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(54) Title: OBJECT DETECTING METHOD AND OBJECT DETECTING APPARATUS

(57) Abstract: The present invention provides an enhanced object detecting method and apparatus. A plurality of successive frames is captured by a monocular camera and the image data of the captured frames are transformed with respect to a predetermined point of view. For instance, the images may be transformed in order to obtain a top-down view. Particular features such as lines are extracted from the transformed image data, and corresponding features of successive frames are matched. An angular change of corresponding features is determined and boundaries of an object are identified based on the angular change of the features. In this way, an efficient and reliable identification of objects based on image data of a single monocular camera can be achieved. Disturbances such as shadows of an object can be omitted. Thus, the reliability of the identified objects is improved.

OBJECT DETECTING METHOD AND OBJECT DETECTING APPARATUS

The present invention relates to an object detecting method and an object detecting apparatus. In particular, the present invention relates to an object detecting method and apparatus for detecting an object in image data captured by a monocular camera.

Related prior art

Detecting obstacles in the environment of a vehicle becomes important, for instance, in advanced driver assistance systems (ADAS). There are currently different approaches for detecting obstacles in images. For example, stereo cameras, ultrasound or equivalent detection means enable reliable estimation of a three-dimensional environment. However, this approach requires complex and expensive hardware. Alternatively, monocular approaches may be used for detecting obstacles. For instance, static approaches may detect objects within a single image by using assumptions about properties of an object. However, these assumptions often fail. Further, a structure from motion (SFM) may be used for estimating three-dimensional properties of an image. These approaches rely on the assumption that the objects in a scene are static. Otherwise, the objects become unpredictable if the scene is not static. Hence, these assumptions are not very reliable and require high computational costs.

Hence, there is a need for an improved approach for detecting objects in an image. In particular, there is a need for a reliable detecting of objects in images captured by a monocular camera.

Disclosure of the invention

According to a first aspect, the present invention provides
an object detecting method comprising the steps of
obtaining first image data of a first frame captured by a
camera at a first point in time; transforming a point of
view of the first image data to a predetermined point of
view to obtain transformed first image data; extracting
first features from the transformed first image data;
obtaining second image data of a second frame captured by
the camera at a second point in time different from the
first point in time; transforming a point of view of the
second image data to the predetermined point of view to
obtain transformed second image data; extracting second
features from the transformed second image data; matching
the extracted first features and the extracted second
features; computing an angular change between matched first
features and second features; and detecting an object based
on the determined angular change between a matched first
features and second features.

According to a further aspect, the present invention
provides an object detecting apparatus, comprising a camera
adapted to provide first image data of a first frame
captured at a first point in time, and second image data of
a second frame captured at a second point in time different
from the first point in time. The object detecting
apparatus further comprises an image data transforming unit
adapted to transform a point of view of the first image
data and a point of view of the second image data to a
predetermined point of view; a feature extractor adapted to
extract first features from the transformed first image

data, and to extract second features from the transformed
second image data; a feature matching unit adapted to match
the extracted first features and the extracted second
features; an angle computing unit adapted to compute an
angular change between the matched first features and
second features; and an object detector adapted to detect
an object based on the determined angular change between a
matched first features and second features.

The present invention takes into account that even small
details of an object are magnified/stretched when
transforming an almost horizontal view to a top-down view.
In particular, an approximately vertical border of an
object in an original image is transformed to a line
segment on the top-down view image that points to a pixel
in the bottom-centre in the transformed image. Accordingly,
vertical elements of objects lead to line segments pointing
approximately at the bottom centre of the object, wherein
the angle of such a line changes when the camera moves
towards to the object. Hence, vertical elements of an
object can be identified by observing the angular change of
features in a top-down view image.

In a top-down view image features such as line segments
formed by stretching object data change their
direction/angle as the camera progresses. However, details
on the ground, such as shadows, do not. This property can
be used to detect objects on monocular images.

