(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 384 429 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
29.01.2020 Bulletin 2020/05

(21) Application number: **16797915.2**

(22) Date of filing: **17.11.2016**

(51) Int Cl.:
G06T 7/70 *(2017.01)* ***G06K 9/46*** *(2006.01)*

(86) International application number:
PCT/EP2016/078011

(87) International publication number:
WO 2017/093037 (08.06.2017 Gazette 2017/23)

(54) **METHOD FOR IDENTIFICATION OF CANDIDATE POINTS AS POSSIBLE CHARACTERISTIC POINTS OF A CALIBRATION PATTERN WITHIN AN IMAGE OF THE CALIBRATION PATTERN**

VERFAHREN ZUR IDENTIFIZIERUNG VON KANDIDATENPUNKTEN ALS MÖGLICHE CHARAKTERISTISCHE PUNKTE EINES KALIBRIERUNGSMUSTERS IN EINEM BILD DES KALIBRIERUNGSMUSTERS

PROCÉDÉ D'IDENTIFICATION DE POINTS CANDIDATS COMME POINTS CARACTÉRISTIQUES POSSIBLES D'UN MOTIF D'ÉTALONNAGE À L'INTÉRIEUR D'UNE IMAGE DU MOTIF D'ÉTALONNAGE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **30.11.2015 EP 15196965**

(43) Date of publication of application:
10.10.2018 Bulletin 2018/41

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Description

[0001] The invention relates to a method for identification of candidate points as possible characteristic points of a calibration pattern within an image of the calibration pattern.

[0002] Such a calibration pattern can for example be used for calibrating the orientation of a camera mounted to a vehicle. The image of the calibration pattern is then acquired by means of this camera. Especially for such a calibration, but also for different possible purposes in different contexts, it can be necessary to identify characteristic points of the calibration pattern within the image of the calibration pattern. Such characteristic points, however, might not be identifiable by a single procedure or a single criterion. Therefore, it might be useful to first identify candidate points having some necessary characteristics of the characteristic points to be identified, with these characteristics, however, not being sufficient for reliable identification of the "true" characteristic points of the calibration pattern. As a result, the candidate points ideally comprise all characteristic points to be identified, though they might also comprise other points only resembling characteristic points to a certain extent.

[0003] For instance, US 2010/0232681 A1 discloses the extraction of characteristic points from the image of a calibration pattern.

[0004] The method for identification of such candidate points as possible characteristic points of the calibration pattern does not necessarily have to be executed on the image as directly obtained photographically from the calibration pattern. Instead the image might be preprocessed, for example, in a manner such that it is better adapted to be searched for candidate points.

[0005] In particular, candidate points can be characterized by an at least local maximum or minimum of pixel values of pixels of the image. Preferably, the resolution of the image is such that a possible characteristic point of the calibration image is represented in the image by an area comprising several pixels. The pixel values of this area might then form an elevation or a depression compared to the pixel values of surrounding pixels. To find such an elevation or depression, the pixel value of each of the pixels of the image could be compared to a threshold, with the location of a candidate point being, for example, determined as an apex of a found elevation or depression. However, due to noise or other errors in the image, identifying as candidate points all pixels having a locally maximal or minimal pixel value and/or being the apex of a pixel value elevation or depression could lead to too many false positives.

[0006] It is an objective of the invention to identify the candidate points in an alternative and, in particular, more specific manner and, preferably, with better resolution.

[0007] The objective is solved by a method in accordance with claim 1.

[0008] The method comprises determining spots within a filtered image derived from the image of the calibration pattern, with a spot being defined as a coherent set of pixels of the filtered image having pixel values exceeding a threshold. In other words, instead of directly searching for individual pixels having features characterizing them as possible characteristic points of the calibration pattern, the filtered image is preferentially searched for spots, i.e. regions of the image which might be indicative of a characteristic point. Such regions comprise pixels with pixel values exceeding a threshold, whereas the pixel values of the pixels surrounding a respective spot in particular do not exceed the threshold. The threshold can be an upper or a lower threshold. Therefore, in the one case, the pixels of the spot exceeding the threshold can all have pixel values above the threshold, and in the alternative case, they can all have pixel values below the threshold.

