Title: ONLINE VEHICLE CAMERA CALIBRATION BASED ON ROAD MARKING EXTRactions

Abstract: The invention relates to a method for online calibration of a vehicle video system evaluated from image frames of a camera containing longitudinal road features. A portion of a road surface is captured by the camera in an image frame. An identification of longitudinal road features within the image frame is performed. Points are extracted along the identified longitudinal road features to be transformed to a virtual road plan view via a perspective mapping taking into account prior known parameters of the camera. The transformed extracted points are analysed with respect to the vehicle by determining a possible deviation of the points from a line parallel to the vehicle while any measured deviation being used to define an offset correction of the camera.
ONLINE VEHICLE CAMERA CALIBRATION BASED ON ROAD MARKING EXTRACTIONS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] This invention relates generally to an online calibration of a vehicle video system, and particularly to a method for online calibration of the vehicle video system evaluated from image frames of a camera. It is also related to a computer program product for processing data relating to the online calibration of the vehicle video system, the computer program product comprising a computer usable medium having a computer usable program code embodied therewith, the computer program code being configured to perform any of the method steps. The present invention is further related to an online calibration system for a vehicle video system for processing the computer implemented online calibration method.

DESCRIPTION OF BACKGROUND

[0002] It is known to mount image capture devices, such as, for example, digital or analogue video cameras, on a motor vehicle in order to produce a video image of an aspect of the environment exterior of the vehicle. For example, in order to assist in parking and manoeuvring a vehicle in confined spaces, it is known to mount such image capturing devices on respective opposite sides of the vehicle, for example, on side rear view mirror housings which extend sidewardly from the driver and front passenger doors of the vehicle. The image capture devices are mounted in the side rear view mirror housings with the field of view of the image capture devices directed downwardly towards the ground for capturing plan view images of the ground on respective opposite sides of the vehicle adjacent the vehicle. Typically, a visual display unit is located in the vehicle, either in or on the dashboard, or in a location corresponding to that of a conventional interiorly mounted rear view mirror. Nowadays, also head-up displays are used for vehicle. Even, a projection onto the windscreen is now possible. When a driver
is undertaking a parking manoeuvre or a manoeuvre in a confined space, a view image of
the vehicle with the respective view images of the ground on respective opposite sides of
the vehicle can be displayed on the visual display unit. The view display of the vehicle
and the ground on respective opposite sides of the vehicle assists the driver in parking,
and in particular, carrying out a parking manoeuvre for parking the vehicle in a parking
space parallel to a kerb of a footpath or the like.

However, in order that the view images of the ground accurately reflect the
positions of objects relative to the vehicle, which are captured in the images, it is
essential that the view images of the ground juxtapositioned with the view image of the
vehicle should accurately represent a top view of the ground adjacent the respective
opposite sides of the vehicle exactly as would be seen when viewed from above. In other
words, the edges of the respective view images of the ground which extend along the
sides of the view image of the vehicle must correspond directly with the edge of the
ground along the sides of the vehicle when viewed in view from a position above the
vehicle. Otherwise, the positions of objects in the respective view images of the ground
will not be accurately positioned relative to the vehicle. For example, if the edge of one
of the view images of the ground adjacent the corresponding side of the view image of
the vehicle corresponds with a portion of a view of the ground which is spaced apart from
the side of the vehicle, then the positions of objects in the view image of the ground will
appear closer to the vehicle in the image than they actually are. Conversely, if one of the
image capture devices is mounted on a side mirror housing so that an image of a portion
of the ground beneath a side of the vehicle is captured, the positions of objects captured
in the view image will appear farther away from the vehicle than they actually are, with
disastrous results, particularly if a driver is parking the vehicle parallel to a wall or
bollards. Similar requirements apply also for front or rear placed image capture devices.
Often, the most obvious effect of poor calibration happens when a merged image is
presented to the user and one of the cameras is not correctly calibrated. In this case an
object/feature on the ground can appear disjointed or elongated or disappear completely
from the view presented to the user.
Accordingly, it is essential that the view images of the ground when displayed on the visual display screen juxtapositioned along with the view image of the vehicle must be representative of views of the ground on respective opposite sides of the vehicle exactly as would be seen from a top view of the vehicle and adjacent ground. In order to achieve such accuracy, the image capture devices would have to be precision mounted on the vehicle. In practice this is not possible. Accordingly, in order to achieve the appropriate degree of exactness and accuracy of the view images of the ground relative to the view image of the vehicle, it is necessary to calibrate the outputs of the image capture devices. Calibration values determined during calibration of the image capture devices are then used to correct subsequently captured image frames for offset of the image capture devices from ideal positions thereof, so that view images of the ground subsequently outputted for display with the view image of the vehicle are exact representations of the ground on respective opposite sides of the vehicle. Such calibration can be accurately carried out in a factory during production of the motor vehicle. The calibration may also use the absolute position/rotation of the camera. Typically, the image capture devices are relatively accurately fitted in the side mirror housings of the motor vehicle, and by using suitable grid patterns on the ground, calibration can be effected. However, the environments in which motor vehicles must operate are generally relatively harsh environments, in that side mirror housings are vulnerable to impacts with other vehicles or stationary objects. While such impacts may not render the orientation of the side mirror housing unsuitable for producing an adequate rear view from a rear view mirror mounted therein, such impacts can and in general do result in the image capturing device mounted therein being knocked out of alignment, in other words, being offset from its ideal position. Additionally, where a vehicle is involved in a crash, or alternatively, where a side mirror housing requires replacement, re-calibration of the image capture device refitted in the new side mirror housing will be required. Such re-calibration, which typically would be carried out using a grid pattern on the ground, is unsatisfactory, since in general, it is impossible to accurately align the vehicle with the grid pattern in order to adequately calibrate the image capture device, unless the calibration is being carried out under factory conditions. The same applies for rear or
front placed image capture devices even in the case, those devices are placed in the interior of the vehicle since harsh conditions apply also there.

