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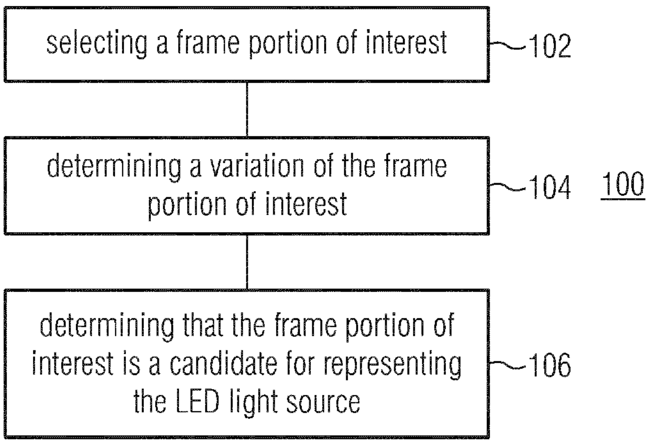
(54) Title: METHOD FOR DETECTING A LED LIGHT SOURCE IN A SEQUENCE OF FRAMES, METHOD FOR DETECTING A TRAFFIC LIGHT WHICH COMPRISES AT LEAST ONE LED LIGHT SOURCE, AND VEHICLE

FIG. 1



(57) Abstract: A method for detecting a LED light source in a sequence of frames of an environment is provided. The method includes selecting a frame portion of interest and determining, using the sequence of frames, a variation of the frame portion of interest. Further, the method includes determining that the frame portion of interest is a candidate for representing the LED light source, if a frequency of the variation is within a predefined frequency range.

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METHOD FOR DETECTING A LED LIGHT SOURCE IN A SEQUENCE OF FRAMES, METHOD FOR DETECTING A TRAFFIC LIGHT WHICH COMPRISES AT LEAST ONE LED LIGHT SOURCE, AND VEHICLE

Field

Examples relate to detecting a Light-Emitting Diode (LED) in a frame sequence. In particular, examples relate to a method for detecting a LED light source in a sequence of frames, a method for detecting a traffic light which comprises at least one LED light source, and a vehicle.

Background

Automatic Traffic Light Detection (TLD) plays an important role for driver-assistance systems and autonomous vehicles. In conventional TLD systems, a camera is mounted in a vehicle and the data of the camera is interpreted via a computer vision approach. An overview on conventional TLD systems is, e.g., given in M. Jensen et al. “Vision for Looking at Traffic Lights: Issues, Survey, and Perspectives” in IEEE Transactions on Intelligent Transportation Systems Vol. 17, Issue 7. For example, model-based approaches rely on heuristically determined models using shape, color and intensity. Learning-based approaches find the solution in a machine learning way using the collection of positive and negative samples and training algorithms (e.g. SVM or AdaBoost). Further, Global Positioning System (GPS) localization may be used as auxiliary data. That is, conventional TLD systems rely on visual information from static frames, and optionally localization data. However, traffic lights from different countries, regions, and manufactures are visually distinct. The, hence, resulting large intra-class variance may allow good performance for the pre-trained detectors on a specific dataset, but cause failure on other datasets. Conventional algorithms extract deliberate visual features (e.g. color, shape, position) and rule them on the basis of trained images. However, under complex circumstances of real life traffic (e.g. distinguishing a red traffic light from vehicle tail lights), decisions relying on visual features suffer from a low detection recall and a high number of false alarms.

Hence, there may be a desire for an improved detection of light sources.

Summary

The desire may be satisfied by the proposed examples.

An example relates to a method for detecting a LED light source in a sequence of frames of an environment. The method comprises selecting a frame portion of interest and determining, using the sequence of frames, a variation of the frame portion of interest. The method further comprises determining that the frame portion of interest is a candidate for representing the LED light source, if a frequency of the variation is within a predefined frequency range. The proposed method may allow to the detect LED light sources with high detection accuracy using the circumstance that LED light sources flash at a certain frequency.

Another example relates to a method for detecting a traffic light which comprises at least one LED light source in a sequence of frames of an environment, wherein the method comprises the above method for detecting a LED light source in a sequence of frames of an environment. The method may allow to detect LED light source based traffic lights with high detection accuracy. For example, a confusion between a traffic light and vehicle tail lights may be omitted. Accordingly, a performance and accuracy of driver-assistance systems or autonomous vehicles may be improved.

A further example relates to a vehicle comprising a processing unit configured to perform one of the above methods. By executing one of the above methods, a performance and accuracy of a driver-assistance system provided by the vehicle, or autonomous driving by the vehicle may be improved.

Yet another example relates to a machine readable storage medium having stored thereon a program having a program code for performing one of the above methods, when the program is executed on a computing unit or a processor. The machine readable storage medium may allow to execute one of the above methods on a computing unit or a processor of a device relying on LED light source detection or traffic light detection. Moreover, the machine readable storage medium may allow to update existing programs, algorithms or configurations to the proposed methods.

Brief description of the Figures

Some embodiments of apparatuses and/or methods will be described in the following by way of example only, and with reference to the accompanying figures, in which

Fig. 1 illustrates a flowchart of an example of a method for detecting a LED light source in a sequence of frames of an environment;

Fig. 2 illustrates an example of a traffic scene;

Fig. 3a illustrates an example of a temporal course of an average luminance in a frame portion of interest;

Fig. 3b illustrates an example of a frequency spectrum for the temporal course illustrated in Fig. 3a;

Fig. 4a illustrates another example of a traffic scene;

Fig. 4b illustrates an example of a motion mask filtered version of the traffic scene illustrated in Fig. 4a;

Fig. 4c illustrates an example of a color mask filtered version of the motion mask filtered version illustrated in Fig. 4b;

Fig. 4d illustrates an example of a temporal contrast mask filtered version of the doubly filtered version illustrated in Fig. 4c;

Fig. 5 illustrates an example of a comparison of characteristic values of a sequence of frames;

Figs. 6a to 6c illustrate a frame in various phases of the proposed method; and

Fig. 7 illustrates an example of a vehicle.

Detailed Description

Various examples will now be described more fully with reference to the accompanying drawings in which some examples are illustrated. In the figures, the thicknesses of lines, layers and/or regions may be exaggerated for clarity.

Accordingly, while further examples are capable of various modifications and alternative forms, some particular examples thereof are shown in the figures and will subsequently be described in detail. However, this detailed description does not limit further examples to the particular forms described. Further examples may cover all modifications, equivalents, and alternatives falling within the scope of the disclosure. Like numbers refer to like or similar elements throughout the description of the figures, which may be implemented identically or in modified form when compared to one another while providing for the same or a similar functionality.

It will be understood that when an element is referred to as being “connected” or “coupled” to another element, the elements may be directly connected or coupled or via one or more intervening elements. In contrast, when an element is referred to as being “directly connected” or “directly coupled” to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent”, to name just a few examples).

The terminology used herein is for the purpose of describing particular examples is not intended to be limiting for further examples. Whenever a singular form such as “a,” “an” and “the” is used and using only a single element is neither explicitly or implicitly defined as being mandatory, further examples may also use plural elements to implement the same functionality. Likewise, when a functionality is subsequently described as being implemented using multiple elements, further examples may implement the same functionality using a single element or processing entity. It will be further understood that the terms “comprises,” “comprising,” “includes” and/or “including,” when used, specify the presence of the stated features, integers, steps, operations, processes, acts, elements and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, processes, acts, elements, components and/or any group thereof.

Unless otherwise defined, all terms (including technical and scientific terms) are used herein in their ordinary meaning of the art to which the examples belong, unless expressly defined otherwise herein.

Fig. 1 illustrates a method 100 for detecting a LED light source in a sequence of frames of an environment. A LED light source is a light source which comprises at least one LED. That is, a LED light source is a light source which emits light to the environment that is radiated by the at least one LED. The LED may radiate light of any color. For example, the LED may radiate green light, blue light, red light, or any combination thereof.

The sequence of frames of the environment is a plurality of frames of a same environment scenery (e.g. a traffic scene). The individual frames of the plurality of frames may, e.g., be in chronological order. For example, the sequence of frames of the environment may be generated by a sensor which is sensitive to photons. The sensor may, e.g., be camera or a high-speed camera. Each frame comprises a plurality of pixels determined by the resolution of the individual frames of the sequence of frames.

The method 100 comprises selecting 102 a frame portion of interest. The frame portion of interest may be selected using one or more frames of the sequence of frames on the basis of one or more selection (filter) criteria. The frame portion of interest may be any portion of a frame of the sequence of frames. For example, the frame portion of interest may comprise one pixel, two pixels, five pixels, ten pixels, one hundred pixels, one thousand pixels, ten thousand pixels, or more. The one or more selection criteria may be applied to a single frame of the sequence of frames and/or to two or more frames of the sequence of frames.