[0009] The filtered image might be identical to the image of the calibration pattern, if the calibration pattern is such that the image of the calibration pattern directly comprises spots indicative of characteristic points of the calibration pattern. However, it may be necessary preprocess the image in of the calibration pattern in some way, especially by filtering, in order to create the spots from which respective characteristic points can then be derived. This will be explained exemplarily in greater detail below.

[0010] After the spots have been determined, for each of the determined spots, a central point of the determined spot is calculated which is then identified as candidate point. In particular, for every spot determined one candidate point is obtained in this way.

[0011] According to an embodiment, the step of determining the spots comprises scanning the filtered image one pixel of the filtered image after another, wherein, if a scanned pixel has a pixel value exceeding the threshold, the scanning is paused and a spot contour tracing is executed starting with the last scanned pixel as current pixel and the second last scanned pixel as previous pixel. In this respect, determining the spots is an iterative procedure. The filtered image is scanned pixel by pixel until a pixel is reached having a pixel value exceeding the threshold. Then, from this pixel on, a contour of a respective spot can be traced by a spot contour tracing algorithm. In this way, a spot in the filtered image can be identified by tracing the spot at least essentially along a border between pixels having pixel values exceeding the threshold and pixels having pixel values not exceeding the threshold.

[0012] As starting values for such a spot contour tracing algorithm, the last scanned pixel, i.e. the pixel having a pixel value exceeding the threshold and having caused the execution of the spot contour tracing, is regarded as the first "current pixel", and the second last scanned pixel, which consequently has a pixel value not exceeding the threshold, is regarded as the frist "previous pixel".

[0013] In particular, said spot contour tracing comprises a tracing step as a result of which the current pixel is logged as a contour pixel of the spot and a new current pixel is determined, wherein this tracing step is repeated until the current pixel is again equal to the last scanned pixel. In other word, the tracing step is repeated until the starting point is reached and thus the contour is closed.

[0014] The tracing step in particular comprises logging the current pixel as a contour pixel; for neighboring pixels adjacent to the current pixel, evaluating the condition, whether both the neighboring pixel has a pixel value exceeding the threshold and another neighboring pixel, which immediately precedes this neighboring pixel with respect to a sense of rotation around the current pixel, has a pixel value not exceeding the threshold; selecting from all neighboring pixels, for which the condition is fulfilled, the neighboring pixel farthest from the previous pixel with respect to said sense of rotation; and defining the current pixel as (new) previous pixel as well as defining the selected neighboring pixel as (new) current pixel. Hence, in a single tracing step, the spot contour tracing algorithm moves from one pixel having a pixel value exceeding the threshold to a neighboring pixel also having a pixel value exceeding the threshold.

[0015] To select the neighboring pixel to move to next, in particular all neighboring pixels of the current pixel are evaluated. A neighboring pixel to the current pixel is preferentially a pixel with direct contact to the current pixel. A direct contact can comprise a common border which can be line or also only a single point. Hence, in a field of pixels arranged in rows and columns, a pixel has eight neighboring pixels having contact to the pixel at one of the pixel's four sides or at one of the pixel's four corners, respectively.

[0016] The selected neighboring pixel to the respective current pixel, on the one hand, has to have a pixel value exceeding the threshold and, on the other hand, has to be near the border between pixels with pixel values exceeding the threshold and pixels with pixel values not exceeding the threshold. Therefore it is preferred to evaluate the neighboring pixels along a sense of rotation around the current pixel, for example clockwise or counter-clockwise, and to compare the pixel value of a respective one of the neighboring pixels with the pixel value of the immediately preceding one of the neighboring pixels with respect to said sense of rotation.

[0017] If for one current pixel more than one neighboring pixel is found whose pixel value exceeds the threshold and whose preceding neighboring pixel has a pixel value not exceeding the threshold, the latest such neighboring pixel is selected. By this the sense of rotation of the spot contour tracing is defined and corresponds to said sense of rotation of successively evaluating the neighboring pixels of a respective current point.

[0018] After a tracing the spot contour has been completed, i.e. after repeating the tracing step has stopped because the last scanned pixel has been reached again, the spot is identified as the set of pixels which comprises the logged contour pixels and the pixels encircled by the logged contour pixels. From this set of pixels the central point of the spot can then be calculated.

