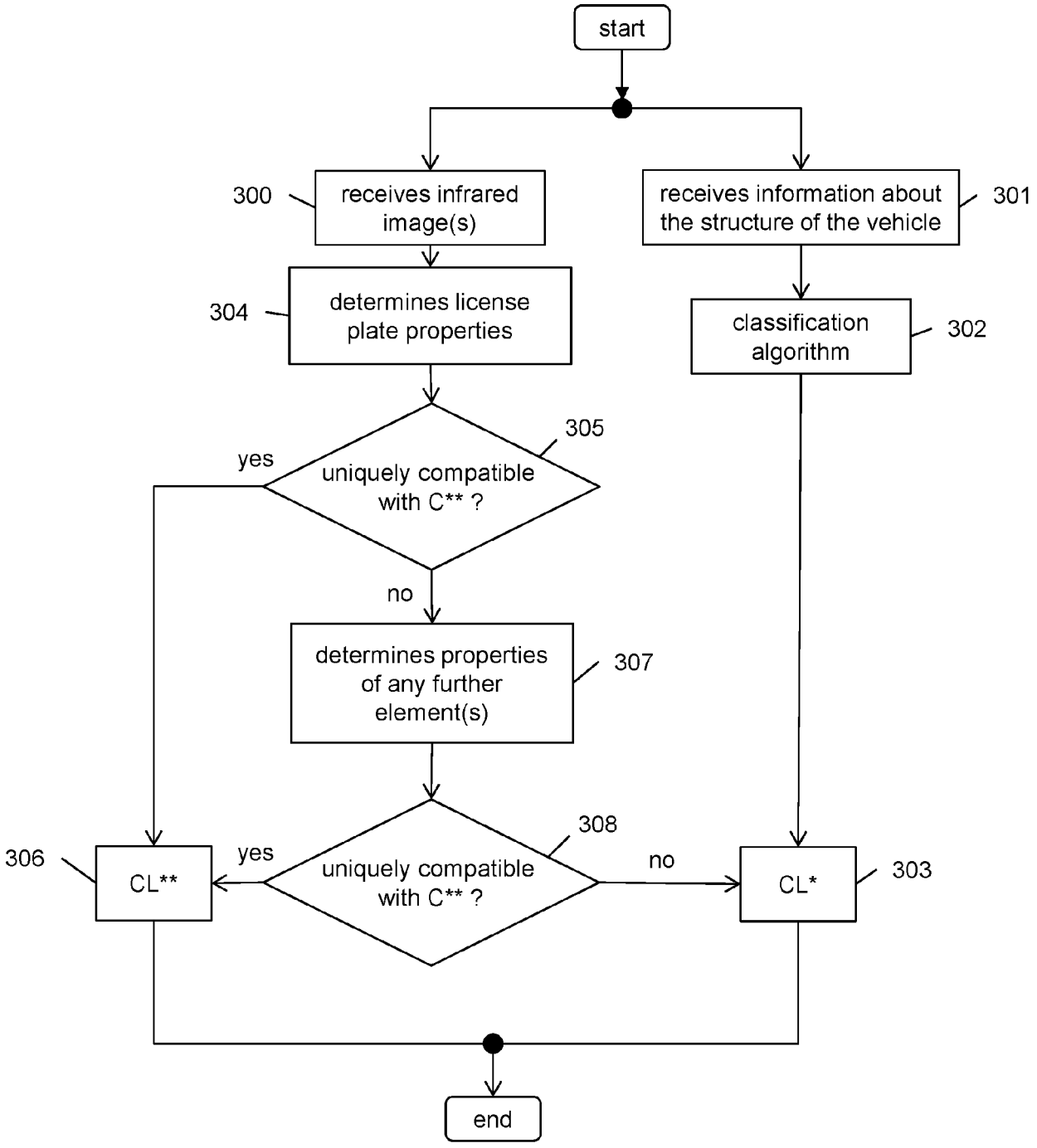
start
300
receives infrared image(s)
301
receives information about the structure of the vehicle
304
determines license plate properties
302
classification algorithm
305
yes
uniquely compatible with C** ?
no
determines properties of any further element(s)
307
306
CL**
yes
308
uniquely compatible with C** ?
no
CL*
303
end