Further, the method 100 comprises determining 104 a variation of the frame portion of interest using the sequence of frames. That is, a variation of a frame portion of interest's characteristic within the sequence of frames is determined. For determining the variation of the frame portion of interest, two or more frames of the sequence of frames may, e.g., be partially compared to each other.

A LED comprises p-n junction which radiates light when a suitable forward voltage is applied to input terminals of the LED. Power grids provide Alternating Current (AC). However, a LED requires Direct Current (DC) at a defined voltage level for operation. Hence, an AC input signal supplied by the power grid is converted to a DC signal having a defined voltage level (e.g. 12 Volts) using, e.g., full-wave rectification. Full-wave rectification converts the AC waveform with alternating polarity to a pulsating DC waveform with constant polarity. Power grids provide the AC signal with a defined frequency. Due to rectification, the frequency of the DC signal is a multiple of the AC signal's frequency. In other words, the frequency of an occurrence of extrema of one polarity in the rectified DC signal is a multiple of an occurrence of extrema of the one polarity in the AC signal. The waviness of the rectified DC signal (i.e. the ripples in the rectified DC signal) translates into a flashing of the LED at the frequency of the rectified DC signal. Hence, a flashing characteristic of the LED light source may be known from the frequency of the AC signal supplied by the power grid and the rectification method. Accordingly, knowledge on the frequency of the LED light source flashing may be used to detect the LED light source in the sequence of frames. This is based on the assumption that the flashing characteristic of the LED light source corresponds to a specific temporal variation of the frame portion of interest.

Hence, the method 100 further comprises determining 106 that the frame portion of interest is a candidate for representing the LED light source, if a frequency of the variation is within a predefined frequency range. If the frequency of the variation is within the predefined frequency range, it may be assumed that the variation corresponds to the flashing of the LED light source. Hence, the frame portion of interest may be classified as candidate for representing the LED light source.

In some examples, the frame portion of interest may be a (single) pixel. Analyzing a single pixel in order to determine whether or not it is a candidate for representing the LED light source may be a beneficial granularity for analysis since a sensor usually provides frame data on a pixel basis.

The sequence of frames may in some examples comprise at least five frames. Five frames may be sufficient to detect a variation of the frame portion of interest that is characteristic for LED flashing. However, also more frames may be used. For example, 10 frames, 15 frames, 20 frames, 25 frames, 30 frames, 35 frames, 40 frames, 45 frames, 50 frames, or more may be used.

In some examples, a frame rate of the sequence of frames is 100 Frames Per Second (FPS) or more. That is, a time lag between consecutive frames of the sequence of frames is 0.01 seconds or less. The small time lag may allow to assume that a relative position of an object within the frame does not change significantly during the time period covered by the sequence of frames. Accordingly, analysis may be facilitated. For example, the frame rate may be 100 FPS, 150 FPS, 200 FPS, 250 FPS, 300 FPS, 350 FPS, 400 FPS, 450 FPS, 500 FPS, 550 FPS, 600 FPS, 650 FPS, 700 FPS, 750 FPS, 800 FPS, 850 FPS, 900 FPS, 950 FPS, 1000 FPS, or more.

The predefined frequency range may, e.g., be between 95 Hz and 105 Hz, or between 115 Hz and 125 Hz. Throughout the world, power grids provide AC signals either at 50 Hz or at 60 Hz. If a conventional full-wave rectifier is used for rectifying the AC signal to a DC signal for the LED light source, the frequency of the rectified DC signal is double the frequency of the AC signal as provided by the power grid. Accordingly, the LED light source flashes either at 100 Hz or at 120 Hz. Hence, using the proposed frequency ranges, candidates for representing an LED light source may be determined under the assumption that the frequency of the variation of the frame portion of interest corresponds to the flashing frequency of the LED light source.

In the following, further aspects of the proposed method are discussed in connection with TLD. However, the proposed method is not limited to this field. In general, the proposed method may be used to detect any kind of LED light source in a sequence of frames.

Fig. 2 illustrates a traffic scene 200. The traffic scene 200 is recorded at a frame rate of 1000 FPS by a high-speed camera mounted in a vehicle. Various light sources are present in traffic scene 200. For example, the tail lights 210 of the vehicle 220 in front, and the traffic light 230.

On the right side of Fig. 2, a detailed view of the traffic light 230 during ten consecutive frames recorded by the high-speed camera is illustrated. The traffic light comprises a plurality of LED light sources. During the ten consecutive frames, the traffic light 230 was set to green light. It is evident from the ten consecutive frames that there are frames in which the LED light sources are totally lighted on and frames in which the LED light sources are lighted off. In other words, the LED light sources of the traffic light are flashing at a certain frequency.

The LED light sources of the traffic light are flashing (blinking) at a high frequency (e.g. 100 Hz or 120 Hz, see above) which is unnoticeable to the naked eye but which may be detected by sensors providing an adequate recording frame rate (e.g. high speed cameras). As discussed above, a frame rate of 100 FPS or more may be used.

That is, a portion of the frame depicting the green light radiated by the LED light sources of the traffic light may, e.g., be determined (selected) as frame portion of interest in the proposed method. For example, the frame portion of interest may be a pixel depicting the green light radiated by the LED light sources. In **Fig. 3a**, an example of a temporal course of an average luminance in the determined frame portion of interest is illustrated. Fig. 3a illustrates the average luminance intensities (in arbitrary units) of the frame portion of interest for each frame in a sequence of 200 frames. The blue dot markers represent the luminance values of the frame portion of interest in the individual frames. The blue dot markers are connected by a solid line. The resulting curve 300 shows a sine-like periodic pattern.

The frequency spectrum 310 of the curve 300 illustrated in Fig. 3a is illustrated in **Fig. 3b**. It is evident from Fig. 3b that a high peak resides at approximately 100 Hz. That is, the LED light sources of the traffic light illustrated in Fig. 2 flash (blink) at a frequency of approximately 100 Hz. As discussed above, the flashing frequency is related to the frequency of the AC signal provided by the power grid to the traffic light.

Unlike visual appearances, which may vary greatly by regions, manufactures, or even illumination changes, the frequency of the electricity as provided by power grids around the world is unified to either 50Hz (e.g. in Europe or Australia) or 60Hz (e.g. in North America). Hence, the flashing pattern of the LED light sources may be a robust feature for TLD.

As discussed above, sensors (high-speed vision systems) having the ability to record (capture) hundreds or thousands of frames within one second may be used to provide the sequence of frames. Along with this very high temporal resolution, the amount of frames (i.e. data) requires efficient and fast data processing. Moreover, since vehicles are moving, a depicted background of the traffic light in the sequence of frames may change. However, due to the high temporal resolution within the sequence of frames (i.e. the high frame rate of, e.g., 100 FPS or more), object displacements in consecutive (adjacent) frames may be (far) less than a sub-pixel – even when the vehicle (i.e. the sensor) is moving at high speed. Therefore, sequence of frames may be limited to a short window (e.g. 10 frames at a frame rate of 1000 FPS), and it may be assumed that most objects depicted in the sequence of frames do not move significantly within the sequence of frames.

For the analysis of the sequence of frames further influences such as lighting (e.g. day, night), exposure, white balance, and defocus blur may be considered. Hence, selecting the frame portion of interest may comprise repeatedly filtering at least part of the sequence of frames using a plurality of filter criteria. The filtering may be understood as pre-processing to filter out non-interesting frame portions in order to speed up the data processing. For example, the one or more filter criteria may be applied to a single frame of the sequence of frames and/or to two or more frames of the sequence of frames. Heuristic features (e.g. color, motion, or contrast) may, e.g., be used as filter criteria.

An exemplary filtering sequence is discussed in the following with respect to Figs. 4a to 4d. However, it is to be noted that the discussed filtering processes are merely illustrative and that other filter criteria, less filter criteria, more filter criteria, or a different order of the filter criteria may be used.

Fig. 4a illustrates another traffic scene 400 which comprises a traffic light 410. Again, the traffic light 410 comprises at least one LED light source.

In order to distinguish static frame portions from flashing (blinking) frame portions, repeatedly filtering at least part of the sequence of frames using a plurality of filter criteria may comprise determining a first set of frame portions, wherein for each frame portion in the first set of frame portions the summed differences in the pixel value between the frame portion in one of the sequence of frames and the frame portion in the other ones of the sequence of frames is above a threshold. That is, a frame portion in one frame of the sequence of frames is compared to the corresponding frame portion in all the other frames of the sequence of frames, respectively.