[0005] In WO2009/027090 is described a method and system for online calibration of a vehicle video system using vanishing points evaluated from frames of a camera image containing identified markings or edges on a road. In US2009/0290032 is described a system and method for calibrating a camera on a vehicle by identifying at least two feature points in at least two camera images from a vehicle that has moved between taking the images. The method then determines a camera translation direction between two camera positions. Following this, the method determines a ground plane in camera coordinates based on the corresponding feature points from the images and the camera translation direction. The method then determines a height of the camera above the ground and a rotation of the camera in vehicle coordinates.

SUMMARY OF THE INVENTION

[0006] In view of the above, there is a need for a method and a calibration system for calibrating an output of an image capture device or camera mounted on a vehicle to compensate for offset of the camera from an ideal position, such method and calibration system being based on a simple use of available longitudinal road features without requiring a calibration of the camera to be carried out in a controlled environment.

[0007] According to a first aspect of the embodiment of the present invention, a method for online calibration of a vehicle video system is evaluated from image frames of a camera containing longitudinal road features. The method comprises the following steps of capturing by the camera of a portion of the road surface in an image. Then longitudinal road features are identified within the image frame. Points along the identified longitudinal features are extracted and transformed to a virtual road plan view via perspective mapping taking into account prior known parameters of the camera. An analysis of the transformed extracted points is performed with respect to the vehicle to determine a possible deviation of the points from a line parallel to a line alongside the
vehicle. The consequently determined deviation is then applied for an online calibration of the camera.

[0008] Advantageously, the determined deviation is applied as error measure to be minimised when adjusting rotation parameters used for the calibration of the camera. In an embodiment according to the invention the extracted points along identified longitudinal road features within a sequence of image frames are analysed in the transformed virtual road plan view and stored over a period of time. Such stored data are then used for a determination of a deviation of the points to be applied as error measure to be minimised when adjusting rotation parameters for the calibration of the camera. In both alternatives, a binary search method can be applied when minimising the error measure. Also a nonlinear optimization method can be applied when minimising the error measure. Alternatively, the calibration is calculated for each frame and the result is stored. The calibrations from all frames are finally averaged.

[0009] In some embodiment according to the invention the calibration of the camera is performed about an y-axis transverse to the vehicle and parallel to the road plan and about an z-axis transverse to the vehicle and perpendicular to the road plan.

[0010] Advantageously, longitudinal road features more then a predefined distance away from the car are used for the calibration of the camera about an y-axis transverse to the vehicle and parallel to the road plan. Also longitudinal road features less then a predefined distance away from the car can be used for the calibration of the camera about an z-axis transverse to the vehicle and perpendicular to the road plan.

[0011] It is further possible according to the invention to use steering angle of the vehicle when transforming the extracted points to the virtual road plan view.