Fig. 3

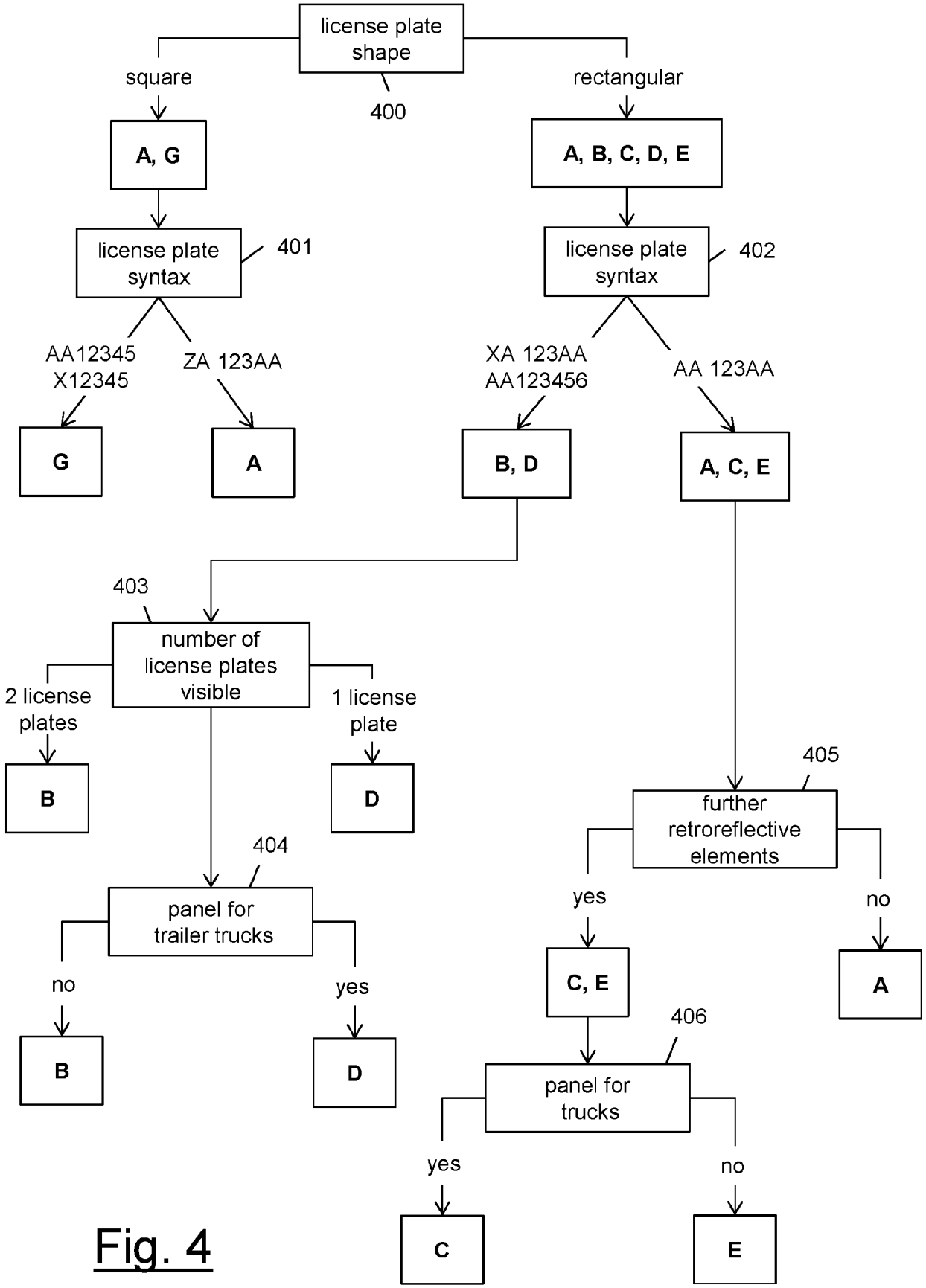
license plate shape
400
square
rectangular
A, G
A, B, C, D, E
license plate syntax
401
license plate syntax
402
AA12345
X12345
ZA 123AA
XA 123AA
AA123456
AA 123AA
G
A
B, D
A, C, E
403
number of license plates visible
2 license plates
1 license plate
B
D
404
panel for trailer trucks
no
yes
B
D
405
further retroreflective elements
yes
no
C, E
A
406
panel for trucks
yes
no
C
E

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 22 18 9229

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