The pixel value indicates the intensity of the photons striking a certain frame portion. That is, each frame portion stores a value proportional to the light intensity at that particular location of the frame. For example, if the frame portion is a single pixel, the pixel value indicates the light intensity (brightness) at that particular pixel in the frame. For example, if the frame portion comprises a plurality of pixels (i.e. two or more), the pixel value indicates the light intensity at that plurality of pixels in the frame. For example, the pixel value of the frame portion may be the summed pixel values for the individual pixels of the plurality of pixels, or an average value of the pixel values for the individual pixels of the plurality of pixels.

For a binary frame, the pixel value may be a 1-bit number indicating either foreground or background. For a grayscale frame, the pixel value may be a figure that represents the brightness of the pixel. The pixel value may be used to decode a frame by storing the pixel value for the individual pixels as, e.g., an 8-bit integer giving a range of possible values from 0 to 255. For example, zero may indicate black and 255 may indicate white. Values in between may, hence, indicate the different shades of gray. To represent colored frames, separate red, green and blue components may be specified for each pixel (assuming an RGB color space). Hence, the pixel value is actually a vector of three numbers. The three different components may, e.g., be stored as three separate “grayscale” frames, which are also known as color planes (one for each of red, green and blue). The three separate “grayscale” frames may be recombined for displaying or processing the frame.

For a sequence of n frames, the comparison between the frame portions may, e.g., be based on an expression which is mathematically correspondent to

$$M_m = \sum_{k=1}^{n} |f_{i-k} - f_i| > TH_m \qquad (1),$$

where M_m denotes the summed differences in the pixel value, f_i denotes the pixel value of the frame portion in the one selected frame of the n frames, f_{i-k} denotes the pixel value of the frame portion in one of the other frames of the sequence of n frames, and TH_m denotes the threshold.

That is, a motion mask M_m is used for eliminating static frame portions (e.g. pixels) and keeping only moving and flashing (blinking) ones. It may be extracted by aggregating the frame differences and comparing it to the threshold TH_m.

Hence, the first set of frame portions comprises merely frame portions which are not static. By adjusting the value of the threshold TH_m, a required minimum variation within a frame portion may be adjusted.

The motion mask filtered version of the traffic scene illustrated in Fig. 4a is illustrated in **Fig. 4b**. In Fig. 4b the non-static frame portions (e.g. pixels) are depicted in white, whereas the static frame portions are depicted in black. That is, the frame portions comprised by the first set of frame portions are depicted in white.

Further, in order to filter out frame portions of wrong color, repeatedly filtering at least part of the sequence of frames using a plurality of filter criteria may further comprise determining a second set of frame portions from the first set of frame portions, wherein the frame portions in the second set of frame portions exhibit a predetermined color range. That is, the frame portions of the first set of frame portions are compared to the predetermined color range. The predetermined color range may, e.g., comprise one or more colors and corresponding nuances of the colors. For example, the predetermined color range may comprise different nuances of red and/or yellow and/or green. The predetermined color range may be selected based on the kind of LED light sources that is to be detected. In some examples, a normalized RGB color space may be used to deal with changing scene conditions such as lighting, exposure, or white balance.

That is, a color mask is used for eliminating frame portions of wrong color and keeping only frame portions of a predetermined (interesting) color range. Hence, the second set of frame portions comprises merely frame portions which exhibit a certain color range.

The further color mask filtered version of the motion mask filtered version of the traffic scene as illustrated in Fig. 4b is illustrated in **Fig. 4c**. In Fig. 4c the non-static frame portions (e.g. pixels) exhibiting the predetermined color range are depicted in white, whereas the frame portions which are static and/or of wrong color are depicted in black. That is, the frame portions comprised by the second set of frame portions are depicted in white.

Frame portions representing a LED light source change between dark and bright within one flashing period (see e.g. Fig. 2). Accordingly, a temporal contrast of the frame portions within the sequence of frames may be used to filter out further non-interesting frame portions. Hence, repeatedly filtering the sequence of frames using a plurality of filter criteria may further comprise selecting a frame portion of the second set of frame portions as the frame portion of interest, wherein for the frame portion of interest a difference in the pixel value between the frame portion of interest exhibiting the highest pixel value among the sequence of frames and the frame portion of interest exhibiting the lowest pixel value among the sequence of frames is above a threshold.

That is, a frame portion of the second set of frame portions is merely selected as frame portions of interest, if a maximum contrast for this frame portion within the sequence of frames is above a threshold.

For a sequence of n frames, the comparison between the frame portions may, e.g., be based on an expression which is mathematically correspondent to

$$M_t = \max_{k=1 \ldots n} \{f_{i-k}\} - \min_{k=1 \ldots n} \{f_{i-k}\} > TH_t \qquad (2),$$

where M_t denotes the difference in the pixel value, f_{i-k} denotes the pixel value of the frame portion in one of the frames of the sequence of n frames, $\max_{k=1 \ldots n} \{f_{i-k}\}$ denotes the maximum pixel value of the frame portion among the sequence of n frames, $\min_{k=1 \ldots n} \{f_{i-k}\}$ denotes the minimum pixel value of the frame portion among the sequence of n frames, and TH_t denotes the threshold.

That is, a temporal contrast mask M_t is used for eliminating non-flashing frame portions (e.g. pixels) and keeping flashing (blinking) ones. For TLD, where the LED light sources are always monochromatic (e.g. red, green, or yellow), e.g., the V-channel may be used instead of a grayscale for determining the contrast and comparing it to the threshold TH_t.

The further temporal contrast mask filtered version of the doubly filtered version of the traffic scene as illustrated in Fig. 4c is illustrated in **Fig. 4d**. In Fig. 4d the non-static frame portions (e.g. pixels) exhibiting the predetermined color range and a minimum contrast are depicted in white, whereas the frame portions which are static and/or of wrong color and/or of a wrong contrast are depicted in black. That is, the frame portions of interest are depicted in white.

It is evident from Figs. 4c to 4d that most frame portions are static, have a wrong color or a wrong contrast, i.e., they are non-interesting frame portions since they cannot represent a flashing LED light source. Accordingly, theses frame portions may be omitted in filtering steps in order to save computing resources and to minimize processing time. For example, all frame portions (e.g. pixels) may initially be marked as true candidates for representing the LED light source. Then, one or more masks are sequentially calculated. The frame portions annotated as false in the previous mask (because they do not satisfy the respective filter criterion) are directly marked as false in the following calculation.

The exemplarily determined frame portions are then frequency analyzed in order to determine candidates for representing the LED light source. Therefore, a variation of the frame portion of interest is determined using the sequence of frames. For example, determining the variation of the frame portion of interest may comprise comparing a characteristic value of the frame portion of interest in one of the sequence of frames to the respective characteristic values of the frame portion of interest in the other ones of the sequence of frames. The characteristic value of the frame portion may, e.g., be the pixel value of the frame portion. Alternatively, the characteristic value of the frame portion may, e.g., be any other value representing a luminance or brightness of the frame portion. By comparing the characteristic value of the frame portion of interest in one frame of the sequence of frames to the respective characteristic values of the frame portion of interest in the other frames of the sequence of frames, a variation of the characteristic value within the sequence of frames may be determined. Hence, a variation of the frame portion of interest within the sequence of frames may be detected.

In some examples, comparing the characteristic value of the frame portion of interest in the one of the sequence of frames to the characteristic value of the frame portion of interest in one of the other ones of the sequence of frames indicates a first comparison result if the characteristic value of the frame portion of interest in the one of the sequence of frames is smaller than a first threshold value. The comparison indicates a second comparison result if the characteristic value of the frame portion of interest in the one of the sequence of frames is smaller than or equal to a second threshold value. Further, the comparison indicates a third comparison result if the characteristic value of the frame portion of interest in the one of the sequence of frames is greater than the second threshold value. In this respect, the first threshold value and the second threshold value are based on the characteristic value of the frame portion of interest in the one of the other ones of the sequence of frames.

An example for such a comparison is given in **Fig. 5**. In Fig. 5, the characteristic value p_i of the frame portion of interest in a frame f_i of the sequence of frames is compared to the characteristic values p_{i-1} to p_{i-10} of the frame portion of interest in the ten temporally preceding frames f_{i-1} to f_{i-10}. That is, the frames f_i to f_{i-10} form a sequence of frames.

On top of each of the frames f_{i-1} to f_{i-10} a figure denotes the comparison result. For example, above frame f_{i-5} the figure “2” is illustrated since the characteristic value p_i of the frame portion of interest in frame f_i of the sequence of frames is greater than a second threshold value, wherein the second threshold value is based on the characteristic value p_{i-5} of the frame portion of interest in the frame f_{i-5}. Above frame f_{i-10} the figure “1” is illustrated since the characteristic value p_i of the frame portion of interest in frame f_i of the sequence of frames is smaller than or equal to a second threshold value, wherein the second threshold value is based on the characteristic value p_{i-10} of the frame portion of interest in the frame f_{i-10}.