[0019] Afterwards the next spot can be searched and its contour can then be traced. To this purpose, an already found spot is preferentially removed at least temporarily from the filtered image so that it is not traced multiple times during the scanning of the filtered image.

[0020] In an embodiment, calculating the central point of a determined spot comprises the steps of determining a first coordinate of the central point by calculating the sum of the products of a respective first coordinate and a respective pixel value of each of the pixels of the spot and dividing this sum by the sum of the pixel values of the pixels of the spot, and determining a second coordinate of the central point by calculating the sum of the products of a respective second coordinate and a respective pixel value of each of the pixels of the spot and dividing this sum by the sum of the pixel values of the pixels of the spot. Such calculation can be regarded as determining the central point as a weighted average of all the points of the respective spot.

[0021] In such an embodiment, the central point is not simply that one of the pixels of the spot having a maximal or minimal value or simply an apex of the spot, but is dependent on the pixel values of all pixels of the spot. By this, determining the central point of a spot is less prone to errors due to noise. Furthermore, the central point is determined with sub-pixel precision, because due to the weighted averaging the resulting position of the central point is not limited to exact pixel positions. Other methods for calculating the central spot than a weighted averaging as defined above might be used alternatively.

[0022] According to an embodiment, the filtered image is derived from a smoothed image obtained from the image of the calibration pattern by, for each pixel of the image of the calibration pattern, replacing a pixel value of the pixel by an average over the pixel values of pixels in a vicinity of the pixel. This can in particular correspond to box filtering or moving average filtering of the image. The degree of smoothing especially depends on the definition of said vicinity of the respective pixel and is preferably adjusted such that image noise can be reduced significantly while the calibration pattern remains clearly recognizable.

[0023] In an embodiment, the filtered image is obtained from the image of the calibration pattern or a smoothed image derived from the image of the calibration pattern by convolution of the image or the smoothed image, respectively, with a filter kernel specific to the calibration pattern or to a sub-pattern of the calibration pattern. Such a convolution is especially suited to result in a filtered image in which the calibration pattern or the sub-pattern stands out from the rest of the filtered image, whereas parts of the image not corresponding to the calibration pattern or the sub-pattern, for example a background, can ideally be smoothed out.

[0024] In particular, the convolution of the image or the smoothed image comprises the steps of obtaining an integral image from the image or the smoothed image by, for each pixel of the image or the smoothed image, replacing the pixel value of the respective pixel by the sum of the pixel values of pixels having smaller first and second coordinates than the respective pixel; and convolving the integral image with a modified filter kernel specific to the calibration pattern or to the sub-pattern of the calibration pattern. In other word, the convolution of the image or smoothed image with a filter kernel can be replaced by a convolution of the integral image of the image the smoothed image with a modified filter, wherein the modified filter kernel is preferably chosen such that the result of the convolution remains the same. By this, computing power and time may be reduced substantially, because calculation of the integral image requires only additions and the modified kernel can be much simpler than the unmodified filter kernel. Especially, a majority of the coefficients of the modified filter kernel can become zero so that comparatively few products have to be calculated for the convolution. If the non-zero coefficients of the modified filter kernel are one or minus one, the convolution might be even further simplified to only a few additions.

[0025] According to an embodiment, the calibration pattern comprises a sub-pattern formed by two equally oriented squares contrasting with a background of the calibration pattern, with a corner of one of the squares coinciding with a corner of the other of the squares. This can be regarded as a checkerboard with two rows and two columns. Especially, the squares can at least essentially be black on a white background. A characteristic point of such a sub-pattern may then be the center of the sub-pattern where the corners of the two squares coincide.

[0026] If the calibration contains such a sub-pattern, in a further embodiment, the filter kernel comprises a field of kernel values corresponding to said sub-pattern by the kernel value of a point of the field being equal to one, if the point corresponds to any of the squares of the sub-pattern, and equal to zero otherwise. In other words, for the sub-pattern described the filter kernel can also be checkerboard-like, with two rows and two columns and the "dark" fields of the checkerboard having kernel values of one and the "light" fields of the checkerboard having kernel values of zero.

