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(54) **METHOD FOR CALIBRATING THE ORIENTATION OF A CAMERA MOUNTED TO A VEHICLE**

VERFAHREN ZUR KALIBRIERUNG DER AUSRICHTUNG EINER AN EINEM FAHRZEUG MONTIERTEN KAMERA

PROCÉDÉ POUR ÉTALONNER L'ORIENTATION D'UNE CAMÉRA MONTÉE SUR UN VÉHICULE

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Description

[0001] The invention relates to a method for calibrating the orientation of a camera mounted to a vehicle.

[0002] Recently, an increasing number of vehicles are provided with at least one camera mounted to the vehicle for capturing information about an environment of the vehicle. In particular, the camera is located at a front of the vehicle for acquisition of the road ahead. Image data thus obtained can then be used by various driver assistance systems, for example.

[0003] Document US 2010/134634A1 relates to methods of and systems for estimating camera parameters from a captured image. Document US 2010/295948A1 relates to methods and devices for camera calibration from a single perspective image. Document US 2012/033087A1 relates to a calibration target detection apparatus, a calibration target detecting method for detecting a calibration target, and a program for a calibration target detection apparatus

[0004] From images acquired by such a camera spatial data about objects within the field of view of the camera can be extracted. However, this data are relative to the camera, but not (at least not directly) to the vehicle. Hence, for example positions of objects captured by the camera can only be determined with respect to the camera. To also obtain from images acquired by the camera the positions of such objects relative to the vehicle with high precision and reliability, it is therefore important to precisely know the position and orientation of the camera relative to the vehicle.

[0005] Especially placing the camera with a well-defined orientation relative to the vehicle is rather difficult. Therefore, the camera will almost certainly deviate from an ideal orientation, with the real orientation varying for different cameras in different vehicles.

[0006] The orientation of the camera can be described by three angles commonly referred to as roll angle, yaw angle and pitch angle. The roll angle specifies the angle of rotation around a longitudinal axis, which for a camera in particular corresponds to an optical axis of the camera. Hence, the axis of rotation of the roll angle is defined relative to the camera and therefore changes its orientation together with the camera, for example if the camera is tilted or panned. The yaw angle specifies an angle of rotation around a vertical axis and thus, at least essentially, defines deviations from the ideal orientation to the left or to the right. The pitch angle specifies an angle of rotation around a horizontal axis and thus, at least essentially, defines deviations from the ideal orientation to the top or to the bottom.

[0007] Calibrating the orientation of a camera mounted to a vehicle preferably comprises determining at least one of the roll angle, the yaw angle and the pitch angle. Preferentially all three of these are determined so as to fully describe the orientation of the camera.

[0008] Determining these angles can generally be done during movement of the vehicle, for example while driving on a road. In this way, the calibration method can take advantage from information which can be derived from differences between consecutively acquired images due to the movement in a specific direction. Such a calibration, however, can be time-consuming and therefore costly. Because of this, a calibration method which can be executed on a stationary vehicle can be preferable.

[0009] There are calibration methods which depend on the height of the camera being known and fixed. However, in particular if the vehicle is a truck, the height of the camera, even though mounted to a defined location at the vehicle, can change significantly. This can be due to a rather soft suspension of the vehicle, as a result of which a driver cabin of the vehicle, to which the camera might be mounted, can change its height by up to several tens of centimeters, for example. It is therefore preferred that the calibration method does not depend on the height of the mounted camera. Preferentially, the height of the camera can even be determined as part of the calibration.

[0010] It is an objective of the invention to provide a method for calibrating the orientation of a camera mounted to a vehicle which is in particular reliable, quick and independent of the height of the mounted camera.

[0011] This objective is solved by a method in accordance with claim 1.

[0012] For calibrating the orientation of the camera, the camera is placed in front of a calibration pattern, especially at a known distance to the calibration pattern. This corresponds to a stationary setup and can for example easily be achieved with a calibration pattern which is fixedly placed. For example, the vehicle can be moved to a defined place, especially at a known distance, in front of the calibration pattern. For this, the vehicle can be driven to this defined place. However, to place the vehicle with high precision, the vehicle is preferably moved by a conveyor.

[0013] Said known distance of the vehicle to the calibration pattern can be predefined and is then at least essentially the same for successive vehicles having cameras to be calibrated. However, the distance can also change, preferably in a controlled manner, and/or be measured individually for every calibration or a group of calibrations. The distance especially is a distance in a direction perpendicular to a plane of the calibration pattern.

[0014] In particular, while the orientation of the camera relative to the calibration pattern is unknown and to be calibrated, the orientation of the vehicle to the calibration pattern is preferably known, especially predefined or at least precisely measurable.

[0015] The calibration pattern defines at least two horizontal lines and two vertical lines. In particular, the calibration pattern is a flat arrangement of graphical symbols, with a plane of the calibration pattern preferentially being vertical. The calibration pattern does not necessarily comprise the horizontal and vertical lines as graphically depicted lines. Instead, the lines can also be defined by one or more symbols from which a respective line can be derived unambiguously.

[0016] According to an embodiment, the calibration pattern comprises at least a first characteristic point, a second characteristic point, a third characteristic point and a fourth characteristic point. One of the two horizontal lines can then be defined by the first and second characteristic points and the other one of the two horizontal lines can be defined by the third and fourth characteristic points. Similarly, one of the two vertical lines can then be defined by the first and third characteristic points and the other one of the two vertical lines can be defined by the second and fourth characteristic points.

[0017] By means of the camera, an image of the calibration pattern is acquired. Such an image in particular comprises a plurality of pixels arranged in lines and columns with each pixel having a color and brightness such that the pixels together represent a projection of the field of view of the camera through a lens of the camera to an image sensor of the camera. Hence, if the calibration pattern is within the field of view of the camera, the image contains a representation of the calibration pattern.

[0018] The image has a first axis and a second axis at least essentially corresponding to a horizontal axis and a vertical axis, respectively. For example, the first axis is parallel to said lines of pixels and the second axis is parallel to said columns of pixels. Depending on the orientation of the camera, which is to be determined, the first and second axes might not correspond exactly to horizontal and vertical axes, respectively.