That is, the figure “1” indicates a second comparison result, whereas the figure “2” indicates a third comparison result. For none of the comparisons between the characteristic value p_i of the frame portion of interest in frame f_i and the characteristic values p_{i-1} to p_{i-10} of the frame portion of interest in the ten temporally preceding frames f_{i-1} to f_{i-10} a first comparison result is indicated.

That is, comparing the characteristic value of the frame portion of interest in the one of the sequence of frames to the characteristic value of the frame portion of interest in the one of the other ones of the sequence of frames may be based on an expression which is mathematically correspondent to

$$T(i,j) = \begin{cases} 0 & if \;\; i < j - t \\ 1 & if \;\; |i - j| \leq t \\ 2 & if \;\; i > j + t \end{cases} \qquad (3),$$

with $T(i,j)$ denoting the comparison result, i denoting the characteristic value of the frame portion of interest in the one of the sequence of frames, j denoting the characteristic value of the frame portion of interest in the one of the other ones of the sequence of frames, and t denoting a constant. The expression $|i - j| \leq t$ may be reformulated as $i \geq j - t$ and $i \leq j +$

t. Regarding equation (3), $j - t$ thus corresponds to a first threshold, whereas $j + t$ corresponds to a second threshold.

The proposed method may further comprise combining the individual comparison results for the sequence of frames. Therefore, the method may further comprise generating a pattern 510 from the respective comparison results of comparing the characteristic value of the frame portion of interest in the one of the sequence of frames to the respective characteristic values of the frame portion of interest in the other ones of the sequence of frames. The pattern 510 illustrated in Fig. 5 is in chronological order. That is, the leftmost figure of the pattern 510 results from the comparison of the characteristic values p_i and p_{i-10}, the second figure from the left of the pattern 510 results from the comparison of the characteristic values p_i and p_{i-9}, etc.

In other words, the frame portion of interest p_i (e.g. a pixel) from current frame f_i is sequentially compared with its counterparts in previous frames. The comparison results (represented by figures 0/1/2) are then concatenated together.

The pattern 510 may, hence, be named a temporal ternary pattern (TTP). Like a Local Binary Pattern (LBP), a TTP may compactly encode temporal information in a small window. It has a low complexity O(n), wherein n is the temporal window size, i.e., the number of frames preceding the one frame in the sequence of frames. For example, for a pixel p_i in a frame f_i and its temporal neighbors at the same position $\{p_{i-k} | k = 1, \dots, n\}$, a TTP is extracted by performing ternary comparisons T between p_i and p_{i-k}, and concatenating them into a compact string.

The TTP has n figures for a sequence of frames comprising $n + 1$ frames:

$$TTP = \{T(p_i, p_{i-n}), T(p_i, p_{i-n+1}), \dots, T(p_i, p_{i-1})\}$$

Each figure is defined by a pair-wise ternary comparison (see, e.g., equation (3)). The three characters depict situations where i is significantly smaller than j (figure "0"), equivalent to j (figure "1"), and significantly greater than j (figure "2"). In contrast to binary comparisons such as LBP, a constant t is used for the ternary comparison. Accordingly, the comparison may be less affected by noise in the individual frames of the sequence of frames (e.g. due to camera noise).

The determined pattern represents the frequency of the variation of a frame portion of interest. Hence, it may be used for determining whether the frame portion of interest is a candidate for representing a LED light source. Hence, determining that the frame portion of interest is a candidate for representing the LED light source may comprise comparing the pattern to at least one reference pattern, wherein the reference pattern indicates the presence of a LED light source.

The reference pattern represents a reference variation for the frame portion of interest whose frequency is within the predefined frequency range. If the determined pattern is equal to the reference pattern, the frame portion of interest is, hence, likely to represent a LED light source. Thus, if the determined pattern is equal to the reference pattern, the frame portion of interest is a suitable candidate for representing a LED light source.

For determining that the frame portion of interest is a candidate for representing a LED light source, a table with one or more reference patterns, each indicating the presence of an LED light source, may be provided. The reference patterns may, e.g., be obtained from training data sets.

Regarding Figs. 4a to 4d and Fig. 5, TTPs may be extracted for each portion of interest (e.g. a pixel) obtained from the pre-processing. Then, these TTPs may be efficiently filtered based on a predefined table with references. A TTP may be extracted not for each recorded frame but only for a peak frame in a period (e.g. 10 recorded frames). The peak frame may, e.g., be the brightest frame. The peak frame may then be compared with, e.g., its preceding 10 frames to form the TTP string as discussed above.

The processing discussed above may provide one or more candidates for representing a LED light source. In order to detect the full LED light source further post-processing may be done. For example, the frame portion of interest-wise results may be merged into BLOBs, i.e., the frame portion of interest-wise results are combined to regions of the frame in which one or more characteristics are constant or approximately constant. For example, if the frame portions of interest (i.e. the candidates for representing a LED light source) are single pixels of the frame, they may be merged to candidate regions. Moreover, the results after frequency analysis might contain some single, isolated false positive points. That is, single determined candidates for representing a LED light source may be false. For example, due to strong defocus blur and lighting condition changes, there might also be some missing pixels of the LED light source near the detected region.

The method may, hence, further comprise combining a subset of the second set of frame portions to a connected frame portion. For example, the frame portions of the second set of frame portions may be divided into BLOBs using 4-connected, 6-connected or 8-connected neighborhood. Further, the determined plurality of candidates for representing the LED light source is used for selecting true positives of the connected frame portions. Therefore, the method may comprise determining that the connected frame portion represents the LED light source, if the connected frame portion comprises a candidate for representing the LED light source. That is, merely a connected frame portion that comprises a candidate for representing the LED light source is determined to represent the LED light source.

In other words, the frequency analysis results may be used as a high-threshold-mask. It may be co-filtered with the color mask M_c which serves as a low-threshold-mask. For example, all the positive pixels of the low-threshold mask may be divided into connected BLOBs using, e.g., 8-connected neighborhood. BLOBs containing at least one positive high-threshold pixel may be preserved, whereas the others are suppressed. Further simple features such as region aspect ratio or average luminance may be extracted to further reject false representatives of the LED light source.

The effect of the post-processing is illustrated in **Fig. 6**. The left part 610 of Fig. 6 illustrates a frame input into the method. A blurred stylized walking figure of a traffic light with LED light sources is depicted. The result of the frequency analysis is illustrated in the middle part 620 of Fig. 6. That is, the white portions in the middle part 620 of Fig. 6 illustrate all determined candidates for representing the LED light source. It is evident from the middle part 620 of Fig. 6 that the candidates for representing the LED light source do not represent the complete walking figure depicted in the leftmost part of Fig. 6. In the right part 630 of Fig. 6, the result after post-processing is illustrated. That is, BLOBs are formed which comprise at least one candidate for representing the LED light source. It is evident from the right part 630 of

Fig. 6 that the result after post-processing is visually more similar to the frame input into the method.

The proposed method was exemplarily discussed in the context of TLD. However, it is not restricted to this context. On the contrary, the proposed method may be used for detecting any kind of LED light source.

It is evident from the above discussion that the proposed method may allow LED light source detection, and hence also detection of traffic lights comprising LED light sources, with high accuracy. Hence, a method for detecting a traffic light which comprises at least one LED light source in a sequence of frames of an environment may comprise one or more of the above discussed steps.

Precision, recall and F_1 score of the proposed method may be higher compared to conventional approaches. Hence, the proposed method may allow improved TLD. Accordingly, a performance and accuracy of a driver-assistance system provided by a vehicle, or autonomous driving by a vehicle may be improved.

An example of an implementation using a method according to one or more aspects of the proposed concept or one or more examples described above is illustrated in **Fig. 7**. Fig. 7 illustrates a vehicle 700. The vehicle 700 is illustrated as an automobile. However, the vehicle 700 may be any apparatus that comprises an engine, a powertrain system and wheels. For example, the vehicle 700 may be a private vehicle or a commercial vehicle. In particular, the vehicle 700 may be an automobile, a truck, a motorcycle, or a tractor.

The vehicle 700 comprises a processing unit 710. The processing unit 710 may, e.g., comprise one or more processors or controller. The term “processor” or “controller” is, however, by far not limited to hardware exclusively capable of executing software, but may include digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage. Other hardware, conventional and/or custom, may also be included.

The processing unit 710 is configured to perform the method for detecting a LED light source according to one or more aspects of the proposed concept or one or more examples described above, or the method for detecting a traffic light according to one or more aspects of the proposed concept or one or more examples described above.

By executing one of the above methods, a performance and accuracy of a driver-assistance system provided by the vehicle, or autonomous driving by the vehicle may be improved.