The present invention can be applied to both static images
as well as dynamic images. An idea underlying the present
invention is to detect features, for example line segments,
in image data, detecting which features in a frame

correspond to which features in another frame captured at a different point in time, and estimating an angular change of the features. If the angle of a particular feature changes consistently over successive images, an object boundary is detected, and the lower point of such feature is considered as the start of the object.

According to an embodiment of the object detecting method, the extracting first details from the transformed first image data and the extracting second details from the transformed second image data comprise identifying lines in the first image data and the second image data, respectively. Identifying lines in image data can be easily performed by a single algorithm. Since an almost straight border of an object corresponds to a line in the transformed image data, borders of an object can be easily identified by extracting lines in the image data.

According to a particular embodiment of the object detecting method, the identifying of lines is based on a Hough-style transform. Such a Houge-style transform is a very reliable and a stable method for identifying lines in image data.

According to a further embodiment of the object detecting method, the detecting an object comprises determining a distance between the camera and the detected object. For instance, such a distance between the camera and the detected object can be determined based on an end point of a feature in the image data. Since such an end point of a feature, in particular the lowest point of a feature in the image data is considered as the bottom of an object, a

distance between the camera and the object can be easily
determined.

According to a further embodiment of the object detecting
method, the method further comprises a step of determining
an ego motion of the camera. Based on the determined ego
motion of the camera, the detection of an object is further
based on the detected ego motion of the camera. In this
way, changes in the image data based on the motion of the
camera can be compensated and the reliability/quality of
the detected objects can be improved.

According to an embodiment of the object detecting
apparatus, the camera is a monocular camera. Monocular
cameras are broadly available. Further, monocular cameras
are less expensive than complex three-dimensional detecting
means such as, for instance, stereoscopic cameras. Hence,
the costs for an object detecting apparatus can be reduced.

According to a further embodiment of the object detecting
apparatus, the camera comprises a fish-eye lens. Image data
captured by a camera comprising a fish-eye lens are very
suitable for detecting objects according to the present
invention.

According to a further embodiment of the object detecting
apparatus, the apparatus comprises a position detector
adapted to determine a position and/or orientation of the
camera. In particular, the position detector determines the
position/orientation of the camera at the point of time
when the camera is capturing a frame. For instance the
position detector may detect an ego-motion of the camera.
Further, the angle computing unit is adapted to compute a

change of position and/or orientation of the camera between the first point in time and the second point in time. Additionally, the object detector is adapted to detect the object based on the computed change of position and/or orientation of the camera between the first point in time and the second point in time. In this way, ego-motion such as linear and/or angular movement of the camera can be compensated.

According to a further aspect, the present invention provides an advanced driver assistance system comprising an object detecting apparatus according to the present invention.

According to still another aspect, the present invention provides a computer program product adapted to perform the steps of the object detecting method.

Further embodiments and advantages will become apparent based on the following description with respect to the accompanying drawings.

Brief description of the drawings

Figure 1   shows a schematical illustration of an image captured by a camera according to an embodiment;

Figure 2   shows transformed image data according to an embodiment;

Figure 3   shows a flowchart of a method underlying a further embodiment of the present invention;

Figure 4   shows an object detecting apparatus according
                to an embodiment; and

Figure 5   shows a schematical drawing illustrating an
                object detecting according to an embodiment.

Description of embodiments

Figure 1 illustrates an image I captured by an image
capturing device, for instance a camera. For a better
understanding of the invention, image I comprises only a
single object O. However, the present invention may be also
applied for image data comprising a plurality of objects.
The object O illustrated in the image I comprises an edge
B. This edge B may relate to a vertical edge of object O.

Figure 2 illustrates image data of an image I1 after
transforming the point of view of image I illustrated in
Figure 1. Image I of Figure 1 may be captured by a camera
having a first distance between the camera and object O.
Such an image I may be captured, for instance that a first
point in time t1. As can be seen, the edge B of the object
O in Figure 1 has been transformed to a line segment B1.
This line segment B1 is continued by dashed line L1. In
case edge B of object O relates to a vertical line of the
object O, line L1 crosses the lower border of image I1 at
point P. This point P relates approximately to a pixel in
the bottom centre of the transformed image data.