[0019] The acquired image might be corrected for distortions due to the optics of the camera, especially a lens or a lens system of the camera. Such a correction of distortions can be executed according to any known method sufficiently reliable.

[0020] Within the acquired image, representations of the horizontal lines and the vertical lines are identified. This can be done, for example, by identifying representations of the graphical symbols of the calibration pattern which define the horizontal and vertical lines. For example, representations of said characteristic points defining the horizontal and vertical lines can be identified within the image by a suitable algorithm.

[0021] Although the horizontal lines of the calibration pattern as well as the vertical lines of the calibration pattern are parallel to each other, the representations of the horizontal lines as well as the representations of the vertical lines within the acquired image will, as a rule, not be parallel to each other. This is because, even after correction of possible distortions, the parallelism is only preserved if the optical axis of the camera is perfectly perpendicular to the horizontal lines or the vertical lines, respectively, which usually will not be the case.

[0022] A horizontal vanishing point is determined from the representations of the horizontal lines. Similarly, a vertical vanishing point is determined from the representations of the vertical lines.

[0023] According to an embodiment, determining the horizontal and/or the vertical vanishing point from the representations of the horizontal and/or vertical lines comprises determining a point of intersection of the horizontal and/or vertical lines, respectively. To determine such a vanishing point, it might be necessary to graphically or mathematically extrapolate continuations of the lines until they intersect. Should the lines defining a respective vanishing point be exactly parallel, they will not intersect and a coordinate of the vanishing point will be infinity. In such an exceptional case, the coordinate of the vanishing point actually being infinity can be defined as having a maximum value great enough so as to lead to only insignificant errors in the determination of the roll angle, yaw angle or pitch angle.

[0024] After determining the horizontal and vertical vanishing points, at least one of the roll angle, the yaw angle and the pitch angle is calculated.

[0025] If the roll angle is calculated, it is calculated from the location of the horizontal vanishing point relative to a principal point of the image. This principle point is in particular located at the center of the image and/or corresponds to the point where the optical axis of the camera crosses the image plane.

[0026] According to an embodiment, calculating the roll angle comprises determining the angle of the line segment defined by the horizontal vanishing point and the principal point of the image with respect to the first axis. This is in particular done by calculating the inverse tangent of the quotient of a second coordinate of the horizontal vanishing point measured along the second axis and a first coordinate of the horizontal vanishing point measured along the first axis. This can be written as $\gamma = \arctan(yH / xH)$, with γ being the roll angle and yH and xH being the first and second coordinates of the horizontal vanishing point.

[0027] If the yaw angle is calculated, it is calculated from the first coordinate of the horizontal vanishing point.

[0028] According to an embodiment, calculating the yaw angle in particular comprises calculating the inverse tangent of the quotient of a focal length of the camera and the product of a pixel pitch of the camera and the first coordinate of the horizontal vanishing point. The pixel pitch is the distance between the sensor pixels of a sensor of the camera corresponding to the pixels of the image acquired by the camera. The pixel pitch in direction of the first axis might differ from the pixel pitch in direction of the second axis. In such a case, the yaw angle is preferably calculated from the pixel pitch in direction of the first axis. Hence, the calculation can be written as $\beta = \arctan(f / (\Delta xP \cdot xH))$, with β being the yaw angle, f being the focal length of the camera, ΔxP being the pixel pitch in direction of the first axis and xH being the first coordinate of the horizontal vanishing point.

[0029] If the camera is oriented with a roll angle not equal to zero, the position of the vanishing point is preferably corrected for displacement due to the rolled orientation of the camera. Therefore, according to a preferred embodiment, calculating the yaw angle comprises calculating the inverse tangent of the quotient of a focal length of the camera and the product of a pixel pitch of the camera and the first coordinate of a corrected horizontal vanishing point. This corrected horizontal vanishing point is determined by rotating the horizontal vanishing point around the principal point of the image by the negative of the roll angle. In this way, the effect of rolling is reversed and the horizontal vanishing point is quasi unrolled. Calculation of the yaw angle can then be written as $\beta = \arctan(f / (\Delta xP \cdot xHR))$, with xHR being the first coordinate of the corrected horizontal vanishing point.

[0030] In particular, the first coordinate of the corrected horizontal vanishing point is calculated as the difference of the product of the first coordinate of the horizontal vanishing point and the cosine of the negative of the roll angle to the product of the second coordinate of the horizontal vanishing point and the sine of the negative of the roll angle. This can be written as $xHR = xH \cos(-\gamma) - yH \sin(-\gamma)$ and corresponds to a rotation around a coordinate origin of the image where the first and second axes intersect. Hence, for this formula to be used, the principal point of the image preferably corresponds to the coordinate origin of the image.

[0031] If the camera is oriented with a pitch angle not equal to zero, and the pitch angle has been determined before the yaw angle, it might be necessary to correct the yaw angle for the pitch. According to an embodiment, this can be done by calculating a corrected yaw angle as the inverse tangent of the quotient of the tangent of the previously calculated yaw angle and the cosine of the pitch angle. This can be written as $\beta' = \arctan(\tan\beta / \cos\alpha)$, with α being the pitch angle, β being the yaw angle prior to correction and β' being the yaw angle after correction.

[0032] If the pitch angle is calculated, it is calculated from the second coordinate of the vertical vanishing point.

[0033] According to an embodiment, calculating the pitch angle in particular comprises calculating the inverse tangent of the quotient of a focal length of the camera and the product of a pixel pitch of the camera and the second coordinate of the vertical vanishing point. If the pixel pitch in direction of the first axis differs from the pixel pitch in direction of the second axis, the pitch angle is preferably calculated from the pixel pitch in direction of the second axis. Hence, the calculation can be written as $\alpha = \arctan(f / (\Delta yP \cdot yV))$, with α being the pitch angle, f being the focal length of the camera, ΔyP being the pixel pitch in direction of the second axis and yV being the second coordinate of the vertical vanishing point.

