



- (51) International Patent Classification:
G06T 3/00 (2006.01)
- (21) International Application Number:
PCT/EP2020/063447
- (22) International Filing Date:
14 May 2020 (14.05.2020)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
10 2019 114 404.3
29 May 2019 (29.05.2019) DE
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,

(54) Title: IMAGE ACQUISITION SYSTEM

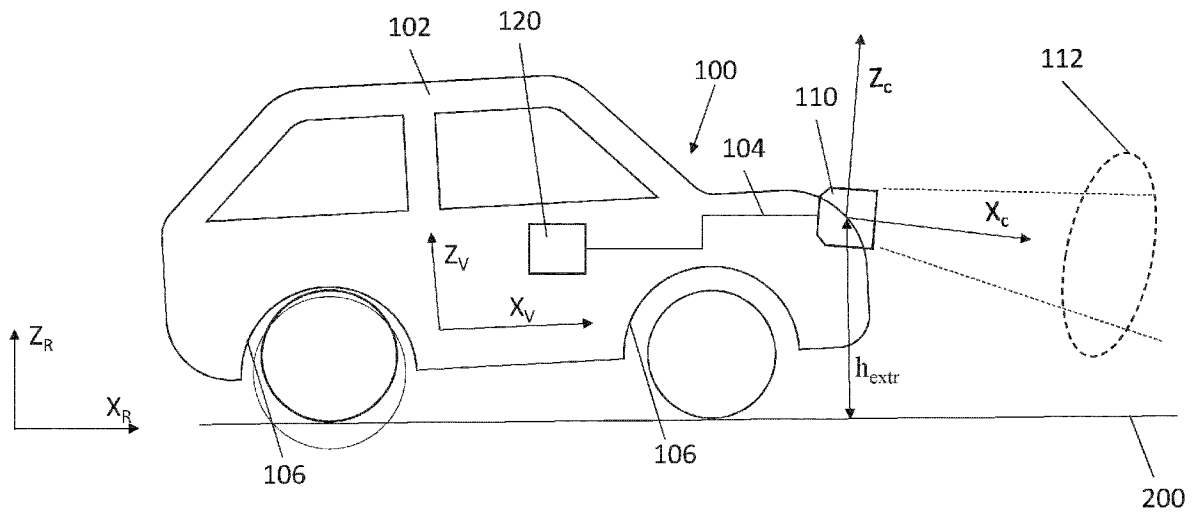


Figure 1

(57) Abstract: An image processing method comprises: determining camera rotation parameters (R_{extr}) around respective horizontal axes of a vehicle (102) and a height parameter (h_{extr}) along a vertical axis extending from a reference plane of the vehicle; acquiring an image from the camera; and determining, from suspension data of the vehicle at a time of acquisition of the image, one or more changes in the camera rotation parameter values and the height parameter value. The changes are applied to the camera rotation parameter values (R_{extr}) and the height parameter value (h_{extr}) to generate one or more adjusted camera rotation parameter values (R_{pose}) or an adjusted height parameter value (h_{pose}). A region of interest within the acquired image is aligned based on the adjusted camera rotation parameter values or the adjusted height parameter value to provide an image of a given portion of the environment surrounding the vehicle from said ROI.



UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Title

Image acquisition system

Field

5 The present invention relates to an image acquisition system and a method performed in such a system.

Background

10 Currently, vehicles are provided with driver assistance systems which rely on the use of an image acquisition system comprising one or more cameras that capture images of a portion of the environment surrounding the vehicle. In some cases, images from more than one camera can be stitched together to provide a top plan or birds eye view image of the environment surrounding vehicle. These images may be displayed on a driver display or processed for feature extraction and/or recognition to assist in the autonomous or semi-autonomous control of the vehicle.

15 WO 2012/139636 (Ref: SIE0025) relates to a method for online calibration of a vehicle video system using image frames captured by a camera containing features on a road surface. At least two different features within an image frame are chosen as respective reference points. A sequence of at least one more image frames is acquired by the camera while locating within each new frame the features chosen as reference points. A geometrical shape is obtained by joining the located reference points in each image and considering the respective 20 trajectories covered by the reference points during a driving interval between images of the sequence. A deviation of the resulting geometrical object from a parallelogram with corners defined by the reference points from at least two subsequent images is calculated with any measured deviation being used to define an offset correction of the camera.

25 WO 2012/139660 (Ref: SIE0028) relates to a method for online calibration of a vehicle video system using image frames captured by a camera containing longitudinal road features on a road surface. 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 30 to the vehicle by determining a possible deviation of the points from a line parallel to the vehicle with any measured deviation being used to define an offset correction of the camera.

WO 2012/143036 (Ref: SIE0029) relates to a method for online calibration of a vehicle video system using image frames containing longitudinal road features. Adjacent portions of a road surface are captured by at least two cameras of the vehicle video system. Longitudinal road features are identified within the image frames. Identified longitudinal road features are selected within at least two image frames respectively taken by two cameras as matching a single line between the two image frames. An analysis of the single line is performed by determining an offset of the line between the two image frames. The consequently determined offset of the line is applied for a calibration of the cameras of the vehicle video system.

10 **Summary**

According to a first aspect, there is provided a method operable in an image acquisition system according to claim 1.

In a second aspect there is provided a computer program product which when executed on a computing device is arranged to perform the method of claim 1.

15 In still a further aspect, there is provided an image acquisition system as detailed in claim 13. Advantageous embodiments are provided in the dependent claims.

Brief Description Of The Drawings

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

20 Figure 1 illustrates a side view of a vehicle comprising an image acquisition system according to an embodiment of the invention;

Figure 2 illustrates a perspective view of a camera component of the system of Figure 1;

Figure 3 illustrates planes indicative of a stance of the vehicle of Figure 1;

Figure 4 is a block diagram illustrating an exemplary configuration of the image acquisition system of Figure 1; and

25 Figure 5 is a block diagram illustrating an image processing method according to an embodiment of the invention.

Detailed Description of the Drawings

Figure 1 illustrates a vehicle 102 including an image acquisition system 100 according to an embodiment of the invention. The image acquisition system 100 comprises one or more cameras 110, only one shown, and a processor 120 for processing images captured by the camera 110.