The image data if image I2 illustrated in Figure 2 relate
to a transform of a further image captured at a shorter
distance between the camera and the object O. Such an image

may be captured, for instance at a further point in time
t2. As can be seen in the image data of image I2, the
orientation of the line segment B2 relating to the edge B
of object O has been changed. Line segment B2 is continued
by a dashed line L2. As can be seen, a line L2 crosses the
bottom border of image I2 approximately at the same bottom
centre point P as in image I1. However, the angle between
the lower border of the image and line L1 and L2,
respectively, has been changed from $\alpha 1$ to $\alpha 2$.

When capturing a further image having still a shorter
distance between camera and object O, transformation of
this image will lead to image data of Image I3 illustrated
in Figure 2. As can be seen in this image I3, the edge B of
the object O will be transformed to line segment B3. Line
segment B3 is continued by a line L3, which crosses the
bottom border of image I3 approximately at the same point
P. The angle between the bottom border of image I3 and line
L3 has been further changed to $\alpha 3$.

Hence, by analyzing features in the transformed image data,
it is possible to identify those features pointing to a
common point P in the transformed images I1-I3. The lowest
point of such a feature, for instance a line segment B1-B3
as illustrated in Figure 2, may be considered as the bottom
point of an object. Based on the assumption that such a
bottom point may be located at the ground, it is possible
to determine the distance between such a bottom point and
the camera. Hence, the distance between the object O and
the camera can be determined. For this purpose, the
distance can be determined based on the knowledge of the
image properties of the camera. For instance, it can be

assumed that each pixel of the captured image data relate
to a particular area, having a predetermined size. Based on
the size of such an area, the distance between the object O
and the camera can be easily determined.

Figure 3 illustrates a flowchart underlying an embodiment
of an object detecting method. In a first step S1, first
image data of a first frame are obtained. The image data of
the first frame may be captured by a camera at a first
point in time. In particular, the image data may be
captured by a camera having a first position.

In step S2 the obtained first image data are processed in
order to transform the point of view of the first image
data to a predetermined point of view. For instance, the
point of view of the transformed image data may be changed
in order to obtain a top-down view. By transforming the
point of view of the image data, a top-down view of a
camera may be simulated, i.e., a view as if the scene was
being observed from a high position is achieved. In this
way, even small details of an object may be greatly
magnified/stressed in the top-down view.

Next, in step S3 first features are extracted from the
transformed first image data. For instance, the first
features may relate to line segments. Such line segments
may relate to edges of objects. However, other features may
be also extracted. For instance, elements having a
particular shape may be identified. The features of the
transformed image data may be extracted, for instance by
analyzing a shape of an element. Other methods for
identifying features in the image data are also possible.

In step S4, second image data from a second frame are obtained. The second frame may be captured by a camera at a second point in time. The second point in time may be different from the first point in time when capturing the first frame. In particular, the position of the camera and/or the orientation of the camera when capturing the second frame may be different from the position and/or orientation of the camera when capturing the first frame.

Subsequently, the point of view of the second image data is transformed to the predetermined point of view in step S5. The predetermined point of view when transforming the second image data is the same as the point of view when transforming the first image data.

In step S6 second features are extracted from the transformed second image data. The extracting of the features from the transformed second image data is performed in the same manner as extracting first features from the transformed first image data.

Subsequently, the extracted first features and the extracted second features are matched in step S7. In this step, features, for instance line segments, are identified which may relate to a same element in the first frame and the second frame. In order to detect features in the transformed first image data corresponding to features in the transformed second image data the characteristics of the individual features may be compared. For instance, a length of a line segment may be analysed. Further, a transition type may be evaluated, for instance a transition from a dark to a bright edge or a bright to a dark edge can be analysed in order to identify corresponding features.

Further, an analysis of a slope or further characteristics
are also possible in order to identify corresponding
features in transformed first image data and the
transformed second image data.