[0027] In such an embodiment, the modified filter kernel preferably comprises a field of kernel values corresponding to said sub-pattern by the kernel value of a point of the field being: equal to one, if the point corresponds to a corner of any of the squares and the sum of first and second coordinates of the corner is smaller or greater than each sum of first and second coordinates of the other corners of the same square; equal to minus one, if the point corresponds to a corner of any of the squares and the sum of first and second coordinates of the corner is neither smaller nor greater than each sum of first and second coordinates of the other corners of the same square; and equal to zero otherwise.

[0028] In other words, only in the corners of the squares the modified kernel has non-zero kernel values. The kernel values in the corners are one or minus one, with kernel values of one in the upper left corner and in the lower right corner and of minus one in the other corners, or vice versa.

[0029] With the described sub-pattern in the calibration pattern, convolution of the image or smoothed image of the calibration pattern using the filter kernel or convolution of the integral image using the modified filter kernel can lead to a filtered image, in which the corners of said squares of the sub-pattern appear as spots comprising pixels having higher pixel values than the other pixels of the filtered image. Therefore such convolution is especially suited to preprocess the image of the calibration pattern for a subsequent determination of these spots within the filtered image by the spot contour tracing described above.

[0030] According to an alternative embodiment, the calibration pattern is an arrangement of sub-patterns comprising at least a first sub-pattern and a second sub-pattern. In particular the second sub-pattern is an inverse of the first sub-pattern. For example, the second sub-pattern can be bright or white, where the first sub-pattern is dark or black, and vice versa.

[0031] With such a calibration pattern, the filtered image can in particular be obtained from the image of the calibration pattern or a smoothed image derived from the image of the calibration pattern by convolution of the image or the smoothed image with a filter kernel specific to a superposition of the first sub-pattern and the second sub-pattern; and after convolution, for each pixel of the image or the smoothed image, replacing a pixel value of the pixel by the absolute value of the pixel value.

[0032] This is similar to the method according to an embodiment described above. However, the filter kernel is now specific to a superposition of the first sub-pattern and the second sub-pattern. For example, the filter kernel can be formed by subtraction of a filter kernel specific to the second sub-pattern from a filter kernel specific to the first sub-pattern. By this, the filter kernel can be usable for detecting both the first sub-pattern and the second sub-pattern at the same time. However, such a filter kernel can lead to spots in the filtered image corresponding to first sub-patterns of the calibration pattern having high positive pixel values and spots corresponding to second sub-patterns of the calibration pattern having high negative pixel values. To be able to use a single threshold for detecting all these spots, it can be preferred that, after convolution, all pixels of the convolved image have their pixel values replaced by the respective absolute values of the pixel values. In this way, all spots have positive values independent of whether they correspond to the first or the second sub-pattern.

[0033] In particular, the convolution of the image or the smoothed image comprises the steps of obtaining an integral image from the image or the smoothed image by, for each pixel of the image or the smoothed image, replacing a pixel value of the pixel by the sum of the pixel values of pixels having smaller first and second coordinates than the pixel; and convolving the integral image with a modified filter kernel specific to the superposition of the first sub-pattern and the second sub-pattern. As described above for another embodiment, such a convolution can be advantageous with respect to the computation power and time.

[0034] According to an embodiment, each of the first and second sub-patterns is formed by two equally oriented squares contrasting with a background of the calibration pattern, with a corner of one of the squares coinciding with a corner of the other of the squares, wherein the relative orientation of the two squares of the first sub-pattern is perpendicular to the relative orientation of the two squares of the second sub-pattern. In particular, the sub-patterns can be similar to the sub-pattern described above. However, with respect to each other the first and second sub-patterns differ in particular in the relative orientation of the two squares. Especially, the two sub-pattern can be checkerboard-like with two rows and two columns each, wherein in the first sub-pattern, for example, the top left field and the bottom right field are dark or black and the other fields are bright or white, and in the second sub-pattern the top right field and the bottom left field are dark or black and the other filed are bright or white.

[0035] If the calibration contains first and second sub-patterns of the described kind, in an embodiment, the filter kernel comprises a field of kernel values corresponding to the superposition of the first sub-pattern and the second sub-pattern by the kernel value of a point of the field being: equal to one, if the point corresponds to any of the squares of the first sub-pattern; equal to minus one, if the point corresponds to any of the squares of the second sub-pattern; and equal to zero otherwise.