[0034] To take into account a displacement of the vertical vanishing point due to a non-zero roll angle of the camera, according to a preferred embodiment, calculating the pitch angle comprises calculating the inverse tangent of the quotient of a focal length of the camera and the product of a pixel pitch of the camera and the second coordinate of a corrected vertical vanishing point. This corrected vertical vanishing point is determined by rotating the vertical vanishing point around the principal point of the image by the negative of the roll angle. In this way, the effect of rolling is reversed and the vertical vanishing point is quasi unrolled. Calculation of the pitch angle can then be written as $\alpha = \arctan(f / (\Delta yP \cdot yVR))$, with yVR being the second coordinate of the corrected vertical vanishing point.

[0035] In particular, the second coordinate of the corrected vertical vanishing point is calculated as the sum of the product of the first coordinate of the vertical vanishing point and the sine of the negative of the roll angle and the product of the second coordinate of the vertical vanishing point and the cosine of the negative of the roll angle. This can be written as $yVR = xV \sin(-\gamma) + yV \cos(-\gamma)$ and corresponds to a rotation around a coordinate origin of the image where the first and second axes intersect. Hence, for this formula to be used, the principal point of the image preferably corresponds to the coordinate origin of the image.

[0036] If the camera is oriented with a yaw angle not equal to zero, and the yaw angle has been determined before the pitch angle, it might be necessary to correct the pitch angle for the yaw. According to an embodiment, this can be done by calculating a corrected pitch angle as the inverse tangent of the quotient of the tangent of the previously calculated pitch angle and the cosine of the yaw angle. This can be written as $\alpha' = \arctan(\tan\alpha / \cos\beta)$, with β being the yaw angle, α being the pitch angle prior to correction and α' being the pitch angle after correction.

[0037] For an improved determination of the horizontal and/or vertical vanishing point, according to a preferred embodiment, the calibration pattern defines more than two horizontal lines and/or more than two vertical lines. Then, it is possible to choose representations of those two horizontal and/or vertical lines for determining the horizontal or vertical vanishing point, respectively, which can be identified most easily or most reliably within the acquired image. Furthermore, it is then also possible to identify within the acquired image representations of more than two horizontal and/or vertical lines, especially of all horizontal and/or vertical lines defined by the calibration pattern, and to determine the horizontal and/or vertical vanishing point from all of these respective representations.

[0038] For example, with more than two horizontal and/or vertical lines, for each pair of two of these lines, the point of intersection of the two lines can be determined, and the horizontal or vertical vanishing point, respectively, can then be defined as an average or center of gravity of the determined points of intersection. By this, random errors in determining the vanishing points can be prevented.

[0039] To further improve precision and reliability of the calibration, part of the method can be executed repeatedly with final calibration results being obtained from individual calibration results by averaging. According to such an embodiment, the steps of acquiring the image of the calibration pattern, of identifying representations of the horizontal and vertical lines, of determining the horizontal and the vertical vanishing points and of calculating at least one of the roll angle, the yaw angle and the pitch angle are executed repeatedly such that at least one of a set of roll angles, a set of yaw angles and a set of pitch angles is obtained. The method for calibrating the orientation of the camera then further comprises the step of calculating at least one of an averaged roll angle, an averaged yaw angle and an averaged pitch angle by averaging the angles of the set of roll angles, the set of yaw angles or the set of pitch angles, respectively. Averaging in particular comprises calculating arithmetic means or medians of the angles of a respective set of angles. By averaging over multiple angles, the risk of random errors can be substantially reduced.

[0040] Especially after the roll angle, the yaw angle and/or the pitch angle of the camera have been determined, it is possible to also extract information about the position of the camera. Hence, in a preferred embodiment, calculation of at least one of the roll angle, the yaw angle and the pitch angle is followed by the step of determining a lateral offset of the camera relative to the calibration pattern and/or a height of the camera. This is done by first correcting the acquired image for at least one of roll, yaw and pitch, preferably for all of these. Such a correction in particular comprises rotating and/or shifting the image by amounts corresponding to the roll angle, the yaw angle and the pitch angle, respectively. Then, within the image a first coordinate difference and/or a second coordinate difference between the principal point of the image and a representation of a reference point of the calibration pattern is determined, wherein the reference point has a known horizontal and/or vertical position. By this, pixel distances between the principal point of the image and the representation of the reference point are obtained along both axes of the image.

[0041] For knowing the real distances, i.e. in particular the distances between a projection of the principal point to a plane of the calibration pattern and the reference point, the coordinate distances have to be scaled so as to reflect the real distances. Therefore, the lateral offset and/or the height of the camera is/are determined by scaling the first coordinate difference and/or the second coordinate difference with a factor obtained by multiplying the distance of the camera to the calibration pattern with the quotient of a pixel pitch of the camera and a focal length of the camera. This converts the coordinate distances to real distances from the reference point. The offset and height of the camera can then be derived from these distances and the known horizontal and vertical position of the reference point, respectively.

[0042] The distance of the camera to the calibration pattern can be predefined or measured. Alternatively, also the distance of the camera to the calibration pattern can be deduced from the image of the calibration pattern, if for example a distance between two characteristic points of the calibration pattern is known. In particular, the ratio between the pixel distance of the representations of these two characteristic points in the image and their real distance can correspond to the product of the distance of the camera to the calibration pattern and the quotient of the pixel pitch and the focal length of the camera. This relation can then be solved for the distance of the camera to the calibration pattern.

[0043] The presented method of calibration does not require movement of the vehicle the camera is mounted to. Instead the vehicle preferably stands still in front of the calibration pattern. This can be achieved especially well during production of the vehicle. According to a preferred embodiment, the step of placing the camera in front of the calibration pattern is therefore executed at the end of a production line which the vehicle the camera is mounted to has run through for its production. This also allows for defined lighting conditions which, in particular, are such that a sharp image of the calibration pattern can be acquired with high contrast.

[0044] The objective of the invention is furthermore solved by a computer program product in accordance with claim 10.

[0045] The computer program of the computer program product can be executed directly on the camera, for example. To this purpose the camera can comprise a computing device such as a microcontroller or any kind of embedded system. After determining the orientation and possibly also the height and/or lateral offset of the camera, the obtained values can be stored on a memory device which preferably is integrated in the camera.

[0046] In the following, the invention is exemplarily further described with reference to the Figures.