In step S8, an angular change between matched first
features and second features is computed. If an angle of a
particular feature changes consistently over the time, such
a feature may be considered as an object boundary. In this
case, a lower point of such a feature may be considered as
a start point of the object. Accordingly, in step S9, an
object can be detected based on the determined angular
change between the matched first features and second
features.

In order to enhance the reliability and accuracy of the
object detecting method, further image data of additional
frames may be obtained and processed in the same manner as
the image data of the first and the second frame. In this
way, the angular change of a feature can be observed over a
longer period of time. If the angular change of a feature
is consistent during a predetermined number of successive
frames, such a feature may be considered as a boundary of
an object. Otherwise, if the angular change is not
consistent over a predetermined number of successive
frames, the corresponding feature will be skipped and not
considered as a boundary of an object.

Figure 4 illustrates a block diagram of an embodiment for
an object detecting apparatus 1. The object detecting
apparatus 1 may comprise a camera 10 and a processor 20.
Camera 10 may be a monocular camera. The camera may capture
monochromatic or coloured images. Additionally or

alternatively, it is also possible to capture infrared or
ultraviolet images. Camera 10 may comprise a fish-eye lens.
In this way, a large field of view can be captured by a
single camera. In order to extend the field of view, it may
be also possible to use a plurality of cameras 10 in
parallel and to merge the image data of all these cameras
10 to a single frame for a further processing. For this
purpose, the capturing of image data of all these cameras
may be synchronized.

Camera 10 may further comprise a position detector 11. This
position detector 11 may determine a position and/or an
orientation of camera 10. For instance, position detector
11 may comprise a GPS receiver, an electronic compass or a
gyroscope. Further means for determining a position and/or
an orientation of camera 10 may be possible, too.
Alternatively, ego-motion of the camera or a related device
may be provided by an external device, for instance an
advanced driver assistance system of a vehicle.

The image data captured by camera 10 and optionally the
position/orientation data are provided to processor 20.
Processor 20 comprises an image data transforming unit 21,
a feature extractor 22, a feature matching unit 23, an
angle computing unit 24, and an object detector 25. Image
data transforming unit 21, feature extractor 22, feature
matching unit 23, angle computing unit 24 and object
detector 25 may be realized by software components which
are executed by a microprocessor of processor 20.
Alternatively, image data transforming unit 21, feature
extractor 22, feature matching unit 23, angle computing
unit 24 and object detector 25 may be realized as separate
processing components in processor 20. Additionally,

processor 20 may comprise at least one memory for storing
intermediate results. For instance, previously captured
image data, transformed image data and/or extracted
features or a determined angle of an extracted feature may
be stored in a memory of processor 20.

After camera 10 has captured an image, the corresponding
image data are provided to a processor 20. The image data
may be received by image data transforming unit 21. Image
data transforming unit 21 performs a processing in order to
transform a point of view of the image data to a
predetermined point of view. In particular, the point of
view of the obtained image data may be changed to obtain a
top-down view of the captured scene. Subsequently, feature
extractor 22 processes the transformed image data to
extract at least one feature from the transformed image
data. For instance, feature extractor 22 may analyze the
transformed image data 2 to identify line segments.
Additionally or alternatively, further features may be
identified, too. The extracted features of the transformed
image data are provided to feature matching unit 23.
Feature matching unit 23 compares the features extracted
from the transformed image data in order to identify
similar features in image data of successive frames. For
instance, a length of feature, a shape of a feature, a
transition from bright to dark or dark to bright or other
properties may be analyzed in order to identify
corresponding features in successive image data.

After corresponding features in successive image data have
been identified, these features are provided to angle
matching unit 24. Angle matching unit 24 computes an
angular orientation of the features. For example, the

angular orientation with respect to a predetermined line,
for instance, the bottom line of an image can be computed.