[0012] It is also possible to analyse the extracted points to be rejected as outlier if fulfilling some criteria. Advantageously, the extracted points are rejected when analysing the transformed extracted points in the case a line with an angle curvature greater than a predefined value is built.
[0013] According to a second aspect of the embodiment, a computer program product for processing data relating to online calibration of a vehicle video system is also described and claimed herein. The computer program product comprises a computer usable medium having computer usable program code embodied therewith, the computer usable program code being configured to perform the above summarized methods.

[0014] According to a third aspect of the embodiment, an online calibration system for a vehicle video system is also described and claimed herein. The online calibration system comprises a computer program product for processing data relating to an online calibration method and an image processing apparatus with a camera for taking image frames to be used by the online calibration method such to perform the above summarized methods.

[0015] Additional features and advantages are realized through the techniques of the present invention. Other embodiments and aspects of the invention are described in detail herein and are considered a part of the claimed invention. For a better understanding of the invention with advantages and features, refer to the description and to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other objects, features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0017] FIG. 1 illustrates a side view and a top view of a vehicle with a 3d co-ordinate system;

[0018] FIG. 2 illustrates an example of longitudinal road features tracking for a wing mirror camera according to the invention;
[0019] FIG. 3 illustrates an example of longitudinal road features tracking for a wing mirror fish eye camera according to the invention;

[0020] FIG. 4 illustrates an example of a virtual road plan view according to the invention;

[0021] FIG. 5 illustrates an example of a virtual road plan view according to the invention;

[0022] FIG. 6 illustrates an example of a virtual road plan view according to the invention;

[0023] FIG. 7 illustrates an example of a virtual road plan view according to the invention.

[0024] The detailed description explains the preferred embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0025] As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, method or computer program product. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, aspects of the present invention may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

[0026] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for
example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0027] A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electro-magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

[0028] Program code embodied on a computer readable medium may be transmitted within the vehicle using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

[0029] Computer program code for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the vehicle's computer, partly on the vehicle's computer, as a stand-alone software
package, partly on the vehicle's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the vehicle's computer through any type of wireless network, including a wireless local area network (WLAN), possibly but not necessarily through the Internet using an Internet Service Provider.

[0030] Aspects of the present invention are described below with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0031] These computer program instructions may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the flowchart and/or block diagram block or blocks.

[0032] The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.
[0033] Present invention is a means of calibrating a camera on a vehicle to determine the extrinsic camera rotation parameters relative to the vehicle co-ordinate system when the camera is positioned in an undetermined relevant position on the vehicle body. Calibration allows the vehicle manufacturer to provide a geometrically representative and more importantly a useful view to a vehicle user.

[0034] Turning now to the drawings in greater detail, it will be seen that in figure 1 is shown a side view and a top view of a vehicle 1 with a defined three dimensional co-ordinate system XYZ as used in the following. X-axis is chosen along the longitudinal direction, Y-axis along the transverse direction and Z-axis along the vertical direction of the vehicle 1.

[0035] The camera, whether placed at rear, front or side usually wing-mirror, captures a significant portion of road surfaces in the scene. Such portion of road surfaces is stored in image frames containing some longitudinal road features like markings or edges. Present invention is preferably adapted for camera placed at the side of the vehicle but could be adapted also for rear or front cameras. Alternately, present invention could be used for the side camera and combined with other online calibration. Accordingly, present invention is best suitable for the estimation of the rotation of the camera about the y- and the z-axes (see fig. 1).

[0036] Figure 2 shows an image taken by a side camera of the vehicle 1. The road ground 20 comprises road markings here broken (dashed) lines 21 as well as edgeline 22 at the edge 23 of the road. Present invention could be applied for any sort of road marking like solid lane line or even dotted lane line. Furthermore, it is also applicable when no marking at all is present by using then the edge 23 of the road as longitudinal road features. On figure 2 is also visible the horizon line 24.

[0037] Longitudinal road features (here broken lines 21 and edgeline 22 on fig. 2) are identified within the image frame captured by the camera. Any adequate method can be used to extract those longitudinal road features from the camera image. Preferably, such longitudinal road features are extracted by analyzing several columns of raw video data
within a predetermined region of interest of the frame at regular vertical intervals to
detect light colored blobs. This can be achieved by looking for rising edge followed by a
falling edge, a method also applicable for road edge 23. A blob is accepted only if its
average luminance is significantly greater than the surrounding road. For road marking
like for markings 21 and 22, a further criterion can be applied namely that its width is
within road marking min and max constraints, usually well defined through some
standards while possibly country dependent.