- 5 The processor 120 can comprise a dedicated processor for processing images provided by the camera 110; or indeed the processor 120 could comprise any processor of a multiple processor core within a vehicle control system and which may be available as required for processing acquired images.

The camera 110 may be any type of image capture device. For example, the camera 110 can
10 be of the type commonly referred to as a digital camera, such as complementary metal-oxide-semiconductor (CMOS) camera, charged coupled device (CCD) camera or the like. The camera 110 can capture images in the visible and/or not visible spectrum and provide these to the processor 120. The processor 120 processes images produced by the camera using any combination of chromatic or intensity image plane information provided by camera 110.

- 15 Notably in vehicle image acquisition systems such as described below, cameras tend to have a wide field of view (FOV) and so capture a highly distorted image. As such, typically only a portion of the rectangular image captured by the camera image sensor is employed to provide a rectilinear, distortion corrected image used by the remainder of a driver assistance system. This distorted portion of the captured image is referred to herein as a region of interest (ROI).
20 Also, in order to compensate for variable alignment of the camera 110 relative to a road surface and possibly relative to the vehicle, the ROI does not extend to the boundaries of the camera image sensor, so allowing the ROI to be aligned as required within any image acquired from the camera 110.

The camera 110 shown is a front facing camera mounted in or on the grille of the vehicle
25 102. The camera 110 is configured to capture a downward looking plan view of the ground towards the front of the vehicle 102.

In alternative embodiments, the camera 110 may be mounted in any desired location, within the cabin or on the exterior of the vehicle 102, for capturing an image looking in a generally forward direction from the vehicle 102. So, for example, the camera 110 could also be
30 located within an overhead console unit (not shown) within the cabin of the vehicle 102; on a forward-facing surface of a rear-view mirror (not shown) of the vehicle 102; or on a wing mirror (not shown) of the vehicle 102.

Other cameras may be mounted in any other desired location of the vehicle 102 for capturing other portions of the environment surrounding the vehicle 102. For example, cameras may be mounted in any desired location of the vehicle 102 for capturing a downward looking plan view of the ground towards the rear of the vehicle 102, or for capturing an image looking in a generally backward direction from the vehicle 102. So, a camera may be mounted at a rear panel of the vehicle, inside a rear windscreen or on a rear-facing surface of a wing mirror. In another implementations, cameras could also be mounted in any desired location of the vehicle 102 for capturing a downward looking plan view of the ground on the left/right side of the vehicle 102. So, cameras may be mounted at the side middle panels of the vehicle 102, wing mirrors or on side windscreens.

So, while in some implementations of the present invention, the processor 120 is tasked with aligning a ROI within images acquired by the camera 110 based on measurements received from the suspension system simply in order to display a consistent image from a given camera on the driver display; in other implementations the fields of view of front, rear and side cameras may overlap to an extent that they can be stitched together to provide a single birds eye view of the environment surrounding the vehicle. Additionally, or alternatively, the processor 120 may perform parking assist function and/or autonomous or semi-autonomous driving such as active cruise control or indeed any other vehicle function based on a ROI aligned based on measurements received from the suspension system.

Figure 2 shows a perspective view of the camera 110 and a three-dimensional coordinate system X_C, Y_C, Z_C of the camera 110. In this system, the X_C -axis extends along a longitudinal direction corresponding to the optical axis of the camera and the Y_C -axis extends in a transverse direction. The Z_C -axis is perpendicular to X_C and Y_C . The Z_C and X_C axes are also shown in Figure 1, however, the Y_C -axis is not shown in Figure 1 as this is perpendicular to the side view image of the vehicle. A roll ($\text{Rot}X_C$) is a rotation about the X_C -axis, a pitch ($\text{Rot}Y_C$) is a rotation about the Y_C -axis and a yaw ($\text{Rot}Z_C$) is a rotation about the Z_C -axis, where $\text{Rot}X_C, \text{Rot}Y_C$ and $\text{Rot}Z_C$ are the angles of rotation.

Note that while in the example below, the embodiment is described in relation to one camera, the invention is equally applicable to multiple cameras, although it will be appreciated that each of these will have nominal camera axes, in particular their X and Y axes, rotated relative to one another in accordance with the direction they face.

In the present embodiment, the vehicle 102 further comprises a suspension system (not shown) comprising any combination of: springs, shock absorbers and linkages that connect the body of the vehicle 102 to respective wheels of the vehicle. The suspension system may be of the dependent, independent, or semi-independent type depending on how each wheel moves with respect to each other wheel of the vehicle 102.

The suspension system may be active or passive and may be controlled in response to the driver settings, in response to changes to the vehicle loading, or in response to body roll of the vehicle. The suspension system may react to signals from an electronic controller (not shown) to adjust the stance of the vehicle or adjust the stance of the vehicle in response to changes to the vehicle loading. For example, the suspension system may include a pneumatically controlled mechanism or an anti-roll bar that adjusts the vehicle stance such that the loading forces or roll forces are substantially cancelled.

In any case, the suspension system is operable to control the body position of the vehicle 102 with respect to its nominal (unloaded) position and so also the ground and thus to actively or reactively change an initial stance of the vehicle to an adjusted vehicle stance.

In the present embodiment, the vehicle 102 is equipped with one or more sensors (not shown) that directly or indirectly monitor changes of the suspension system from their nominal settings. The one or more sensors determine suspension data for the vehicle 102 including one or more of vehicle pitch around a horizontal transverse axis of the vehicle; roll around a horizontal longitudinal axis of the vehicle; and height of the vehicle. These one or more sensors measurements may be a set of rotation angles and/or distances.