Object detector 25 analysis the computed angular
orientation of the features and compares an angular change
of corresponding features in successive image data. Based
on this angular change of a feature, object detector 25
determines whether or not a feature may relate to an
object, in particular to a boundary of an object in the
captured image data. If the angular change of a feature is
consistent, the respective feature may be considered as a
boundary of an object. In this case, a lower point of the
feature may be considered as a starting point of the
object. In particular, this starting point at the bottom of
the feature may be considered as a base point of the object
on the ground. Based on this assumption, namely that the
lower point of the object is on the ground, a distance
between the object and the camera 10may be computed. For
instance, the number of pixels between the lower point of
the feature in the image data, in particular the
transformed image data, and a particular point in the image
data (the transformed image data) may be computed. Based on
the assumption that each pixel in the image data relates to
a particular distance, the distance between the camera and
the object can be computed. However, other methods for
determining a distance between the camera 10 and the object
are possible, too.

Even though the object detecting method and apparatus are
described with respect to only two successive frames, it is
also possible to capture more than two successive frames at
different positions, in particular at different points in
time and to analyse the angular change of features in a

plurality of transformed image data relating to successive
frames. In this way, the reliability and the accuracy of
the detected objects can be further improved. If the object
detecting apparatus 1 comprises a position detector 11, the
position and/or orientation of camera 10 can be further
considered when analysing the image data. In particular, an
angular change of camera 10 can be identified and
considered when analysing the angular change of the
extracted features. In this way, the accuracy of the object
detection can be further improved.

Figure 5 shows a schematical illustration of a further
object detection according to an embodiment. In this case,
three successive frames are captured by a camera 10 at t1,
t2 and t3. Further, position and/or orientation of the
camera 10 are determined, for instance by a motion detector
11. In this way, the ego-motion of camera 10 can be
determined. Based on this ego-motion of the camera, the
image data of the captured frames can be compensated
accordingly. As can be seen in Figure 5, all line segments
directing to an object should intersect at the point where
the object is located after compensating the ego-motion of
the camera 10. In order to aggregate all the information of
the lines to an object and to determine where the object
is, Hough-style transform may be used. In this way, the
position of an object can be determined.

The information about one or more objects which are
identified in the environment of a camera 10 may be
provided, for instance to an advanced driver assistance
system of a vehicle. In this way, this information about
objects can be used in order to control the vehicle or to
provide additional information to a driver of the vehicle.

However, the present invention is not limited to an object detecting for an advanced driver assistance system or to the use in a vehicle. Further applications for detecting objects by a monocular camera are possible, too.

Summarizing, the present invention relates to an enhanced object detecting method and apparatus. A plurality of successive frames is captured by a monocular camera and the image data of the captured frames are transformed with respect to a predetermined point of view. For instance, the images may be transformed in order to obtain a top-down view. Particular features such as lines are extracted from the transformed image data, and corresponding features of successive frames are matched. An angular change of corresponding features is determined and boundaries of an object are identified based on the angular change of the features. In this way, an efficient and reliable identification of objects based on image data of a single monocular camera can be achieved. Disturbances such as shadows of an object can be omitted. Thus, the reliability of the identified objects is improved.

CLAIMS

1. An object detecting method comprising the steps of:

obtaining (S1) first image data of a first frame captured by a camera (10) at a first point in time;

transforming (S2) a point of view of the first image data to a predetermined point of view to obtain transformed first image data;

extracting (S3) first features from the transformed first image data;

obtaining (S4) second image data of a second frame captured by the camera (10) at a second point in time different from the first point in time;

transforming (S5) a point of view of the second image data to the predetermined point of view to obtain transformed second image data;

extracting (S6) second features from the transformed second image data;

matching (S7) the extracted first features and the extracted second features;

computing (S8) an angular change between matched first features and second features; and

detecting (S9) an object (O) based on the determined angular change between the matched first features and second features

2.   The method according to claim 1, wherein the extracting (S3) first details from the transformed first image data and the extracting (S6) second details from the transformed second image data comprise identifying lines in the first image data and the second image data.