The vehicle 700 may further comprise a sensor 720 configured to generate the sequence of frames of the environment, which is input into the above discussed methods. That is, the sensor 720 may be sensitive to photons. For example, the sensor 720 may be a camera, in particular a high-speed camera. That is, the sensor may be configured to generate the sequence of frames of the environment with a frame rate of 100 FPS or more. The sensor 720 may be arranged within the vehicle 700 (i.e. the sensor 720 may be part of the vehicle's interior), or at the vehicle 700 (i.e. the sensor 720 is connected to the car from the outside). For example, the sensor 720 may be arranged at a windscreen of the vehicle 700, or at a front part of the vehicle 700.

The aspects and features mentioned and described together with one or more of the previously detailed examples and figures, may as well be combined with one or more of the other examples in order to replace a like feature of the other example or in order to additionally introduce the feature to the other example.

Examples may further be a computer program having a program code for performing one or more of the above methods, when the computer program is executed on a computing unit or processor. Steps, operations or processes of various above-described methods may be performed by programmed computers or processors. Examples may also cover program storage devices such as digital data storage media, which are machine, processor or computer readable and encode machine-executable, processor-executable or computer-executable programs of instructions. The instructions perform or cause performing some or all of the acts of the above-described methods. The program storage devices may comprise or be, for instance, digital memories, magnetic storage media such as magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. Further examples may also cover computers, processors or control units programmed to perform the acts of the above-described methods or (field) programmable logic arrays ((F)PLAs) or (field) programmable gate arrays ((F)PGAs), programmed to perform the acts of the above-described methods. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which or all of which may be shared.

The description and drawings merely illustrate the principles of the disclosure. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the disclosure and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the disclosure and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and examples of the disclosure, as well as specific examples thereof, are intended to encompass equivalents thereof.

A block diagram may, for instance, illustrate a high-level circuit diagram implementing the principles of the disclosure. Similarly, a flow chart, a flow diagram, a state transition diagram, a pseudo code, and the like may represent various processes, operations or steps, which may, for instance, be substantially represented in machine readable medium and so executed by a computing unit or processor, whether or not such computing unit or processor is explicitly shown. Methods disclosed in the specification or in the claims may be implemented by a device having means for performing each of the respective acts of these methods.

It is to be understood that the disclosure of multiple acts, processes, operations, steps or functions disclosed in the specification or claims may not be construed as to be within the specific order, unless explicitly or implicitly stated otherwise, for instance for technical reasons. Therefore, the disclosure of multiple acts or functions will not limit these to a particular order unless such acts or functions are not interchangeable for technical reasons. Furthermore, in some examples a single act, function, process, operation or step may include or may be broken into multiple sub–acts, -functions, -processes, -operations or –steps, respectively. Such sub acts may be included and part of the disclosure of this single act unless explicitly excluded.

Furthermore, the following claims are hereby incorporated into the detailed description, where each claim may stand on its own as a separate example. While each claim may stand on its own as a separate example, it is to be noted that - although a dependent claim may refer in the claims to a specific combination with one or more other claims - other example examples may also include a combination of the dependent claim with the subject matter of each other dependent or independent claim. Such combinations are explicitly proposed herein unless it is stated that a specific combination is not intended. Furthermore, it is intended to include also features of a claim to any other independent claim even if this claim is not directly made dependent to the independent claim.

Claims

What is claimed is:

1. A method (100) for detecting a LED light source in a sequence of frames of an environment, comprising:

selecting (102) a frame portion of interest;

determining (104), using the sequence of frames, a variation of the frame portion of interest; and

determining (106) that the frame portion of interest is a candidate for representing the LED light source, if a frequency of the variation is within a predefined frequency range.

2. The method of claim 1, wherein determining (104) the variation of the frame portion of interest comprises comparing a characteristic value of the frame portion of interest in one of the sequence of frames to the respective characteristic values of the frame portion of interest in the other ones of the sequence of frames.

3. The method of claim 2, wherein comparing the characteristic value of the frame portion of interest in the one of the sequence of frames to the characteristic value of the frame portion of interest in one of the other ones of the sequence of frames indicates a first comparison result if the characteristic value of the frame portion of interest in the one of the sequence of frames is smaller than a first threshold value, a second comparison result if the characteristic value of the frame portion of interest in the one of the sequence of frames is smaller than or equal to a second threshold value, and a third comparison result if the characteristic value of the frame portion of interest in the one of the sequence of frames is greater than the second threshold value, wherein the first threshold value and the second threshold value are based on the characteristic value of the frame portion of interest in the one of the other ones of the sequence of frames.

4. The method of claim 3, wherein comparing the characteristic value of the frame portion of interest in the one of the sequence of frames to the characteristic value of the frame

portion of interest in the one of the other ones of the sequence of frames is based on an expression which is mathematically correspondent to

$$T(i,j) = \begin{cases} 0 & if \;\; i < j - t \\ 1 & if \;\; |i - j| \le t \\ 2 & if \;\; i > j + t \end{cases},$$

with $T(i,j)$ denoting the comparison result, i denoting the characteristic value of the frame portion of interest in the one of the sequence of frames, j denoting the characteristic value of the frame portion of interest in the one of the other ones of the sequence of frames, and t denoting a constant.

5. The method of any of claims 2 to 4, wherein the method further comprises generating a pattern from the respective comparison results of comparing the characteristic value of the frame portion of interest in the one of the sequence of frames to the respective characteristic values of the frame portion of interest in the other ones of the sequence of frames.

6. The method of claim 5, wherein determining that the frame portion of interest is a candidate for representing the LED light source comprises comparing the pattern to a reference pattern, wherein the reference pattern indicates the presence of an LED light source.

7. The method of any of claims 2 to 6, wherein the characteristic value of the frame portion of interest is a pixel value of the frame portion of interest.

8. The method of any of the preceding claims, wherein selecting (102) the frame portion of interest comprises repeatedly filtering at least part of the sequence of frames using a plurality of filter criteria.

9. The method of claim 8, wherein repeatedly filtering at least part of the sequence of frames using a plurality of filter criteria comprises determining a first set of frame portions, wherein for each frame portion in the first set of frame portions the summed differences in the pixel value between the frame portion in one of the sequence of frames and the frame portion in the other ones of the sequence of frames is above a threshold.

10. The method of claim 9, wherein repeatedly filtering at least part of the sequence of frames using a plurality of filter criteria further comprises determining a second set of frame portions from the first set of frame portions, wherein the frame portions in the second set of frame portions exhibit a predetermined color range.

11. The method of claim 10, wherein repeatedly filtering the sequence of frames using a plurality of filter criteria further comprises selecting a frame portion of the second set of frame portions as the frame portion of interest, wherein for the frame portion of interest a difference in the pixel value between the frame portion of interest exhibiting the highest pixel value among the sequence of frames and the frame portion of interest exhibiting the lowest pixel value among the sequence of frames is above a threshold.

12. The method of claim 10 or claim 11, further comprising:

combining a subset of the second set of frame portions to a connected frame portion;

determining a plurality of candidates for representing the LED light source; and

determining that the connected frame portion represents the LED light source, if the connected frame portion comprises a candidate for representing the LED light source.

13. The method of any of the preceding claims, wherein the frame portion of interest is a pixel.

14. The method of any of the preceding claims, wherein the sequence of frames comprises at least 5 frames.

15. The method of any of the preceding claims, wherein a frame rate of the sequence of frames is 100 frames per second or more.

16. The method of any of the preceding claims, wherein the predefined frequency range is between 95 Hz and 105 Hz, or between 115 Hz and 125 Hz.

17. A method for detecting a traffic light which comprises at least one LED light source in a sequence of frames of an environment, wherein the method comprises the method according to any of claims 1 to 16.

18. A vehicle (700) comprising a processing unit (710) configured to perform the method for detecting a LED light source of any of claims 1 to 16, or the method for detecting a traffic light of claim 17.

19. The vehicle of claim 18, further comprising a sensor (720) configured to generate the sequence of frames of the environment.

20. The vehicle of claim 19, wherein the sensor (720) is configured to generate the sequence of frames of the environment with a frame rate of 100 frames per second or more.

21. A machine readable storage medium having stored thereon a program having a program code for performing the method for detecting a LED light source of any of claims 1 to 16 or the method for detecting a traffic light of claim 17, when the program is executed on a computing unit or a processor.