For example, with reference to Figure 3, in one embodiment, the one or more sensors are configured to monitor the heights of the wheel arches 106 with respect to their nominal settings thus providing four height measurements E-H indicative of the vehicle stance. In this example point E corresponds to the height measurement of the rear right wheel arch of the vehicle, point F corresponds to the height measurement of the rear left wheel arch of the vehicle, point G corresponds to the height measurement of the front right wheel arch of the vehicle, point H corresponds to the height measurement of the front left wheel arch of the vehicle. Points E-H are vertically displaced from the corresponding reference points A-D. (In the example, the displacements are all positive, but this need not be the case. Reference points A-D correspond to the known nominal height settings for the wheel arches and define a reference plane 310 of the vehicle 102 (dashed line). The X_R -axis extends along the

longitudinal direction and Y_R -axis extends along the transverse direction of the reference plane 310. The Z_R -axis is perpendicular to both X_R and Y_R axes and extends vertically from the reference plane 310 of the vehicle 102. In alternative implementations, points A-D may be points where the wheels of the vehicle 102 touch the ground and in this case the
5 displacements of points E-G would all be positive. In any case, the reference plane 310 is fixed in response to changes to the vehicle stance.

It will be appreciated that any such suspension measurements can be converted to a set of rotation angles comprising rotations $\text{Rot}X_V$, $\text{Rot}Y_V$ around the X_R and Y_R axes respectively and collectively referred to as R_{susp} and an overall height offset (h_{susp}) from a nominal height
10 of the vehicle 102. Note that when as in the present embodiment, only changes in the height of the suspension are measured, there should be no effect on the rotation angle $\text{Rot}Z_V$ around the axis Z_T caused by changes in the suspension height.

The one or more sensors measurements may be provided at any frequency and/or basis. For example, such one or more sensors measurements may be performed continuously or
15 periodically (asynchronously or synchronously). The measurements may be performed at a regular time interval within a predetermined time period or in response to a change of the road surface condition, the stance of the vehicle, the status of the suspension system, the loading of the vehicle 112, or in response to the acquisition of an image from the camera 110.

It is appreciated that these measurements may be run as a background service in a vehicle
20 processor and may be rendered available to the processor 120 via a dedicated memory or via a vehicle network, such as a system bus 104. As it will be appreciated, the system bus 104 can comprise any suitable mechanism for communicating vehicle information from one part of a vehicle to another, for example, a CAN, FlexRay, Ethernet or the like.

Referring in more detail to Figure 4, there is shown a block diagram of a system according to
25 an embodiment of the invention showing the processor 120 in more detail. In this system, the processor 120 includes a Motion Tracking Calibration (MTC) module 122 and an intermediate module 124.

In the embodiment, the MTC module 122 is configured to determine extrinsically, based on at least one or more images acquired from a camera, a set of X, Y and possibly Z camera
30 offsets from nominal rotation angles ($\Delta\text{Rot}X_C$, $\Delta\text{Rot}Y_C$, and $\Delta\text{Rot}Z_C$), referred to collectively as R_{extr} and a height parameter h_{extr} along the vertical axis Z_R -axis extending from a reference

plane of the vehicle 102. (This could be the same reference plane as the plane 310 in Figure 3, or the plane could be a ground plane.)

Note that speed information or odometry is available to the processor 120 across the vehicle system bus 104. These may include wheel rotation per minutes (rpm), yaw rate (deg/s), steering angle or the like and in certain embodiments, this information can be used by the MTC module 122 to determine the above extrinsic parameters R_{extr} , h_{extr} .

Similarly, details of the vehicle geometry are also available to the processor 120, including for example, the nominal height of each of the wheel arches, the nominal rotation angles of each camera as well as their nominal X,Y, Z coordinates within the vehicle – in particular relative to the wheels.

The intermediate module 124 acquires the output of the MTC module 122 as well as the suspension information across the system bus 104 and in response generates one or more adjusted camera rotation parameter values (R_{pose}) and/or an adjusted height parameter value (h_{pose}).

Referring now to Figure 5 there is shown a block diagram illustrating a method according to an embodiment of the invention operable in the system of Figure 4.

In step 1, the processor 120 obtains an image N in a succession of images from the camera 110 covering a FOV 112, extending around a ROI, Figure 2.

As will be understood, the FOV 112 may change in accordance with vehicle stance. For example, as shown in Figure 1, if the vehicle 102 carries a load weight (not shown) which is unevenly distributed within the vehicle 102 this causes a change in the vehicle stance. In particular, the load weight may cause the suspension system to rise up the front of the vehicle 102 and lower down the rear of the vehicle 102 towards the ground. Alternatively, as the vehicle 102 corners, one part of the suspension may compress relative to another so causing the stance of the body of the vehicle to change relative to the road surface. Consequently, the FOV 112 of the camera 110 changes from an initial orientation to a different orientation according to the movement of the vehicle body.

In step 2, the processor 120 determines the one or more camera rotation parameters (R_{extr}) and a height parameter (h_{extr}) along the vertical axis Z_R -axis extending from a reference plane of the vehicle 102. In one embodiment, the processor determines R_{extr} and h_{extr} parameters extrinsically using the MTC module 122 disclosed in WO 2012/139636 (Ref: SIE0025). As

outlined above, the MTC module 122 can use the currently acquired image N as well as up to m previous (or possibly future relative to N) images, as well as knowledge of the nominal vehicle geometry and speed to determine the one or more camera rotation parameters (R_{extr}) and height parameter (h_{extr}).

- 5 Note where images from the same camera which are to be aligned as described below are also used to determine the extrinsic values, these images need not necessarily be the same images as the images whose ROI is to be aligned. For example, one or more of the extrinsic values may be calculated more or less frequently than the ROI in any given image is adjusted.