3.   The method according to claim 2, wherein the identifying lines is based on a Hough-style transform.

4.   The method according to any of claims 1 to 3, wherein said detecting (S9) an object (O) comprises determining a distance between the camera (10) and the detected object (O).

5.   The method according to any of claims 1 to 4, further comprising a step of determining an ego-motion of the camera (10), wherein said detection (S9) on object (O) is further based on the detected ego-motion of the camera (10).

6.   An object detecting apparatus (1), comprising:

a camera (10) adapted to provide first image data of a first frame captured at a first point in time, and second image data of a second frame captured at a second point in time different from the first point in time;

an image data transforming unit (21) adapted to transform a point of view of the first image data and the second image data to a predetermined point of view;

an feature extractor (22) adapted to extract first features from the transformed first image data and to extract second features from the transformed second image data;

a feature matching unit (23) adapted to match the extracted first features and the extracted second features;

an angle computing unit (24) adapted to compute an angular change between matched first features and second features; and

an object detector (25) adapted to detect an object (O) based on the determined angular change between the matched first features and second features.

7.   The object detecting apparatus (1) according to claim 6, wherein said camera (10) is a monocular camera.

8.   The object detecting apparatus (1) according to claim 6 or 7, wherein said camera (10) comprising a fish-eye lens.

9.   The object detecting apparatus (1) according to any of claims 6 to 8, further comprising a position detector (11) adapted to determine a position and/or orientation of said camera (10);

wherein said angle computing unit (24) is further adapted to compute a change of position and/or orientation of the camera (10) between the first point in time and the second point in time; and

wherein the object detector (25) is adapted to detect the object (O) based on the computed change of position and/or orientation of the camera (10) between the first point in time and the second point in time.