[0047] Fig. 1 shows a truck 11 at the end of a production line which the truck 11 has run through for its production. The truck 11 is moved by a conveyor system 13 and placed in front of a calibration pattern 15 situated on an upright panel 17. A camera 19 is mounted to a driver cabin 21 of the truck 11. The camera 19 is located at a precise position relative to the driver cabin 21. But since the driver cabin 21 is softly supported, for example by means of an air suspension, the height of the camera 19 can vary and is therefore unknown. However, the truck 11 is placed such that the camera 19 has a known distance to the calibration pattern 15.

[0048] The camera 19 has a field of view 23 depending on the orientation of the camera 19. Since the orientation of the camera 19 can vary, it has to be calibrated. To this purpose, the camera 19 acquires an image 25 of the calibration pattern 15. An exemplary such image 25 is shown in Fig. 2.

[0049] The calibration pattern 15 comprises ten sub-patterns 27, 27', representations of which can be recognized in the image 25. There are sub-patterns of a first type 27 and sub-patterns of a second type 27'. The sub-patterns 27, 27' of both types are each formed by two equally oriented squares, with a corner of one of the squares coinciding with a corner of the other of the squares, wherein the relative orientation of the two squares of a respective sub-patterns of the first type 27 is perpendicular to the relative orientation of the two squares of a respective sub-pattern of the second type 27'.

[0050] Five of the sub-patterns 27, 27' are arranged along a first vertical line, the other five along a second vertical line. Each of the sub-patterns 27, 27' on the first vertical line forms a pair with a respective sub-pattern 27, 27' on the second vertical line such that both sub-patterns 27, 27' of a respective pair are aligned on a horizontal line. Hence, in total there are five horizontal lines. While the two vertical lines and the five horizontal lines are not depicted and hence are no explicit part of the calibration pattern, they are unambiguously defined by the sub-patterns 27, 27', in particular by respective central points of these sub-patterns 27, 27'.

[0051] Due to roll, yaw and pitch of the camera 19, even after correction of the image 25 for lens distortions, optical aberrations or the like, the representations of the horizontal or vertical lines defined by the sub-patterns 27, 27' of the calibration pattern 15 within the image 25 are not parallel to each other. This is schematically shown in Fig. 3 for a set of four representations of horizontal lines denoted, LH1, LH2, LH3 and LH4, and a set four representations of vertical lines denoted, LV1, LV2, LV3 and LV4. It is to be noted that these representations of horizontal and vertical lines, respectively, have been derived from a different calibration pattern 15 than the one shown in Fig. 1 and 2.

[0052] The representations of the horizontal lines LH1, LH2, LH3 and LH4 intersect at a horizontal vanishing point PH. If all four lines do not intersect at a single point, the vanishing point PH can be defined as an average point of the different pairwise intersections. In a corresponding manner a vertical vanishing point PV is determined from the intersections of the representations of the vertical lines LV1, LV2, LV3 and LV4.

[0053] After having determined the horizontal and/or the vertical vanishing point PH or PV, respectively, calculation of at least one of the roll angle, the yaw angle and the pitch angle of the camera 19 can be executed as described above, especially taking into account coordinates of these determined vanishing points.

[0054] When the roll, yaw and pitch of the camera 19 are known, the image 25 can be corrected for these values so as to create a corrected image which corresponds to the image 25 as it would have looked (at least essentially), if acquired by the camera 19 in an orientation with zero roll, zero yaw and zero pitch. From this corrected image, then, a height 29 of the camera 19 and a lateral offset of the camera 19 relative to the calibration pattern 15 can be determined. This is schematically illustrated in Fig. 4 for the height 29.

[0055] The calibration pattern 15 contains a reference point 31, which might be the central point of one of the sub-patterns 27, 27' of the calibration pattern 15 or any otherwise characteristic point within the calibration pattern 15. The representation of this reference point 31 in the corrected image of the calibration pattern 15 has a certain coordinate in vertical direction which corresponds to a distance from a point of origin in the image. Since the distance 33 of the camera 19 to the calibration pattern 15, the distance being defined in a longitudinal direction perpendicular to the plane of the calibration pattern 15, is known, the coordinate can be converted into a real vertical distance of the reference point 31 to the camera 19. Since furthermore also the height of the reference point 31 is known, the height 29 of the camera 19 can be determined. Determination of the lateral offset of the camera 19 is done correspondingly.

List of reference signs

[0056]

11	truck
13	conveyor system
15	calibration pattern
17	panel
19	camera
21	driver cabin
23	field of view
25	image
27	sub-pattern of first type
27'	sub-pattern of second type
29	height
31	reference point
33	distance

Claims

1. Method for calibrating the orientation of a camera (19) mounted to a vehicle, in particular a truck (11), comprising the steps of

   - placing the camera in front of a calibration pattern (15) defining at least two horizontal lines and two vertical lines;
   - acquiring an image (25) of the calibration pattern (15) by means of the camera (19), the image (25) having a first axis and a second axis at least essentially corresponding to a horizontal axis and a vertical axis, respectively;
   - identifying representations of the horizontal lines and the vertical lines within the acquired image (25);
   - determining a horizontal vanishing point from the representations of the horizontal lines;
   - determining a vertical vanishing point from the representations of the vertical lines;

   characterized in that the method further comprises the steps of

   - calculating a roll angle by calculating the inverse tangent of the quotient of a second coordinate of the horizontal vanishing point measured along the second axis and the first coordi-

nate of the horizontal vanishing point,
- calculating a yaw angle by calculating the inverse tangent of the quotient of a focal length of the camera (19) and the product of a pixel pitch of the camera (19) and the first coordinate of the horizontal vanishing point or of a corrected horizontal vanishing point, and
- calculating a pitch angle by calculating the inverse tangent of the quotient of a focal length of the camera (19) and the product of a pixel pitch of the camera (19) and the second coordinate of the vertical vanishing point or of a corrected vertical vanishing point.

2. Method in accordance with claim 1, wherein the calibration pattern (15) comprises at least a first characteristic point, a second characteristic point, a third characteristic point and a fourth characteristic point, with the two horizontal lines being defined by the first and second characteristic points and the third and fourth characteristic points, respectively, and the two vertical lines being defined by the first and third characteristic points and the second and fourth characteristic points, respectively.