FIG. 1

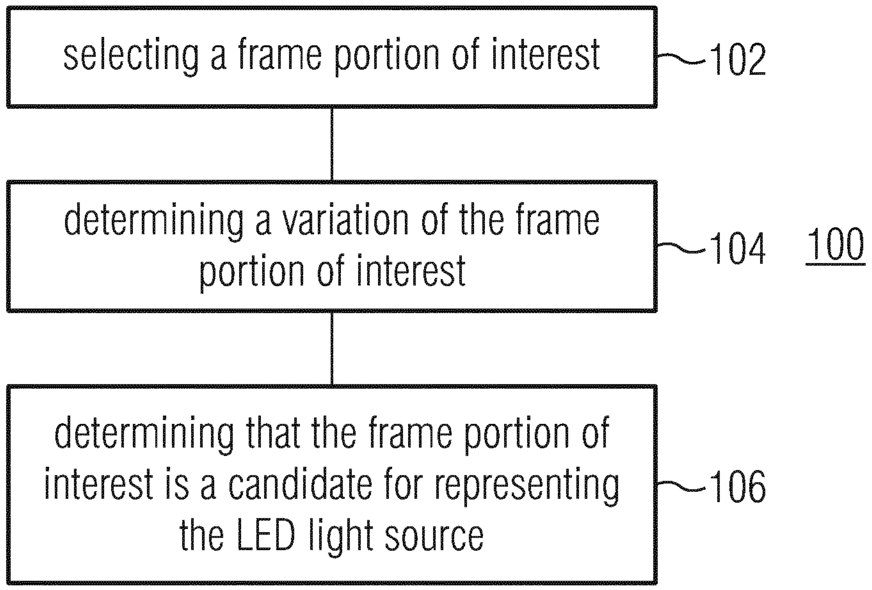

selecting a frame portion of interest
102
determining a variation of the frame portion of interest
104
100
determining that the frame portion of interest is a candidate for representing the LED light source
106

FIG. 2

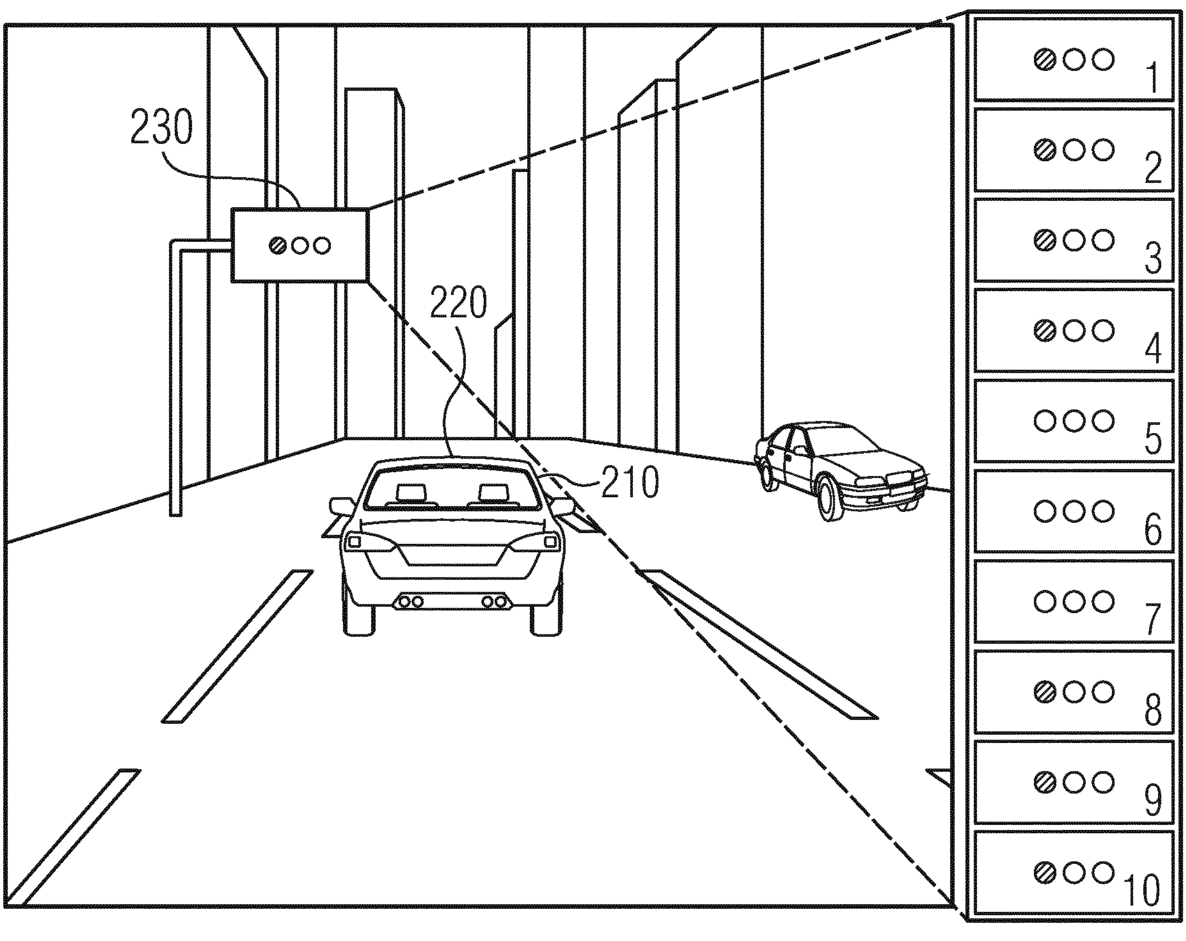

230
220
210
1
2
3
4
5
6
7
8
9
10

FIG. 3a

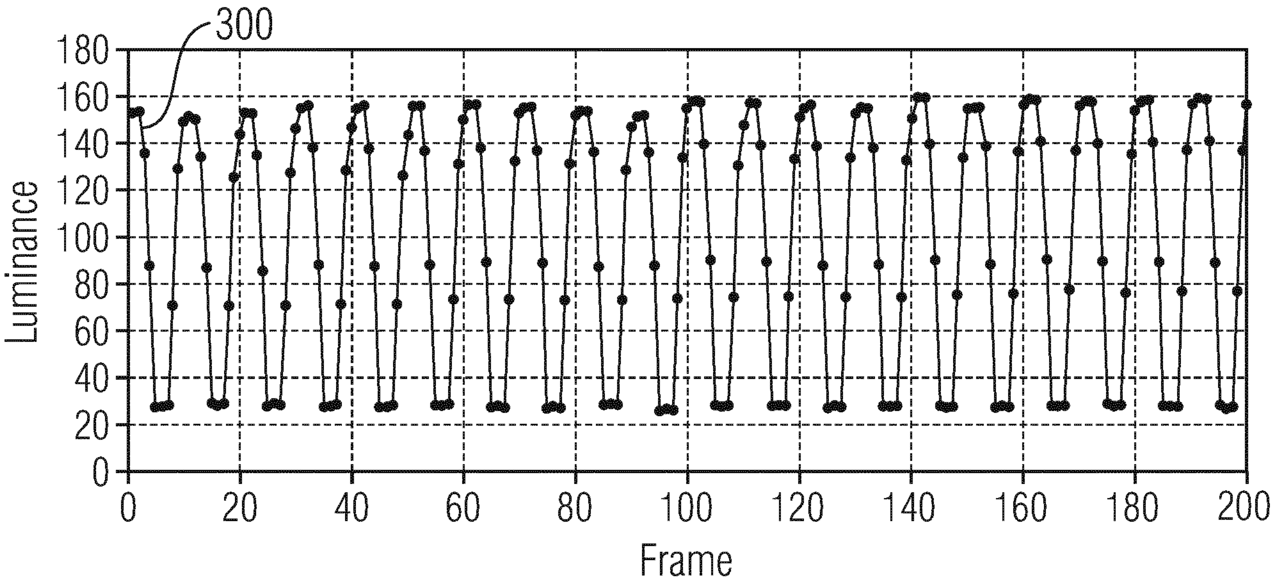

300
180
160
140
120
100
80
60
40
20
0
Luminance
0 20 40 60 80 100 120 140 160 180 200
Frame