[0036] In such an embodiment, the modified filter kernel preferably comprises a field of kernel values corresponding to the superposition of the first sub-pattern and the second sub-pattern by the kernel value of a point of the field being: equal to one, if the point corresponds to a corner of any of the squares of the first sub-pattern and the sum of first and second coordinates of the corner is smaller or greater than each sum of first and second coordinates of the other corners of the same square; equal to minus one, if the point corresponds to a corner of any of the squares of the first sub-pattern and the sum of first and second coordinates of the corner is neither smaller nor greater than each sum of first and second coordinates of the other corners of the same square; equal to minus one, if the point corresponds to a corner of any of the squares of the second sub-pattern and the sum of first and second coordinates of the corner is smaller or greater than each sum of first and second coordinates of the other corners of the same square; equal to one, if the point corresponds to a corner of any of the squares of the second sub-pattern and the sum of first and second coordinates of the corner is neither smaller nor greater than each sum of first and second coordinates of the other corners of the same square; and equal to zero otherwise.

[0037] In other words, the modified kernel has non-zero kernel values only in corners of the checkerboard fields. In these corners the kernel values are one or minus one, wherein for the "dark" fields of the checkerboard the kernel values in the upper left corner and in the lower right corner are one and the kernel values in the other corners are minus one, and wherein for the "bright" fields of the checkerboard the kernel values in the upper right corner and in the lower left corner are one and the kernel values in the other corners are minus one, or vice versa.

[0038] Such a filter kernel or modified kernel can then be suited for determining both first sub-patterns and second sub-patterns within the image or smoothed image at the same time. In particular, such kernels can be able to transform corners of the squares of a respective sub-pattern to respective spots of pixels whose pixel values stand out from the pixel values of surrounding pixels.

[0039] The objective of the invention is furthermore solved by a computer program product in accordance with claim 15 and in particular by a computer program product with a computer program which has software means for carrying out a method in accordance with at least one of the embodiments described above, if the computer program is executed in a computing device. Due to the preferably low complexity of the calculations during execution of the method, the computer program may especially be suited to be executed on a microcontroller or an embedded system of a camera with which the image of the calibration pattern is acquired.

[0040] In the following, the invention is exemplarily further described with reference to the Figures.

[0041] Fig. 1 shows an exemplary image 11 of a calibration pattern 13 acquired with a camera which is not shown. The calibration pattern 13 comprises ten sub-patterns 15, 15', representations of which can be recognized in the image 11. There are sub-patterns of a first type 15 and sub-patterns of a second type 15'. The sub-patterns 15, 15' of both types are each formed by two equally oriented squares, with a corner of one of the squares coinciding with a corner of the other of the squares, wherein the relative orientation of the two squares of a respective sub-patterns of the first type 15 is perpendicular to the relative orientation of the two squares of a respective sub-pattern of the second type 15'.

[0042] Five of the sub-patterns 15, 15' are arranged along a first vertical line, the other five along a second vertical line. Each of the sub-patterns 15, 15' on the first vertical line forms a pair with a respective sub-pattern 15, 15' on the second vertical line such that both sub-patterns 15, 15' of a respective pair are aligned on a horizontal line. Hence, in total there are five horizontal lines. While the two vertical lines and the five horizontal lines are not depicted and hence are no explicit part of the calibration pattern, they are unambiguously defined by the sub-patterns 15, 15', in particular by respective characteristic points of these sub-patterns 15, 15'.

[0043] For example to use the horizontal lines and the vertical lines for calibrating an orientation of the camera, the characteristic points of the calibration pattern 13 are to be determined. For this, the image 11 can be convolved with a filter kernel k having the following kernel values:

$$k = \begin{bmatrix} 1 & 1 & \cdots & 1 & 1 & 0 & 0 & \cdots & 0 & 0 \\ 1 & 1 & \cdots & 1 & 1 & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 1 & 1 & \cdots & 1 & 1 & 0 & 0 & \cdots & 0 & 0 \\ 1 & 1 & \cdots & 1 & 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 1 & 1 & \cdots & 1 & 1 \\ 0 & 0 & \cdots & 0 & 0 & 1 & 1 & \cdots & 1 & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 1 & 1 & \cdots & 1 & 1 \\ 0 & 0 & \cdots & 0 & 0 & 1 & 1 & \cdots & 1 & 1 \end{bmatrix}$$

[0044] The size of the filter kernel is specifically adapted at least approximately to the size (in pixels) of the representations of the first sub-patterns 15 in the image 11.