3. Method in accordance with claim 1 or 2, wherein determining the horizontal vanishing point from the representations of the horizontal lines comprises determining a point of intersection of the horizontal lines
and/or
wherein determining the vertical vanishing point from the representations of the vertical lines comprises determining a point of intersection of the vertical lines.

4. Method in accordance with at least one of the preceding claims, wherein the corrected vertical vanishing point is determined by rotating the vertical vanishing point around the principal point of the image (25) by the negative of the roll angle.

5. Method in accordance with claim 4, wherein the second coordinate of the corrected vertical vanishing point is calculated as the sum of the product of the first coordinate of the vertical vanishing point and the sine of the negative of the roll angle and the product of the second coordinate of the vertical vanishing point and the cosine of the negative of the roll angle.

6. Method in accordance with at least one of the preceding claims, wherein the calibration pattern defines more than two horizontal lines and/or more than two vertical lines, representations of which are identified within the acquired image (25).

7. Method in accordance with at least one of the preceding claims,
wherein the steps of acquiring the image (25) of the calibration pattern (15), of identifying representations of the horizontal and vertical lines, of determining the horizontal and the vertical vanishing points and of calculating at least one of the roll angle, the yaw angle and the pitch angle are executed repeatedly such that at least one of a set of roll angles, a set of yaw angles and a set of pitch angles is obtained,
the method further comprising the step of calculating at least one of an averaged roll angle, an averaged yaw angle and an averaged pitch angle by averaging the angles of the set of roll angles, the set of yaw angles or the set of pitch angles, respectively.

8. Method in accordance with at least one of the preceding claims,
further comprising the step of determining a lateral offset of the camera (19) relative to the calibration pattern (15) and/or a height (29) of the camera (19) by

- correcting the acquired image (25) for at least one of roll, yaw and pitch,
- determining a first coordinate difference and/or a second coordinate difference between the principal point of the image (25) and a representation of a reference point (31) of the calibration pattern (15) within the image (25), the reference point (31) having a known horizontal and/or vertical position, and
- determining the lateral offset and/or the height (29) of the camera (19) by scaling the first coordinate difference and/or the second coordinate difference with a factor obtained by multiplying a known distance (33) of the camera to the calibration pattern (15) with the quotient of a pixel pitch of the camera (19) and a focal length of the camera (19).

9. Method in accordance with at least one of the preceding claims,
wherein the step of placing the camera in front of the calibration pattern (15) is executed at the end of a production line which the vehicle the camera is mounted to has run through for its production.

10. Computer program product with a computer program which has software means for carrying out a method in accordance with at least one of the preceding claims if the computer program is executed in a computing device.

Patentansprüche

1. Verfahren zum Kalibrieren der Orientierung einer Kamera (19), die an einem Fahrzeug, insbesondere einem Lastwagen (11) montiert ist, mit den Schritten:

    - Anordnen der Kamera vor einem Kalibrierungsmuster (15), das zumindest zwei horizontale Linien und zwei vertikale Linien definiert;
    - Aufnehmen eines Bildes (25) des Kalibrierungsmusters (15) mittels der Kamera (19), wobei das Bild (25) eine erste Achse und eine zweite Achse aufweist, die zumindest im Wesentlichen einer horizontalen Achse bzw. einer vertikalen Achse entsprechen;
    - Identifizieren von Darstellungen der horizontalen Linien und der vertikalen Linien in dem aufgenommenen Bild (25);
    - Bestimmen eines horizontalen Fluchtpunktes aus den Darstellungen der horizontalen Linien;
    - Bestimmen eines vertikalen Fluchtpunktes aus den Darstellungen der vertikalen Linien;

    dadurch gekennzeichnet, dass das Verfahren ferner die Schritte umfasst:

    - Berechnen eines Wankwinkels durch Berechnen des Arkustangens des Quotienten einer zweiten Koordinate des horizontalen Fluchtpunktes, die entlang der zweite Achse gemessen ist, und der ersten Koordinate des horizontalen Fluchtpunktes,
    - Berechnen eines Gierwinkels durch Berechnen des Arkustangens des Quotienten eines Brennpunktes der Kamera (19) und des Produktes eines Pixelabstands der Kamera (19) und der ersten Koordinate des horizontalen Fluchtpunktes oder eines korrigierten horizontalen Fluchtpunktes, und
    - Berechnen eines Nickwinkels durch Berechnen des Arkustangens des Quotienten eines Brennpunktes der Kamera (19) und des Produktes eines Pixelabstands der Kamera (19) und der zweiten Koordinate des vertikalen Fluchtpunktes oder eines korrigierten vertikalen Fluchtpunktes.

2. Verfahren nach Anspruch 1, wobei das Kalibrierungsmuster (15) zumindest einen ersten charakteristischen Punkt, einen zweiten charakteristischen Punkt, einen dritten charakteristischen Punkt und einen vierten charakteristischen Punkt umfasst, wobei die zwei horizontalen Linien durch die ersten und zweiten charakteristischen Punkte bzw. die dritten und vierten charakteristischen Punkte definiert sind und die beiden vertikalen Linien durch die ersten und dritten charakteristischen Punkte bzw. die zweiten und vierten charakteristischen Punkte definiert sind.

3. Verfahren nach einem der Ansprüche 1 oder 2, wobei das Bestimmen des horizontalen Fluchtpunktes aus den Darstellungen der horizontalen Linien ein Bestimmen eines Schnittpunktes der horizontalen Linien umfasst,
    und/oder
    wobei das Bestimmen des vertikalen Fluchtpunktes aus den Darstellungen der vertikalen Linien ein Bestimmen eines Schnittpunktes der vertikalen Linien umfasst.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei der korrigierte vertikale Fluchtpunkt durch Drehen des vertikalen Fluchtpunktes um den Hauptpunkt des Bildes (25) um das Negative des Wankwinkels bestimmt wird.

5. Verfahren nach Anspruch 4,
    wobei die zweite Koordinate des korrigierten vertikalen Fluchtpunktes als die Summe des Produktes der ersten Koordinate des vertikalen Fluchtpunktes und dem Sinus des Negativen des Wankwinkels und dem Produkt der zweiten Koordinate des vertikalen Fluchtpunktes und dem Kosinus des Negativen des Wankwinkels berechnet wird.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Kalibrierungsmuster mehr als zwei horizontale Linien und/oder mehr als zwei vertikale Linien aufweist, deren Darstellungen in dem aufgenommenen Bild (25) identifiziert werden.

7. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Schritte zum Aufnehmen des Bildes (25) des Kalibrierungsmusters (15), zum Identifizieren von Darstellungen der horizontalen und vertikalen Linien, zum Bestimmen der horizontalen und der vertikalen Fluchtpunkte und zum Berechnen zumindest eines von dem Wankwinkel, dem Gierwinkel und dem Nickwinkel wiederholt ausgeführt werden, so dass zumindest einer eines Satzes von Wankwinkeln, eines Satzes von Gierwinkeln und eines Satzes von Nickwinkeln erhalten wird,
    wobei das Verfahren ferner den Schritt zum Berechnen zumindest eines aus einem gemittelten Wankwinkel, einem gemittelten Gierwinkel und einem gemittelten Nickwinkel durch Mitteln der Winkel des Satzes von Wankwinkeln, des Satzes von Gierwinkeln bzw. des Satzes von Nickwinkeln berechnet wird.

8. Verfahren nach einem der vorhergehenden Ansprüche, ferner mit dem Schritt zum Bestimmen eines seitlichen Versatzes der Kamera (19) relativ zu dem Kalibrierungsmuster (15) und/oder einer Höhe (29) der Kamera (19) durch:

    - Korrigieren des aufgenommenen Bildes (25)

in Bezug auf zumindest eines von Wanken, Gieren und Nicken,
- Bestimmen einer ersten Koordinatendifferenz und/oder einer zweiten Koordinatendifferenz zwischen dem Hauptpunkt des Bildes (25) und einer Darstellung eines Referenzpunktes (31) des Kalibrierungsmusters (15) in dem Bild (25), wobei der Referenzpunkt (31) eine bekannte horizontale und/oder vertikale Position aufweist, und
- Bestimmen des seitlichen Versatzes und/oder der Höhe (29) der Kamera (19) des Skalierens der ersten Koordinatendifferenz und/oder der zweiten Koordinatendifferenz mit einem Faktor, der durch Multiplizieren einer bekannten Distanz (33) der Kamera zu dem Kalibrierungsmuster (15) erhalten wird, mit dem Quotienten eines Pixelabstands der Kamera (19) und einer Brennweite der Kamera (19).

9. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt zum Platzieren der Kamera vor dem Kalibrierungsmuster (15) an dem Ende einer Fertigungslinie ausgeführt wird, die das Fahrzeug, an dem die Kamera montiert ist, für seine Herstellung durchlaufen muss.

10. Computerprogrammprodukt mit einem Computerprogramm, das ein Softwaremittel zum Ausführen eines Verfahrens nach einem der vorhergehenden Ansprüche aufweist, wenn das Computerprogramm in einer Berechnungsvorrichtung ausgeführt wird.

Revendications

1. Procédé pour étalonner l'orientation d'une caméra (19) montée sur un véhicule, en particulier un camion (11), comprenant les étapes consistant à :

- placer la caméra devant un motif d'étalonnage (15) définissant au moins deux lignes horizontales et deux lignes verticales ;
- acquérir une image (25) du motif d'étalonnage (15) au moyen de la caméra (19), l'image (25) ayant un premier axe et un deuxième axe correspondant au moins essentiellement, respectivement, à un axe horizontal et un axe vertical ;
- identifier des représentations des lignes horizontales et des lignes verticales dans l'image acquise (25) ;
- déterminer un point de disparition horizontal à partir des représentations des lignes horizontales ;
- déterminer un point de disparition vertical à partir des représentations des lignes verticales ;

caractérisé en ce que le procédé comprend en outre les étapes consistant à :

- calculer un angle de roulis en calculant l'arc tangente du quotient d'une deuxième coordonnée du point de disparition horizontal mesurée le long du deuxième axe et de la première coordonnée du point de disparition horizontal,
- calculer un angle de lacet en calculant l'arc tangente du quotient d'une longueur focale de la caméra (19) et du produit d'un pas de pixel de la caméra (19) et de la première coordonnée du point de disparition horizontal ou d'un point de disparition horizontal corrigé, et
- calculer un angle de tangage en calculant l'arc tangente du quotient d'une longueur focale de la caméra (19) et du produit d'un pas de pixel de la caméra (19) et de la deuxième coordonnée du point de disparition vertical ou d'un point de disparition vertical corrigé.

2. Procédé selon la revendication 1,
dans lequel le motif d'étalonnage (15) comprend au moins un premier point caractéristique, un deuxième point caractéristique, un troisième point caractéristique et un quatrième point caractéristique, les deux lignes horizontales étant définies par les premier et deuxième points caractéristiques et les troisième et quatrième points caractéristiques, respectivement, et les deux lignes verticales étant définies par les premier et troisième points caractéristiques et les deuxième et quatrième points caractéristiques, respectivement.

3. Procédé selon la revendication 1 ou 2,
dans lequel l'étape consistant à déterminer le point de disparition horizontal à partir des représentations des lignes horizontales consiste à déterminer un point d'intersection des lignes horizontales
et/ou
dans lequel l'étape consistant à déterminer le point de disparition vertical à partir des représentations des lignes verticales consiste à déterminer un point d'intersection des lignes verticales.

4. Procédé selon au moins l'une des revendications précédentes,
dans lequel le point de disparition vertical corrigé est déterminé en faisant tourner le point de disparition vertical autour du point principal de l'image (25) du négatif de l'angle de roulis.

5. Procédé selon la revendication 4,
dans lequel la deuxième coordonnée du point de disparition vertical corrigé est calculée comme la somme du produit de la première coordonnée du point de disparition vertical et du sinus du négatif de l'angle de roulis et du produit de la deuxième coordonnée du point de disparition vertical et du cosinus du né-

gatif de l'angle de roulis.

6. Procédé selon au moins l'une des revendications précédentes,
dans lequel le motif d'étalonnage définit plus de deux lignes horizontales et/ou plus de deux lignes verticales, dont les représentations sont identifiées dans l'image acquise (25).