FIG. 3b

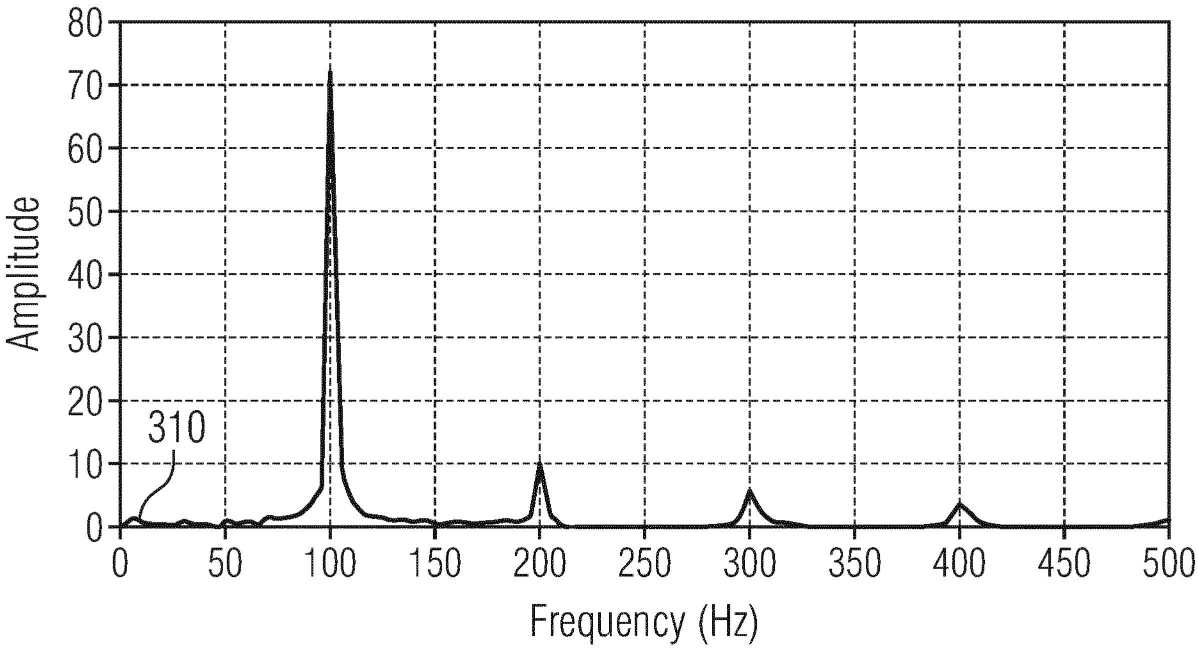

80
70
60
50
40
30
20
10
0
Amplitude
310
0 50 100 150 200 250 300 350 400 450 500
Frequency (Hz)

FIG. 4a

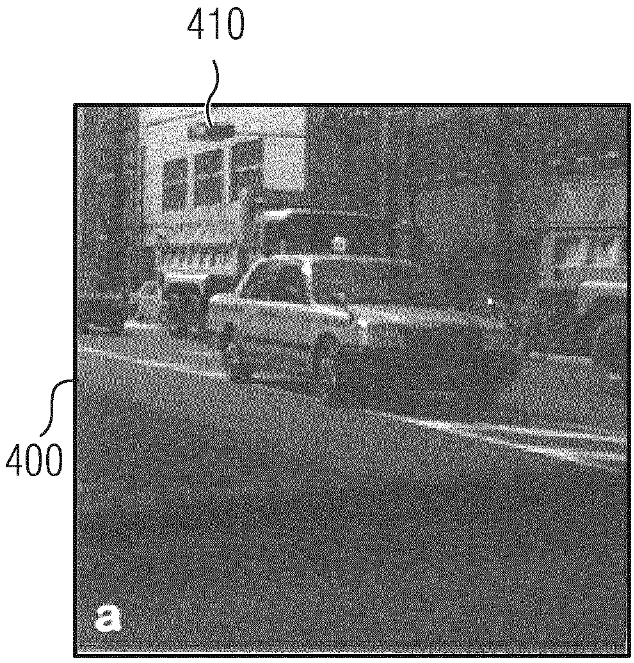


FIG. 4b

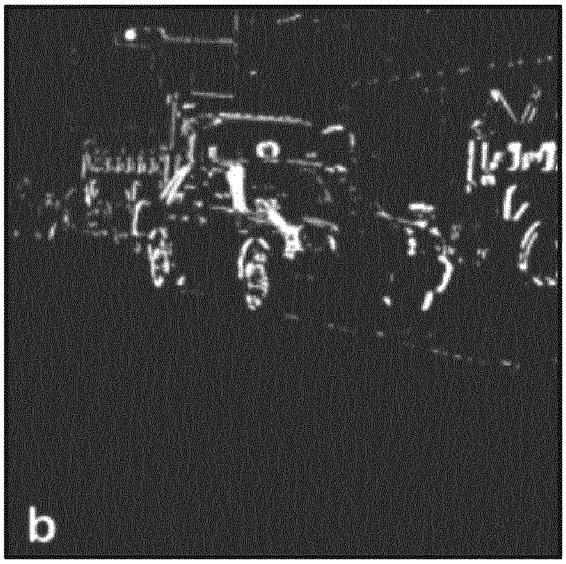


FIG. 4c

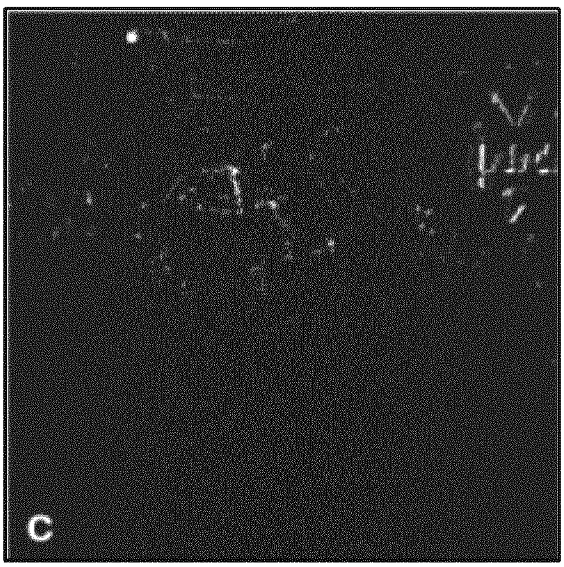
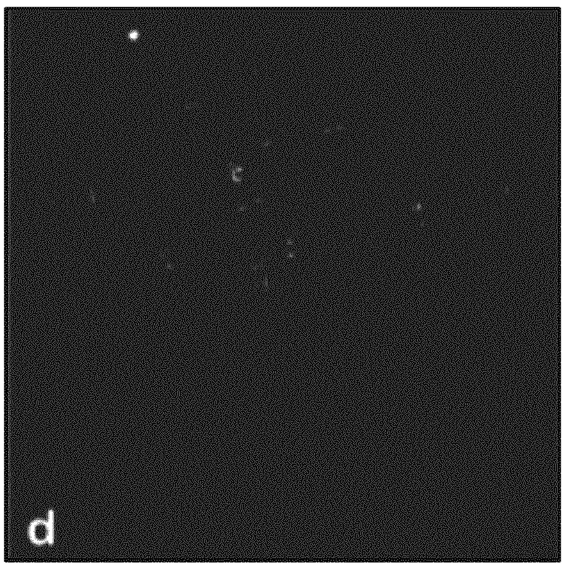
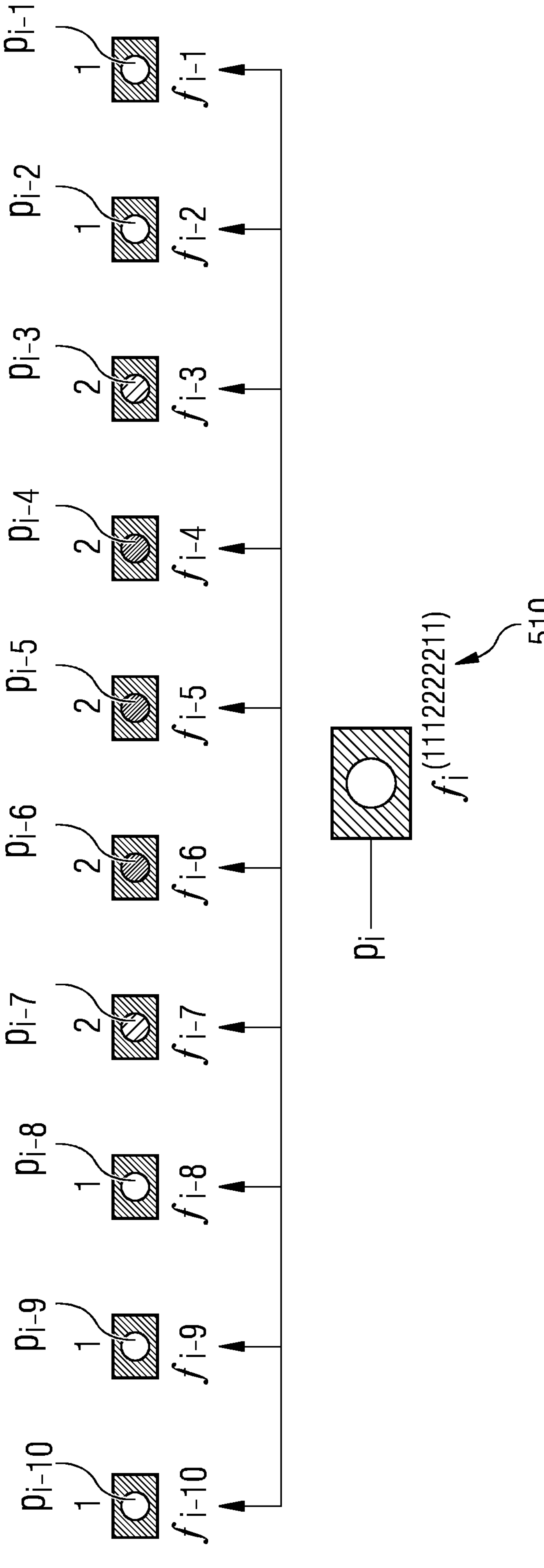