[0038] Once longitudinal road features are identified then points 26, 27 can be extracted
along them. Those points 26, 27 are used on a virtual road plan view for the online
calibration. Similar method can be applied for a side camera with a fish eye or wide-angle
like optic. Fig. 3 shows a similar image of road ground as shown on fig. 2 but this time
taken using some side camera with a fish eye lens. The road ground 30 comprises again
some road markings as broken lines 31 and edgeline 32. The road markings 31, 32 as
well as the road edge 33 and the horizon 34 show a clear distortion typical for a camera
with a wide-angle optic. The characteristics of the camera being known, it is possible to
subtract the distortion coming from the wide-angle optic (fish eye lens) when identifying
the longitudinal road features 31, 32, 33. In a same way as in the case of figure 2, points
36, 37 can be extracted here from the road markings respectively broken line 31, and
edgeline 32.

[0039] The extracted points (26, 27 for Fig. 2 and 36, 37 for Fig. 3) are transformed to a
virtual road view perspective mapping. Several parameters like the initial or the last
defined position of the camera are preferably but not necessarily been taken for such
mapping. The initial position or location as well as possible rotation along the x-axis (see
Fig. 1) are fixed possibly by some previous calibration. Also an initial estimate of a
rotation about the y- and z-axes can be considered possibly from mechanical data. Any
other intrinsic parameters from the camera can advantageously be taken into account.

[0040] The transformation of the extracted points to a perspective image can be
performed using usual rotation matrices (see e.g.
http://en.wikipedia.org/wiki/Euler_angles) and camera projection matrices (see
http://www.cs.unc.edu/~marc/tutorial/node39.html). Given the fact that the road
markings are known to be on the ground plane, each of the extracted points in the image
can be transformed to a point on the road plane. With a fish eye camera, such
transformation must take into account the fish eye projection function (see e.g.
http://en.wikipedia.org/wiki/Fisheye_lens, though any such projection function can be
used). Once lines have been detected along the extracted points, they are then mapped to
the ground to adjust the camera rotation to make the line parallel to the vehicle.

[0041] Figure 4 shows accordingly a projection of the extracted points to a virtual road
plan view with the road 40 and the vehicle 41. Longitudinal road features like broken
lines 42 in the middle of the road and edgelines 43, 44 at the right and the left of the road
are represented together with the right edge 45 of the road. The representation on figure 4
corresponds to a left-hand driving situation typical for some countries like the UK or
Ireland. Also shown are the points 46 extracted along the broken lines 42 as well as the
points 47 extracted along the edgeline 43. It is clearly visible from figure 4 that the
extracted points 46 and 47 do not follow the corresponding chosen longitudinal road
features i.e. are not parallel to the vehicle x-axis. This comes from the fact that the y- and
z-rotations of the selected camera to calibrate are considered with incorrect initial
parameters.

[0042] The advantage of present invention is currently to adjust y- and z-rotation
parameters such that the re-projected points form lines that are parallel to the vehicle x-
axis. The introduced error-function, therefore, becomes the measure of how parallel the
projected points are to the vehicle x-axis. A minimization algorithm based on simple
binary search (usually one angle camera at a time is solved) can be used to estimate the
parameters (y and z rotation parameters) that minimize this error measure. Initial rotation
parameters are chosen as starting point for the solver.

[0043] On figure 5 is shown a similar plan view of the virtual road 50 as in figure 4 with
the vehicle 51, the longitudinal road features with markings 52 (broken lines), 53, 54
(right and left edgelines) and right edge of the road 55. Also are shown the re-projected points 56, 57 after the solver selects the correct y- and z-rotations. The points 56, 57 follow now the respective longitudinal road features in a parallel way while still not matching them. This is due to the fact that the x-axis rotation parameter cannot be estimated with the use of present method.

[0044] In case such x-axis rotation parameter is available using an alternative method then it is possible to complete the online calibration taking into account latter parameter. Figure 6 shows the final result with a calibration on the three axes with the road 60, the vehicle 61, the longitudinal road features 62, 63, 64, 65 and the projected points 66 and 67.

[0045] It appears that the primary cause of non-parallelism to the vehicle x-axis is rotation about the y-axis for lines that are parallel to the side of the vehicle and more than a given distance $A$ m away. Thus, the problem of online calibration is preferably divided into two problems, namely lines that are more than $A$ meters away are only used to determine the rotation about the y-axis. $A$ is set to 2m but other values could be chosen as a predefined parameter (stored in some memory let available for the online calibration). Such parameter can be adjusted according to the camera being calibrated and the location of the camera on the vehicle.