7. Procédé selon au moins l'une des revendications précédentes,
dans lequel les étapes consistant à acquérir l'image (25) du motif d'étalonnage (15), à identifier des représentations des lignes horizontales et verticales, à déterminer les points de disparition horizontaux et verticaux et à calculer au moins un angle parmi l'angle de roulis, l'angle de lacet et l'angle de tangage sont exécutés de manière répétée de telle sorte qu'au moins un ensemble parmi un ensemble d'angles de roulis, un ensemble d'angles de lacet et un ensemble d'angles de tangage soit obtenu,
le procédé comprenant en outre l'étape consistant à calculer au moins un angle parmi un angle de roulis moyen, un angle de lacet moyen et un angle de tangage moyen en faisant la moyenne des angles de l'ensemble d'angles de roulis, de l'ensemble d'angles de lacet ou de l'ensemble d'angles de tangage, respectivement.

8. Procédé selon au moins l'une des revendications précédentes, comprenant en outre l'étape consistant à déterminer un décalage latéral de la caméra (19) par rapport au motif d'étalonnage (15) et/ou une hauteur (29) de la caméra (19) en

- corrigeant l'image acquise (25) pour au moins un mouvement parmi le roulis, le lacet et le tangage,
- déterminant une première différence de coordonnées et/ou une deuxième différence de coordonnées entre le point principal de l'image (25) et une représentation d'un point de référence (31) du motif d'étalonnage (15) dans l'image (25), le point de référence (31) ayant une position horizontale et/ou verticale connue, et
- déterminant le décalage latéral et/ou la hauteur (29) de la caméra (19) en mettant à l'échelle la première différence de coordonnées et/ou la deuxième différence de coordonnées avec un facteur obtenu en multipliant une distance connue (33) de la caméra au motif d'étalonnage (15) par le quotient d'un pas de pixel de la caméra (19) et d'une longueur focale de la caméra (19).

9. Procédé selon au moins l'une des revendications précédentes,
dans lequel l'étape consistant à placer la caméra devant le motif d'étalonnage (15) est exécutée à la fin d'une ligne de production que le véhicule sur lequel la caméra est montée a traversée pour sa production.

10. Produit programme d'ordinateur avec un programme d'ordinateur qui présente des moyens logiciels pour mettre en oeuvre un procédé selon au moins l'une des revendications précédentes si le programme d'ordinateur est exécuté sur un dispositif informatique.