FIG. 4d




pi-1
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fi-1
pi-2
1
fi-2
pi-3
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pi-4
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fi-5
pi-6
2
fi-6
pi-7
2
fi-7
pi-8
1
fi-8
pi-9
1
fi-9
pi-10
1
fi-10
fi(1112222211)
510
pi

FIG.5

FIG. 6

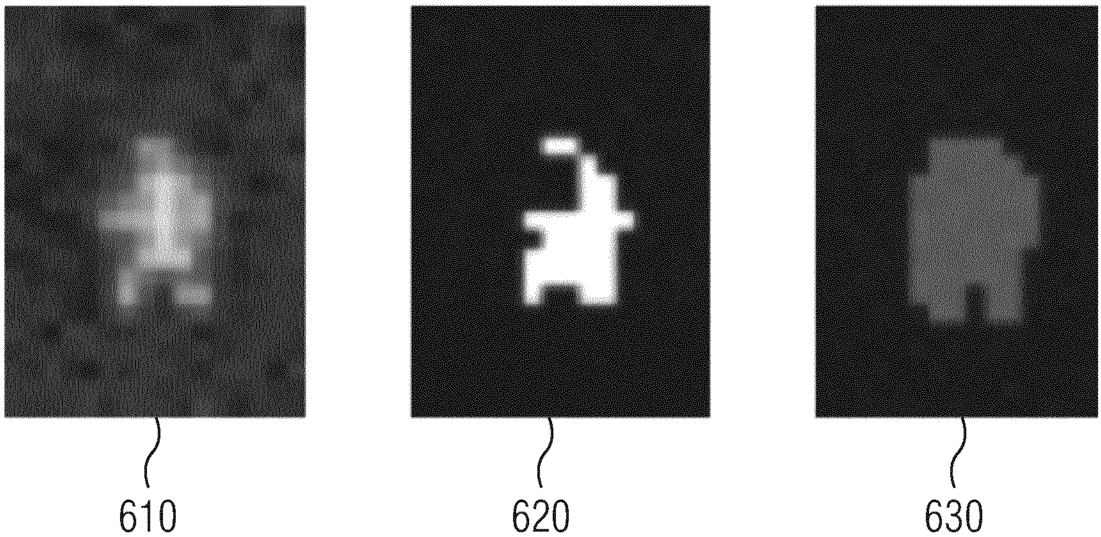
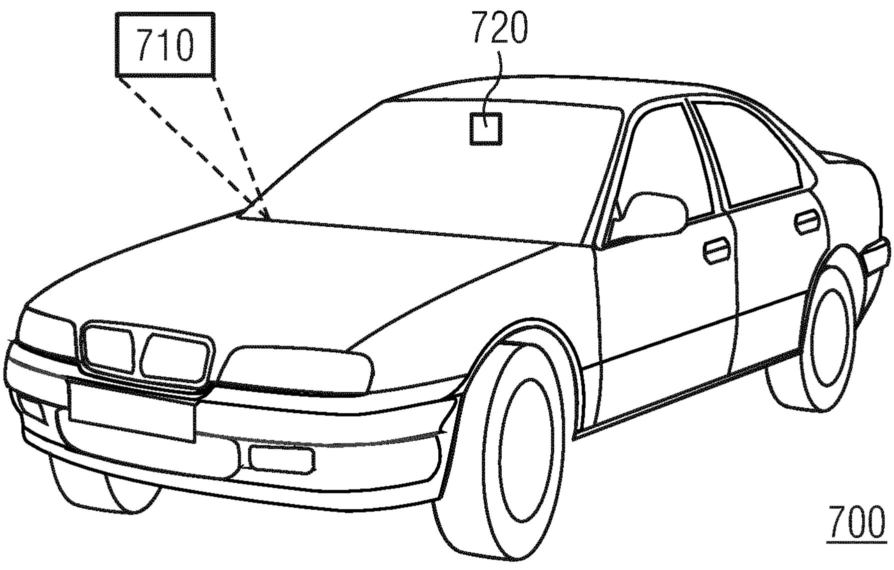


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/069611

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06K9/00
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)
G06K

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, INSPEC, 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	H. Premachandra ET AL: "LED Traffic Light Detection Using High-speed-camera Image Processing for Visible Light Communication", Information and Media Technologies, 1 January 2011 (2011-01-01), pages 785-791, XP55410838, DOI: 10.11185/imt.6.785 Retrieved from the Internet: URL:https://www.jstage.jst.go.jp/article/imt/6/3/6_3_785/_pdf	1,2,5-21
Y	Section 3. Section 4. Section 5. figures 4,5,6,12,13	3,4

X	WO 2015/136601 A1 (NISSAN MOTOR [JP]) 17 September 2015 (2015-09-17) abstract	1,13, 16-19,21
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] 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
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 October 2017	10/10/2017

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

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	-& EP 3 118 833 A1 (NISSAN MOTOR [JP]) 18 January 2017 (2017-01-18) paragraph [0010] - paragraph [0011] paragraph [0014] paragraph [0016] paragraph [0038] paragraph [0040] - paragraph [0043] claim 1 -----	
X	JP 2005 301518 A (TOYOTA MOTOR CORP) 27 October 2005 (2005-10-27) paragraph [0006] - paragraph [0008] abstract figures 3,4 -----	1,2,5,6, 15-21
Y	Adín Ramírez Rivera ET AL: "Local Directional Texture Pattern Image Descriptor", , 1 January 2015 (2015-01-01), XP55410790, Retrieved from the Internet: URL:http://www.ic.unicamp.br/~adin/downloads/pubs/RamirezRivera2015.pdf [retrieved on 2017-09-27] Section 2. -----	3,4
A	WADA M ET AL: "Road-to-vehicle communication using LED traffic light", INTELLIGENT VEHICLES SYMPOSIUM, 2005, 6 June 2005 (2005-06-06), - 8 June 2005 (2005-06-08), pages 601-606, XP010833861, IEEE, PISCATAWAY, NJ, USA DOI: 10.1109/IVS.2005.1505169 ISBN: 978-0-7803-8961-8 Section II.B-C Section III. Section IV. C figures 13,14 -----	1,2, 5-11, 13-21
A	ZHANG YUE ET AL: "A multi-feature fusion based traffic light recognition algorithm for intelligent vehicles", PROCEEDINGS OF THE 33RD CHINESE CONTROL CONFERENCE,, 28 July 2014 (2014-07-28), pages 4924-4929, XP032641526, IEEE, Piscataway, NJ, USA DOI: 10.1109/CHICC.2014.6895775 [retrieved on 2014-09-11] Section 4 -----	1,8-12, 17,18,21

-/--

2

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Ronan O'malley ET AL: "Vehicle Detection at Night Based on Tail-Light Detection", International Symposium on Vehicular Computing Systems, Trinity College Dublin, 1 July 2008 (2008-07-01), XP55036740, Retrieved from the Internet: URL:http://www.eee.nuigalway.ie/Research/car/documents/romalley_isvcs08.pdf [retrieved on 2012-08-29] Section 5 -----	1,8,10, 18,21
A	XIAOYANG TAN ET AL: "Enhanced Local Texture Feature Sets for Face Recognition Under Difficult Lighting Conditions", IEEE TRANSACTIONS ON IMAGE PROCESSING,, vol. 19, no. 6, 1 June 2010 (2010-06-01), pages 1635-1650, XP011328557, IEEE SERVICE CENTER, PISCATAWAY, NJ, US ISSN: 1057-7149, DOI: 10.1109/TIP.2010.2042645 Section III. -----	1-4
T	WU ZHIPENG ET AL: "Hybrid LED traffic light detection using high-speed camera", 2016 IEEE 19TH INTERNATIONAL CONFERENCE ON INTELLIGENT TRANSPORTATION SYSTEMS (ITSC), IEEE, 1 November 2016 (2016-11-01), pages 1235-1241, XP033028498, DOI: 10.1109/ITSC.2016.7795715 [retrieved on 2016-12-22] the whole document -----	1-21

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/069611

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015136601 A1	17-09-2015	CN 106068531 A	02-11-2016
		EP 3118831 A1	18-01-2017
		JP WO2015136601 A1	06-04-2017
		RU 2628639 C1	21-08-2017
		US 2017017850 A1	19-01-2017
		WO 2015136601 A1	17-09-2015
EP 3118833 A1	18-01-2017	CN 106062851 A	26-10-2016
		EP 3118833 A1	18-01-2017
		JP WO2015136594 A1	06-04-2017
		US 2016371552 A1	22-12-2016
		WO 2015136594 A1	17-09-2015
JP 2005301518 A	27-10-2005	NONE	