In any case, using the MTC module 122, the processor 120 uses reference points extracted
10 from images of the road surface to determine an offset rotation about the X_R -axis with respect to a measured deviation based on parallelism between lines obtained from subsequent image frames by joining the tracked reference points within each frame. The processor 120 applies a similar approach for an offset rotation about the Y_R -axis, although in this case the trajectory of tracked reference points in a plurality of up to m successive image frames is considered.

- 15 The MTC module 122 can also provide an offset rotation about the vehicle Z_R -axis, however, as this rotation is not significantly affected by changes in vehicle stance, in preferred embodiments, this parameter is not adjusted by the intermediate module 124.

Furthermore, where the speed of the vehicle 102 is known, the actual physical distance
20 between the tracked features on the road surface can be determined and thus the height parameter (h_{extr}) of the camera can be determined using triangulation.

Alternatively or in addition, the processor 120 may determine the one or more camera
rotation parameters (R_{extr}) and the height parameter (h_{extr}) using methods disclosed in WO
2012/139660 (Ref: SIE0028) or in WO 2012/143036 (Ref: SIE0029). Irrespective of the
method used, such one or more camera rotation parameters (R_{extr}) and the height parameter
25 (h_{extr}) may be rendered available within the processor 120 or may be already available to the
processor 120 via the dedicated memory or via the vehicle network.

In step 3, the intermediate module 124 determines, from suspension data of the vehicle 102 at
a time of acquisition of the image, one or more changes in such one or more camera rotation
parameter values and the height parameter value (R_{susp} , h_{susp}). In particular, the processor 120
30 acquires suspension data for the vehicle 102 via the dedicated memory or via the vehicle
network. The processor 120 extracts a current plane 320 of the vehicle from the suspension
data. Subsequently, the processor 120 determines one or more changes in such one or more

camera rotation parameter values and the height parameter value (R_{susp} , h_{susp}) by comparing the current plane 320 with the reference plane 310. Note that the height offset h_{susp} may need to be translated to account for the X,Y location of the camera within the vehicle i.e. positive offset values E or F at the rear of the vehicle, along with negative offset values G or H at the front of the vehicle will mean that the offset for any given camera location in between may or may not be the same.

With reference to Figure 3, the processor extracts a current plane 320 of the vehicle 102 from the data points E to H (solid line) and compares such plane with the plane defined by the reference points A-D to determine two rotations about the X and Y axis. Specifically, the processor 120 extracts the current plane 320 of the vehicle from the data points E to H using a linear least square planar fit. The least square method can advantageously identify an outlier in the four data points E to H as the data point that is displaced at a distance from the plane of fit. The outlier may correspond to a displacement of a wheel with respect to the other wheels if the distance is above a threshold. For example, the outlier may indicate that a wheel is parked on a speed bump or sidewalk. Alternatively, any other method can be used to fit a current plane 320 of the vehicle to data points E to H.

In response to the determination of a current plane 320, the processor determines the position of the current plane 320 with respect to the reference plane 310. Specifically, the processor 120 determines the current plane 320 as the rotation about X_R axis and Y_R axis ($\Delta\text{Rot}X_V$ and $\Delta\text{Rot}Y_V$) of the reference plane 310 and the height parameter value (h_{susp}). Such rotations correspond to respectively roll and pitch which can be described by corresponding basic rotation matrixes R_{X-V} and R_{Y-V} . As will be appreciated the suspension changes would not typically lead to any significant yaw change, and so, as provided in this embodiment, the third rotation parameter ($\Delta\text{Rot}Z_V$) is ignored. In an alternative, the third rotation parameter ($\Delta\text{Rot}Z_V$) can be considered. In this case, any significant yaw change may be indicative of a response of the braking system that causes a net centring steering force substantially greater than zero at a zero steer-angle. Thus, the third rotation parameter ($\Delta\text{Rot}Z_V$) may be used as an indicator of an optimal or not optimal response of the braking system, such as when the braking system is unbalanced.

In step 4, the processor applies the one or more changes (R_{susp} , h_{susp}) to the one or more camera rotation parameter values (R_{extr}) and height parameter value (h_{extr}) to generate one or more adjusted camera rotation parameter values (R_{pose}) or an adjusted height parameter value

(h_{pose}). In one embodiment, the processor applies the one or more changes (R_{susp} , h_{susp}) by multiplying the one or more camera rotation parameter values (R_{extr}) with the one or more changes in the camera rotation parameter values (R_{susp}) as follows: $R_{\text{pose}} = R_{\text{extr}} R_{\text{susp}}$. R_{pose} can thus be a 3x3 rotation matrix that better estimates the camera pose relative to the road surface.

In the present embodiment, the processor 120 determines the adjusted height parameter value (h_{pose}) from the adjusted position of the camera 110 in response to the change in the vehicle stance.

At its simplest, this can simply involve adding the offset h_{susp} for the camera derived from the suspension data to the extrinsically calculated value h_{extr} to provide h_{pose} .

Alternatively or in addition to the adjustment of the angular orientation of the camera due to changes in vehicle stance, P_{pose} a new x,y,z position of the camera, taking into account the changed suspension can be given by:

$$P_{\text{pose}} = R_{\text{susp}} (P_{\text{extr}} + [0, 0, h_{\text{susp}}]^T)$$

where P_{extr} is the x, y, z position of the camera relative to a vehicle origin based on extrinsic calibration. The matrix $[0, 0, h]^T$ is used, as in the embodiment there is only a height change measure derived from the suspension data. The zero parameters could be measured, but they will typically be so much smaller in magnitude than h_{susp} that they can be ignored.

In step 5, the processor 120 aligns the ROI within the acquired image based on one or more of the adjusted camera rotation parameter values or the adjusted height parameter value. In particular, the processor 120 shifts and/or rotates the ROI within the FOV 112 of the camera to compensate for variable alignment of the camera 110 relative to a road surface. The shift and/or rotation of the ROI is relative to the one or more of the adjusted camera rotation parameter values or the adjusted height parameter value.