[0046] In a similar way, to reduce the dependence of the z-axis calibration on the previous y-axis calibration, only lines within $B$ m of the vehicle can be used in the calibration of the z-axis rotation. $B$ can be chosen as a predefined parameter also to be stored in some memory let available for the online calibration. Such parameter can be adjusted based on the camera type and position on the vehicle. $B$ is set to 0.5m but also other values could be chosen according to some criteria possibly related to the kind of camera to be calibrated.

[0047] Figure 7 shows a similar plan view as in figure 6 now with selections of the different extracted points on the one hand for the calibration for z-axis rotation and on the other hand for the calibration for y-axis rotation. On the road 70 with the vehicle 71 are
shown the different longitudinal road features 72, 73, 74, 75 as well as the extracted points 76 and 77. In the considered case of the calibration of a camera at the right side of the vehicle 1 and left-hand driving situation, the points 76 extracted from the broken lines 72 are the ones close to the vehicle. In the case those extracted points 76 are within the predefined interval $B$ possibly defined from the approximate trajectory 78 (broken line) of the camera (wing-mirror camera) outwards and set to be equal to 0.5m then those points 76 are considered exclusively for the calibration along the z-axis rotation. In the same way, the points 77 extracted from the edgeline 73 are the ones far to the vehicle. Therefore, those extracted points 77 being within the predefined interval $A$ possibly defined from the approximate trajectory 78 of the camera outwards and set to be equal to 2m then those points 77 are considered exclusively for the calibration along the y-axis rotation.

[0048] Above described online calibration can be applied in a similar way for a camera placed at the left side of the vehicle. Also, different longitudinal road features can be selected from which points can be extracted. For example, in case no markings or the markings are not clearly visible then the edge of the road can be used as a longitudinal feature for the online calibration.

[0049] In an embodiment according to the invention, lines that are extracted (using the extracted points) can be stored over a period of time. Thus, a large set of lines can be stored and a minimization algorithm can be used to determine the y- and z-axes rotations. For that, extracted lines are stored for some possibly predefined length of time/number of image frames taken by the camera to be calibrated. Once a number of edges have been extracted at different points in time, then the rotation parameters are determined using a search or error minimization algorithm. Currently, a binary search method (http://en.wikipedia.org/wiki/Binary_search_algorithm) is used possibly combined with the use of the $A$ and $B$ intervals to differentiate between the calibration along the y- and the z-axes. Any other appropriate error minimization algorithm could also be applied here. Also a more complex algorithm like Nelder-Mead shall be preferably used when the y- and z-axes rotations calibration are solved together.
[0050] Advantageously, the steering angle of the vehicle can be currently used to ensure that the vehicle is travelling along a straight direction when online calibration shall be applied. Additionally, a rejection criterion can be defined for outlier such that a line detected with an angle greater than a given threshold could be rejected. The threshold can be predefined possibly according to some experience collected in advance. Alternatively, the constraint that the tracks are parallel to the x-axis of the vehicle could be eliminated for by using the steering information or by having a range of predefined expected steering curvature. If initial estimates of the camera extrinsic parameters are known (e.g. from vehicle mechanical data), they can be used as starting points for the calibration. Advantageously, the speed and steering information possibly available on the vehicular network (e.g. via CAN, LIN, Wireless or other) can be used when transforming the extracted points to remove (relax) the necessity for the vehicle to be moving in a straight line and at constant speed.

[0051] The criteria for rejecting extracted points as outliers using the velocity of the vehicle could be based on the fact that when a vehicle is travelling faster, it is more likely to be travelling parallel to the longitudinal road features like the markings or the edge of the road. In contrast, when a vehicle is travelling slower (e.g. at junctions and roundabouts, etc.) it is likely that the road features captured by the camera are not actually parallel to the direction of the vehicle motion (i.e., parallel to the vehicle x-axis). Road-marking color information could also be considered as rejection criteria possibly but not necessarily in combination with the vehicle velocity. For example, if a green road blob is detected in areas where only white or yellow/orange markings are expected, it is highly likely that this is an erroneous detection and should be rejected as outlier.

[0052] Online calibration for camera of a vehicle video system according to the present invention is particularly suitable above a minimum speed of the vehicle e.g. above 50 km/h. Therefore, it is of advantage to combine the online calibration according to the present invention with other online calibration methods.
[0053] The capabilities of the present invention can be implemented in software, firmware, hardware or some combination thereof.