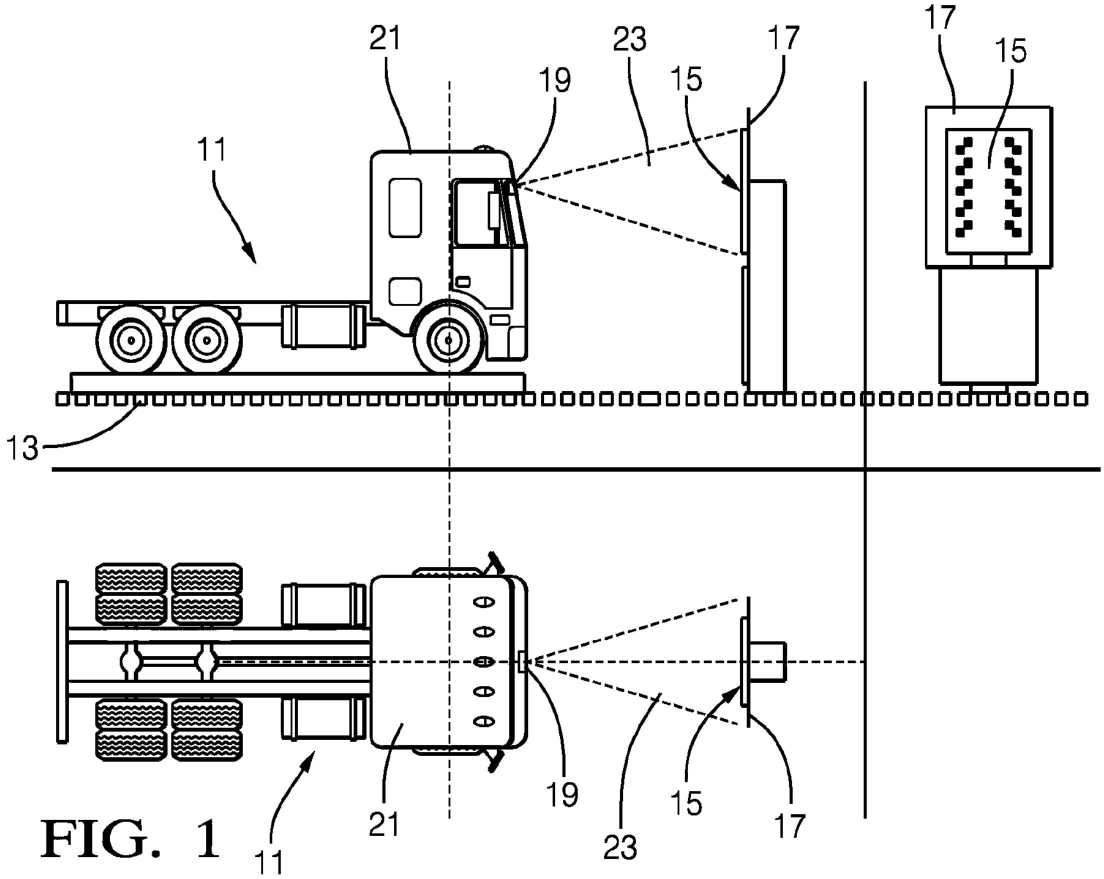

FIG. 1

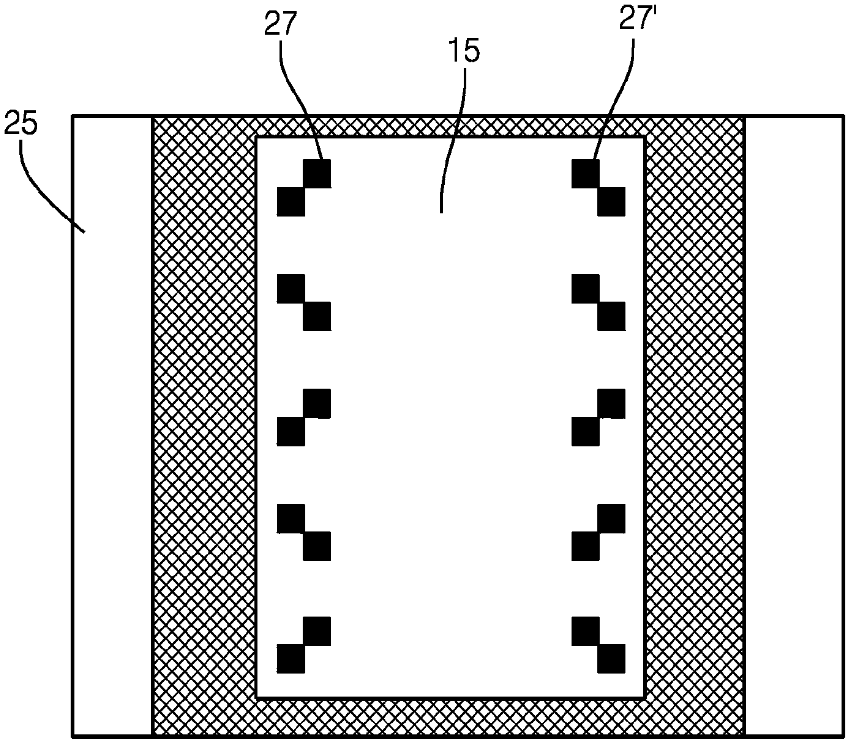

FIG. 2

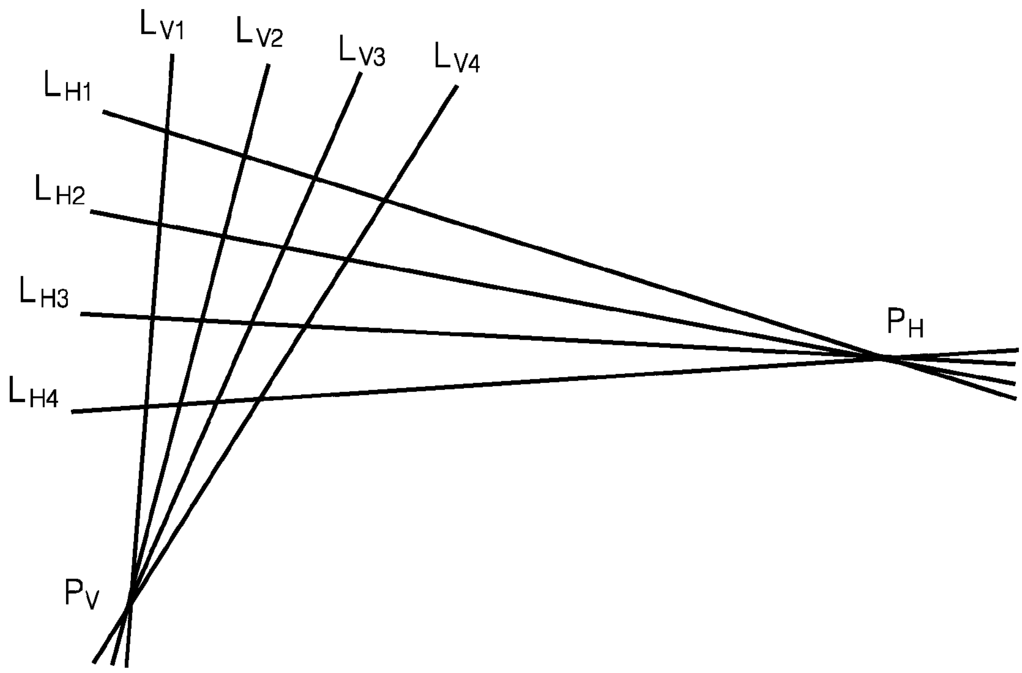

FIG. 3

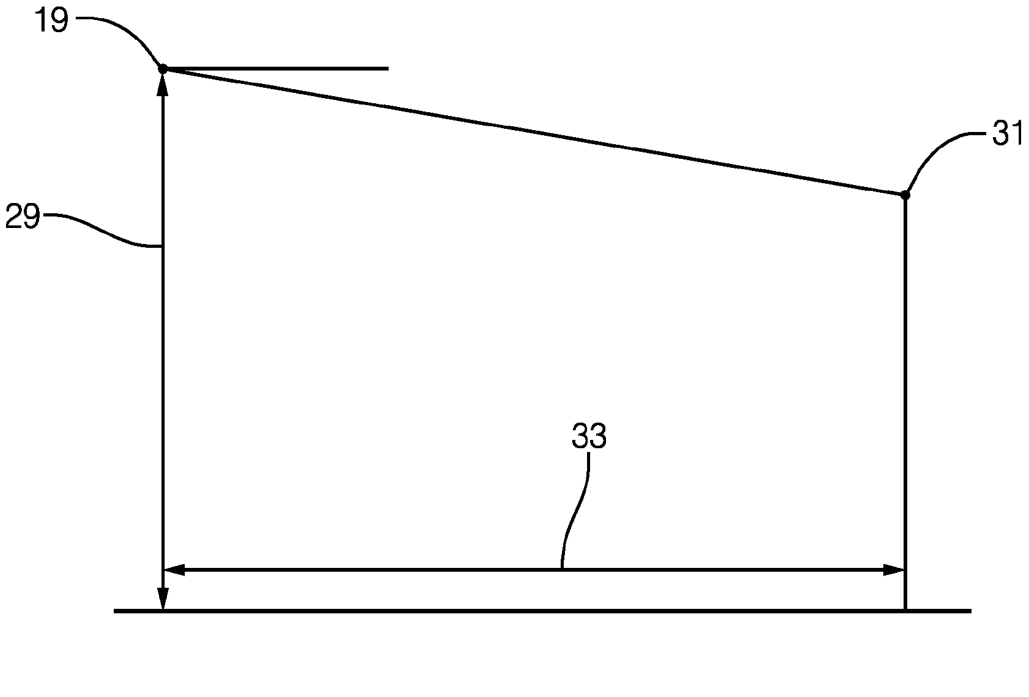

FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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