10. An advanced driver assistance system comprising an object detecting apparatus (1) according to any of claims 6 to 9.

11. A computer program product adapted to perform all steps of any of claims 1 to 5.

FIG 1
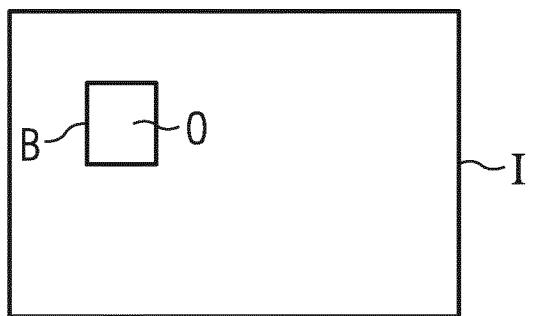
FIG 2
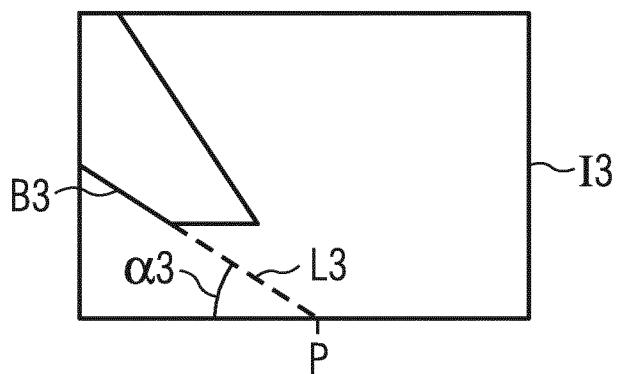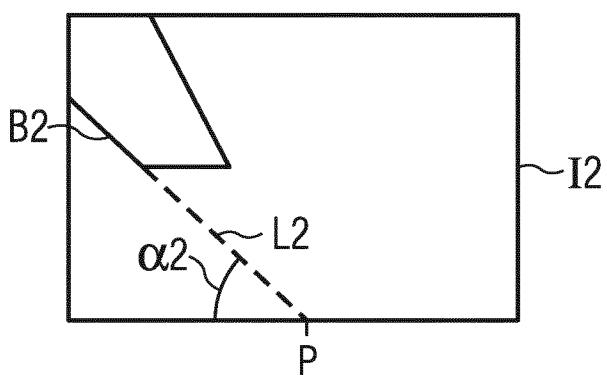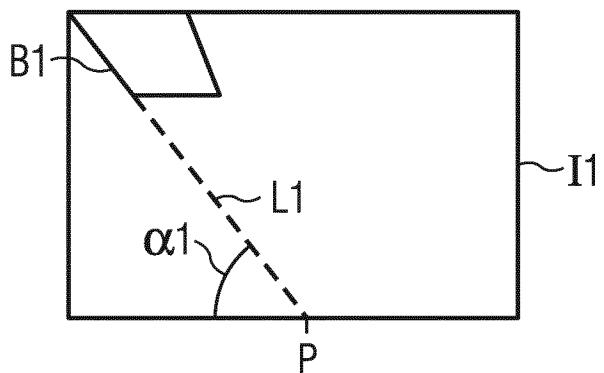
FIG 3
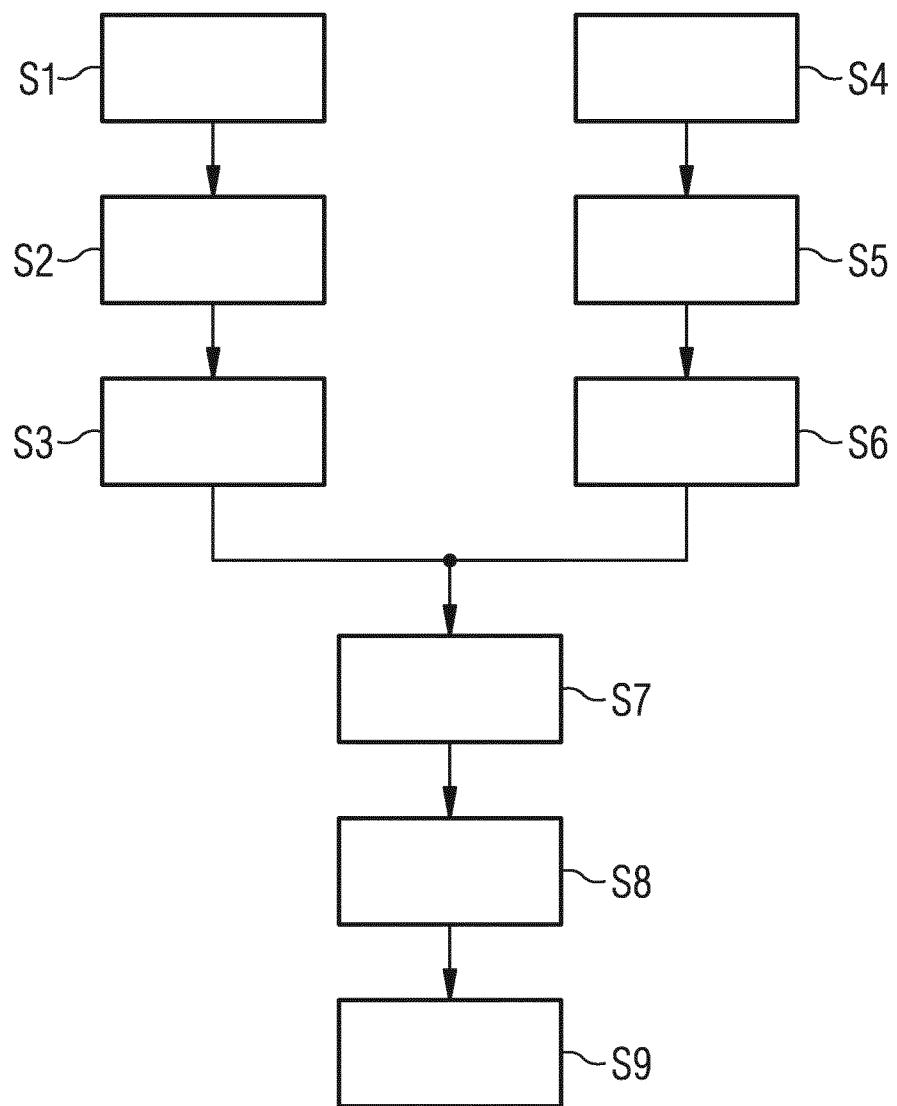
FIG 4
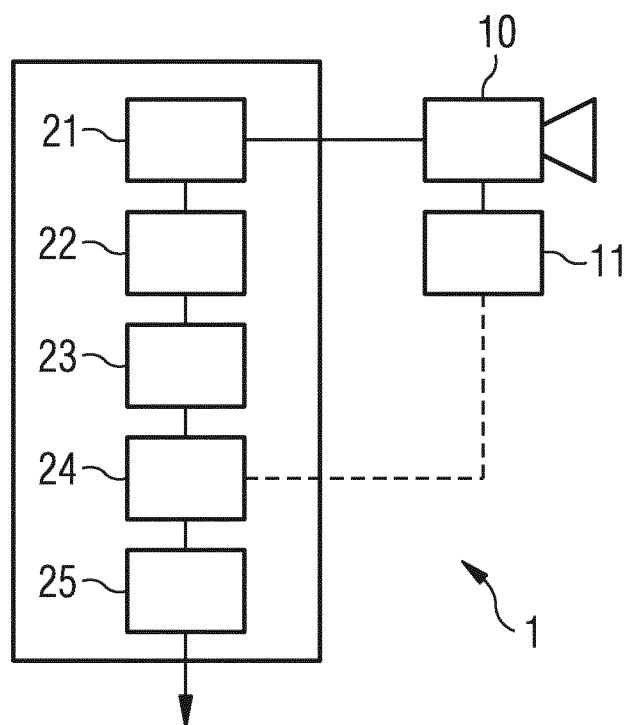
FIG 5
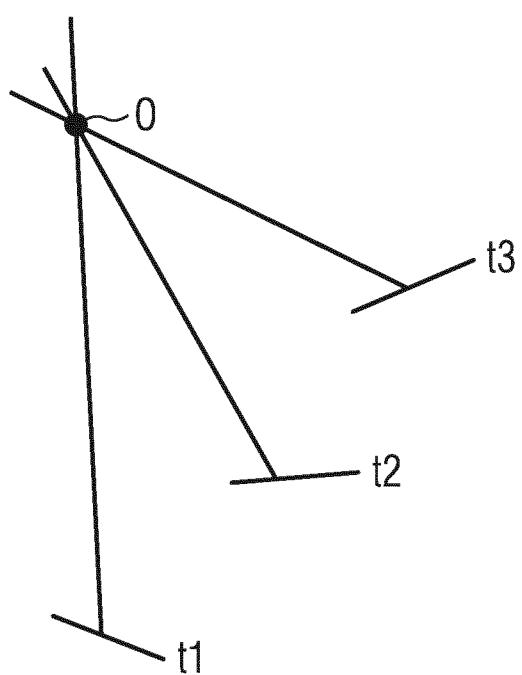
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. G06K9/00 G06T7/20
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)

G06K 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 1 964 719 A2 (SANYO ELECTRIC CO [JP]) 3 September 2008 (2008-09-03)	1,2,5-7, 9-11
Y	paragraphs [0009], [0028] - paragraph [0052]; figures 3, 4, 5, 7 -----	3,4,8
Y	EP 1 830 321 A2 (HITACHI LTD [JP]) 5 September 2007 (2007-09-05) paragraph [0016] - paragraph [0023] -----	3,8
Y	EP 2 233 358 A1 (AISIN SEIKI [JP]) 29 September 2010 (2010-09-29) paragraph [0041] - paragraph [0058] -----	4
A	US 2013/222589 A1 (LALONDE JEFFREY [CA] ET AL) 29 August 2013 (2013-08-29) paragraph [0019] - paragraph [0040] paragraph [0075] - paragraph [0097] -----	1-11

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

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 February 2016	25/02/2016

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 Martinière, Anthony

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

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