In step 6, the processor 120 provides an image of a given portion of the environment surrounding the vehicle from the ROI. In particular, the processor 120 acquires an image that corresponds with the adjusted ROI and transforms such image into a flattened rectangular image representative of a portion of the environment surrounding the vehicle 102.

The processing method described hereinabove may be operable in the image acquisition system 100 to capture successive images and process them. These images can be displayed

by an imaging system (not shown) as top plan views of the ground surrounding the vehicle 102. Thus, if a plurality of vehicle cameras is provided, each having a field of view different from or at least partially overlapping one another, the images of each camera displayed juxtapositioned along with the top plan view image of the vehicle provide an accurate
5 representation of the top plan view of both the vehicle and the adjacent ground.

The improved measurement of each camera's rotational and height offset based on suspension data means that image information at the adjacent boundaries of images will tend to be more aligned and this reduces the need for extensive image analysis, transformation and stitching to produce a composite top plan view image.

10 Note that the rate at which the extrinsic parameters (R_{extr} , h_{extr}) are determined by the MTC module 122 need not be the same as the rate at which the suspension parameters (R_{susp} , h_{susp}) and so the adjusted parameters (R_{pose} , h_{pose}) are determined by the intermediate module 124. So, for example, if a vehicle speed were too high, for example, > 50 kph, for the MTC module 122 to generate new extrinsic parameters (R_{extr} , h_{extr}) or if the MTC module 122 were
15 only run at vehicle start-up, the extrinsic parameters (R_{extr} , h_{extr}) could nonetheless be updated quickly, i.e. at almost the update cycle of the suspension signal data from the CAN bus, by the intermediate module 124. Thus, the module 124 can adjust camera extrinsic parameters after power up (ignition) in response to an increased the loading of the vehicle or when cornering on an embankment (roll-angle data), and/or whilst driving on a motorway/highway,
20 when the suspension settings are actively changed by the vehicle controller.

As will be appreciated, where a plurality of vehicle cameras are provided, each camera orientation will change by the same pitch, roll and yaw angle in response to the change in the vehicle stance. Therefore, the process 120 does not need to repeat the determining one or more changes in the camera rotation parameter values for each camera as the rotation matrix
25 adjustment (R_{pose}) derived from the suspension data (R_{susp} , h_{susp}) is the same for each camera. However, the vertical height offset derived from the suspension data may need to be translated in accordance with each cameras X,Y displacement within the vehicle before this offset is applied.

Claims:

1. A method operable in an image acquisition system (100) for a vehicle (102) comprising a camera (110) arranged to capture successive images having respective fields of view of a portion of an environment surrounding a vehicle (102), said fields of view changing in accordance with vehicle stance, the method comprising:
 - a) determining one or more camera rotation parameters (R_{extr}) around a respective horizontal axis of said vehicle (102) and a height parameter (h_{extr}) along a vertical axis extending from a reference plane of the vehicle;
 - 10 b) acquiring an image from said camera;
 - c) determining, from suspension data of the vehicle at a time of acquisition of said image, one or more changes in said one or more camera rotation parameter values and said height parameter value (R_{susp} , h_{susp});
 - d) applying said one or more changes to said one or more of said camera rotation parameter values (R_{extr}) and said height parameter value (h_{extr}) to generate one or more adjusted camera rotation parameter values (R_{pose}) or an adjusted height parameter value (h_{pose}); and
 - 15 e) aligning a ROI within said acquired image based on one or more of the adjusted camera rotation parameter values or the adjusted height parameter value;
 - f) providing an image of a given portion of the environment surrounding the vehicle from said ROI; and
 - 20 g) repeating steps b) to f) for successive acquired images.
2. The method of claim 1 wherein suspension data for the vehicle includes one of more of vehicle pitch around a horizontal transverse axis of the vehicle and roll around a horizontal longitudinal axis of the vehicle.
- 25 3. The method of claim 2 wherein the reference plane is defined by the respective points of contact of the vehicle wheels with a surface of the ground.
- 30 4. The method of claim 3 wherein said suspension data comprises a vertical displacement of a wheel arch for each wheel relative to a nominal position.
5. The method of claim 4 further comprising converting each of said vertical displacements into each of said vehicle pitch and said vehicle roll.

6. The method of claim 1 wherein said step of determining said one or more camera rotation parameters (R_{extr}) and said height parameter (h_{extr}) is based on extrinsic information extracted from at least said acquired image.
- 5 7. The method of claim 6 wherein said step of determining said one or more camera rotation parameters (R_{extr}) and said height parameter (h_{extr}) is based on extrinsic information extracted from at least one further image acquired before said acquired image.
8. The method of claim 1 further comprising reading said suspension data from a vehicle
10 system bus.
9. The method of claim 1 further comprising defining a plane relative to said reference plane based on a least squares analysis of said vertical displacements.
- 15 10. The method of claim 1 wherein applying said changes to said camera rotation parameter values (R_{extr}) comprises multiplying a rotation matrix comprising said camera rotation parameter values (R_{extr}) by a matrix comprising said changes in said camera rotation parameter (R_{susp}).
- 20 11. The method of claim 1 wherein applying said changes to said height parameter value (h_{extr}) comprises transforming a matrix P_{extr} comprising an extrinsically calculated x, y, z position of the camera according to the formula:
$$P_{\text{pose}} = R_{\text{susp}} (P_{\text{extr}} + [0, 0, h_{\text{susp}}]^T)$$

where R_{susp} is a matrix comprising said one or more changes in said camera rotation
25 parameter values;
 h_{susp} is said height parameter value for said camera determined from said suspension data; and
 P_{pose} comprises a matrix including an adjusted height value for the camera.
12. A computer program product comprising computer readable instructions stored on a
30 computer readable medium which when executed on a processor are arranged to carry out the method according to any one of the preceding claims.