[0054] As one example, one or more aspects of the present invention can be included in an article of manufacture (e.g., one or more computer program products) having, for instance, computer usable media. The media has embodied therein, for instance, computer readable program code means for providing and facilitating the capabilities of the present invention. The article of manufacture can be included as a part of a computer system or sold separately. Additionally, at least one program storage device readable by a machine, tangibly embodying at least one program of instructions executable by the machine to perform the capabilities of the present invention can be provided.

[0055] While the preferred embodiment to the invention has been described, it will be understood that those skilled in the art, both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow. These claims should be construed to maintain the proper protection for the invention first described.
CLAIMS

1. A method for online calibration of a vehicle video system evaluated from image frames of a camera containing longitudinal road features, the method comprising the following steps of:
   - Capturing by the camera of a portion of the road surface (20, 30, 40, 50, 60, 70) in an image;
   - Identifying longitudinal road features (21-23, 31-33, 42-45, 52-55, 62-65, 72-75) within the image frame;
   - The method being characterized by the further steps of
     - Extracting points (26, 27, 36, 37, 46, 47, 56, 57, 66, 67, 76, 77) along the identified longitudinal road features;
     - Transforming the extracting points to a virtual road plan view via perspective mapping taking into account prior known parameters of the camera;
     - Analysing the transformed extracted points with respect to the vehicle by determining a deviation of the points from a line parallel to the vehicle (1, 41, 51, 61, 71);
     - Applying the determined deviation for a calibration of the camera.

2. The online calibration method according to claim 1 whereby the determined deviation is applied as error measure to be minimised when adjusting rotation parameters used for the calibration of the camera.

3. The online calibration method according to claim 1 whereby extracting points along identified longitudinal road features within a sequence of image frames to be analysed in the transformed virtual road plan view and stored over a period of time for a determination of a deviation of the points applied as error measure to be minimised when adjusting rotation parameters used for the calibration of the camera.

4. The online calibration method according to claim 2 or 3 whereby a binary search method is applied when minimising the error measure.

5. The online calibration method according to claim 2 or 3 whereby a nonlinear optimization method is applied when minimising the error measure.

6. The online calibration method according to one of the preceding claims whereby the calibration of the camera is performed about an y-axis transverse to the vehicle and parallel to the road plan and about an z-axis transverse to the vehicle and perpendicular to the road plan.

7. The online calibration method according to claim 1 whereby longitudinal road features more then a predefined distance away from the car are used for the calibration of the camera about an y-axis transverse to the vehicle and parallel to the road plan.
8. The online calibration method according to claim 1 whereby longitudinal road features less than a predefined distance away from the car are used for the calibration of the camera about an z-axis transverse to the vehicle and perpendicular to the road plan.

9. The online calibration method according to claim 1 whereby steering angle of the vehicle is used when transforming the extracted points to the virtual road plan view.

10. The online calibration method according to claim 1 whereby analysing the extracted points to be rejected as outlier if fulfilling some criteria.

11. The online calibration method according to claim 10 whereby rejecting the extracted points when analysing the transformed extracted points if building a line with an angle curvature greater than a predefined value.

12. A computer program product for processing data relating to online calibration of a vehicle video system, the computer program product comprising a computer usable medium having computer usable program code embodied therewith, the computer usable program code being configured to perform the steps of any of the preceding claims 1 to 11.

13. An online calibration system for a vehicle video system, the online calibration system comprising a computer program product for processing data relating to an online calibration method and an image processing apparatus with a camera for taking image frames to be used by the online calibration method such to perform the steps of any of the preceding claims 1 to 11.
Fig. 1
**INTERNATIONAL SEARCH REPORT**

A. **CLASSIFICATION OF SUBJECT MATTER**
   INV. G06T7/00
   ADD.

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

B. **FIELDS SEARCHED**

Minimum documentation searched: (classification system followed by classification symbols)
G06T

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, COMPENDEX, INSPEC, IBM-TDB, WPI Data

C. **DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier document but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed
  "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
  "S" document member of the same patent family

Date of the actual completion of the international search: 6 December 2011

Date of mailing of the international search report: 23/12/2011

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax (+31-70) 340-3016

Authorized officer:
Rockinger, Oliver

Form PCT/ISA/210 (second sheet) (April 2005)
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>US 2005113995 A1</td>
<td>26-05-2005</td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2004198211 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2005163343 A1</td>
</tr>
</tbody>
</table>