13. An image acquisition system comprising one or more cameras, a plurality of suspension sensors and a processor operable to perform the method of any one of claims 1 to 11.

14. A vehicle comprising the image acquisition system of claim 13.

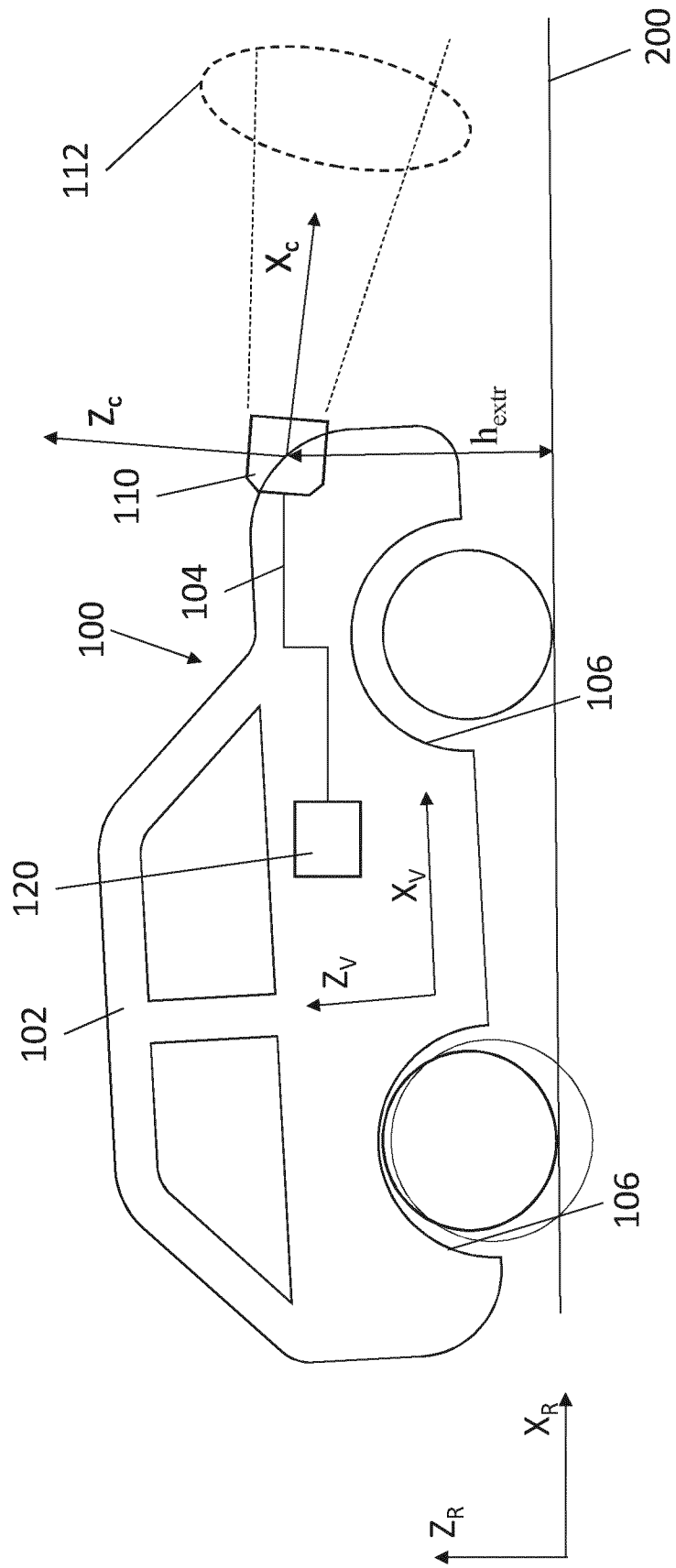


Figure 1

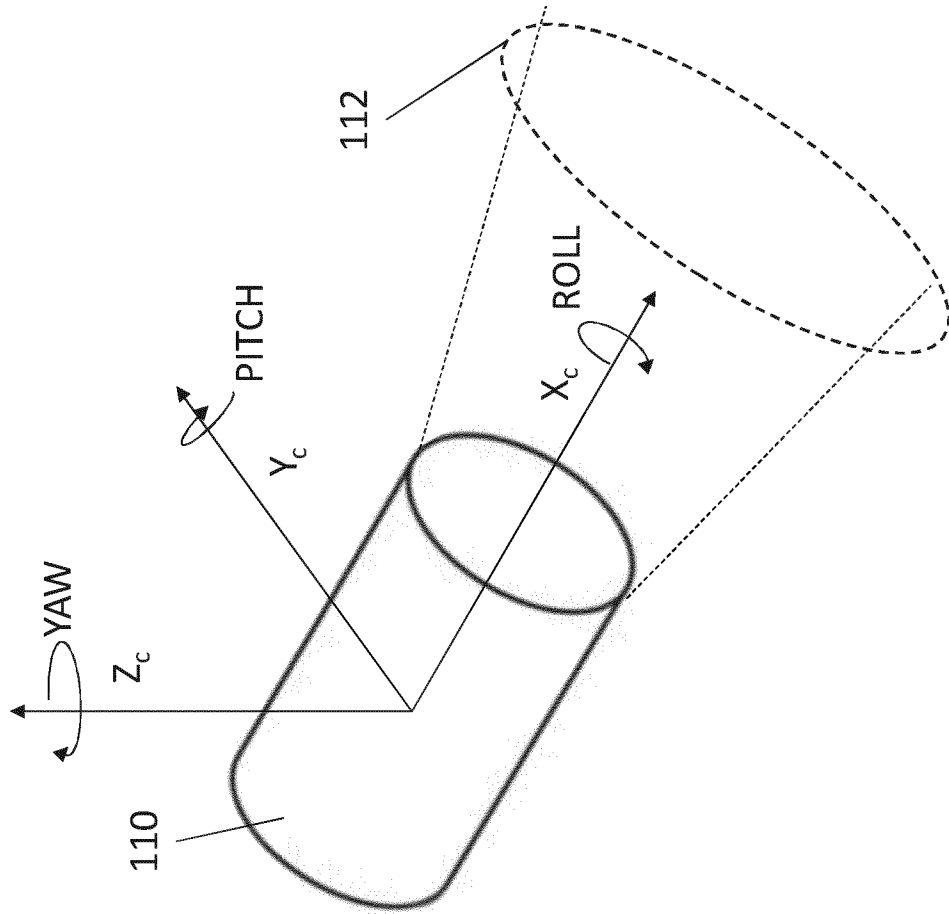


Figure 2

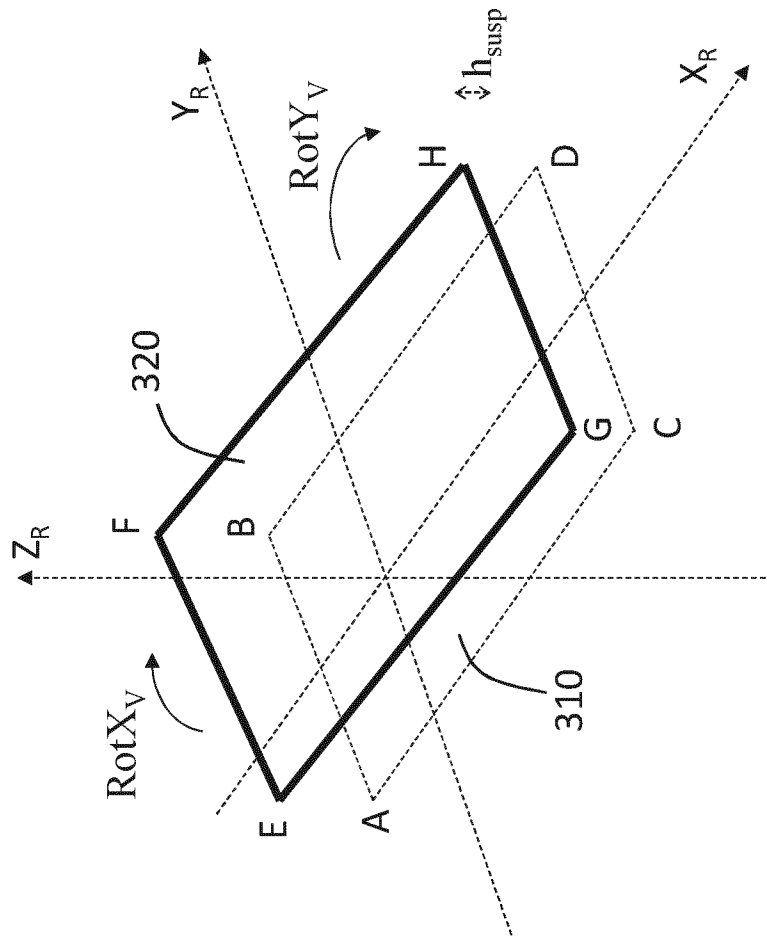


Figure 3

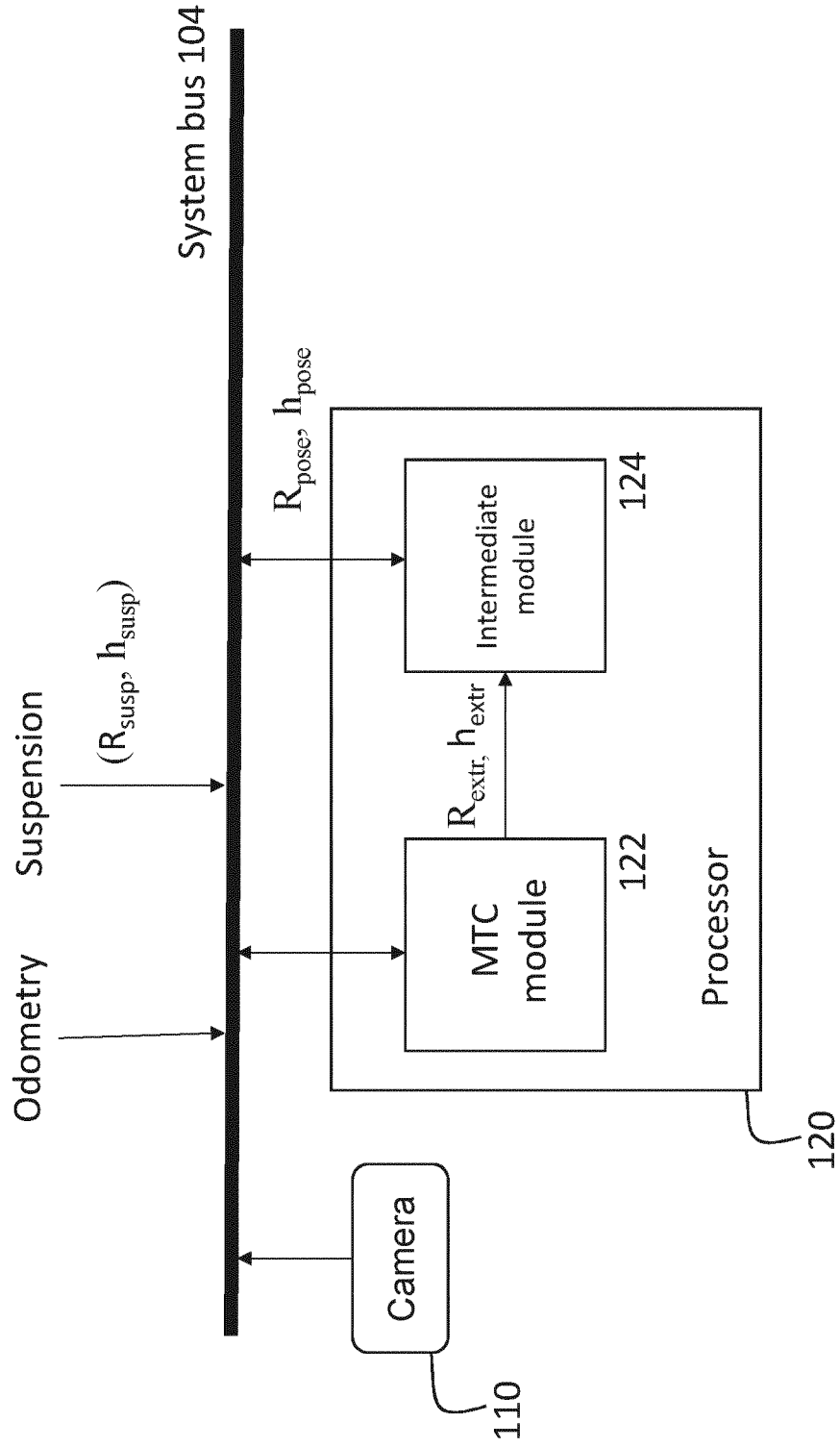


Figure 4

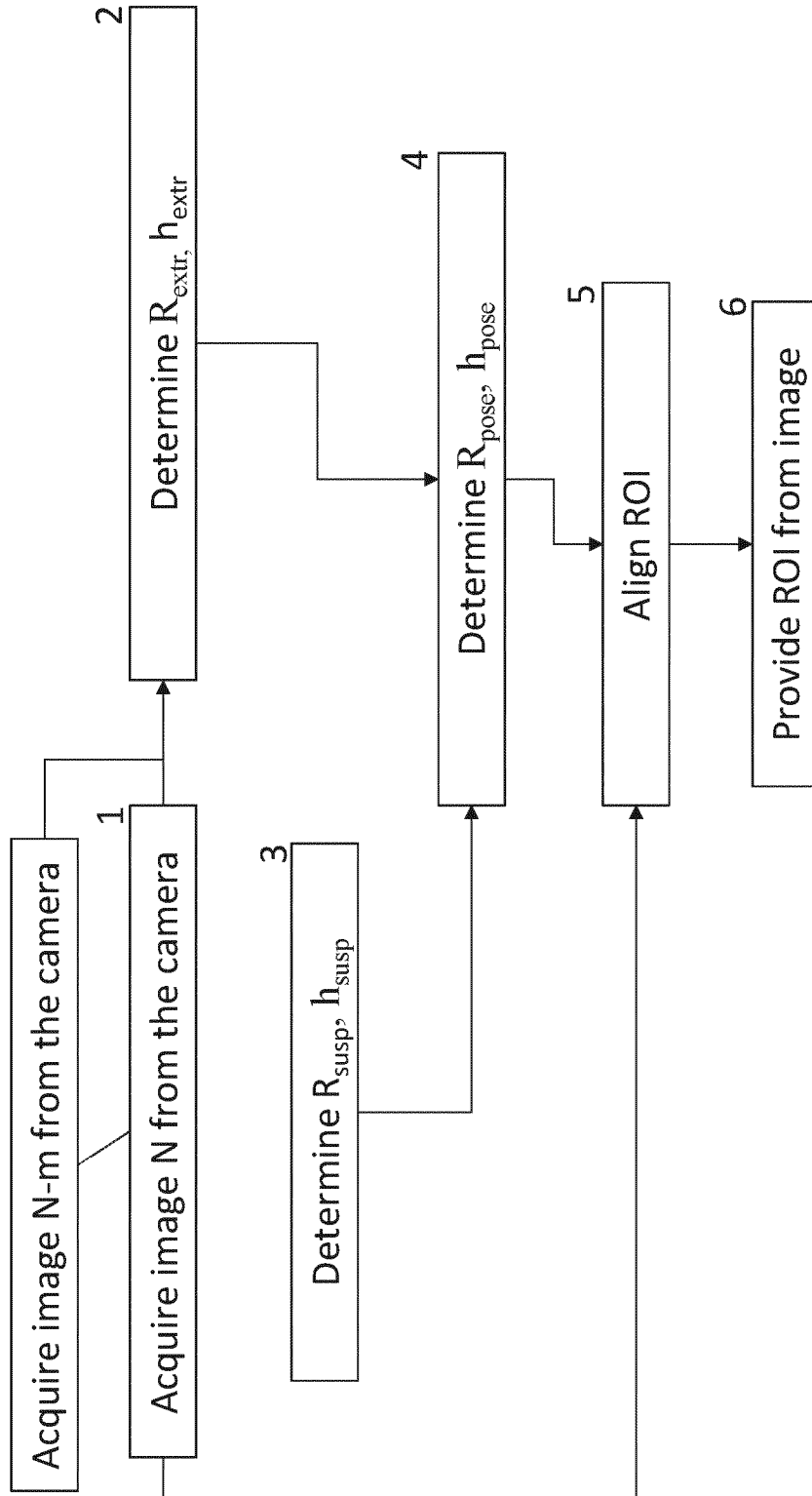


Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/063447

A. CLASSIFICATION OF SUBJECT MATTER
 INV. G06T3/00
 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 practicable, search terms used)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 942 951 A1 (APPLIC SOLUTIONS ELECTRONICS & VISION LTD [GB]) 11 November 2015 (2015-11-11) abstract paragraph [0003] paragraph [0029] paragraph [0050] paragraph [0058] paragraph [0062] - paragraph [0069] figures 6,8 -----	1-14

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 application or patent but published on or after the international filing date
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- "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
- "&" document member of the same patent family

Date of the actual completion of the international search
 17 July 2020

Date of mailing of the international search report
 28/07/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/063447

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
EP 2942951	A1	11-11-2015	EP 2942951 A1	11-11-2015
			US 2015324984 A1	12-11-2015