[0045] Alternatively, the integral image of the image 11 can be calculated, which is then convolved with a modified filter kernel k' having the following kernel values:

$$k' = \begin{bmatrix} 1 & 0 & \cdots & 0 & -1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ -1 & 0 & \cdots & 0 & 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 1 & 0 & \cdots & 0 & -1 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & -1 & 0 & \cdots & 0 & 1 \end{bmatrix}$$

[0046] This leads to a reduced computational complexity compared to the direct convolution of the image 11 with the unmodified filter kernel k.

[0047] For the calibration pattern 13 having first and second sub-patterns 15, 15', a filter kernel j can be used which is specific for both the first and second sub-pattern 15, 15' at the same and has the following kernel values:

$$j = \begin{bmatrix} 1 & 1 & \cdots & 1 & 1 & -1 & -1 & \cdots & -1 & -1 \\ 1 & 1 & \cdots & 1 & 1 & -1 & -1 & \cdots & -1 & -1 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 1 & 1 & \cdots & 1 & 1 & -1 & -1 & \cdots & -1 & -1 \\ 1 & 1 & \cdots & 1 & 1 & -1 & -1 & \cdots & -1 & -1 \\ -1 & -1 & \cdots & -1 & -1 & 1 & 1 & \cdots & 1 & 1 \\ -1 & -1 & \cdots & -1 & -1 & 1 & 1 & \cdots & 1 & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ -1 & -1 & \cdots & -1 & -1 & 1 & 1 & \cdots & 1 & 1 \\ -1 & -1 & \cdots & -1 & -1 & 1 & 1 & \cdots & 1 & 1 \end{bmatrix}$$

[0048] The corresponding modified filter kernel j', which can alternatively be used for convolution of the integral image (instead convolving the image 11 with the unmodified filter kernel j) to reduce the computational complexity, has the following kernel values:

$$j' = \begin{bmatrix} 1 & 0 & \cdots & 0 & -1 & -1 & 0 & \cdots & 0 & 1 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ -1 & 0 & \cdots & 0 & 1 & 1 & 0 & \cdots & 0 & -1 \\ -1 & 0 & \cdots & 0 & 1 & 1 & 0 & \cdots & 0 & -1 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 1 & 0 & \cdots & 0 & -1 & -1 & 0 & \cdots & 0 & 1 \end{bmatrix}$$

[0049] With such a filter kernel *j* or auch a modified filter kernel *j'*, the image 11 is transformed into a filtered image 17 shown in Fig. 2. As can be seen from Fig. 2, corners of the squares of the first and second sub-pattern 15, 15' of the calibration pattern 13 appear as bright dots against a dark background in the filtered image 17. The position of a corner of a square can then be determined from the respective spot, in particular as an average position over the pixels of the spot weighted by their pixel values.

[0050] The spots in the filtered image 17 can be determined by the spot contour tracing algorithm, which is described above and is for a single spot 19 schematically shown in Fig. 3. In this Figure, the spot 19 comprises pixels shown as bordered squares.

[0051] When, during scanning of the filtered image 17 line by line and pixel by pixel, the pixel A having a pixel value above some threshold is reached, the spot contour tracing starts and moves around the spot 19 as shown by the arrows connecting the pixels of the contour 21. For each of the pixels of the contour, the respective next pixel to move to is searched for in every possible direction (eight directions as indicated by the short arrows in the pixels A to L of the contour 21). The eight neighboring pixels of the respective pixel are evaluated clockwise with regard to whether their pixel value is above the threshold while the pixel value of the preceding pixel (with respect to the clockwise direction of rotation) is not above the threshold. The latest neighboring pixel for which this condition is met, is chosen as the next pixel. In this manner, the entire contour 21 is traced.

[0052] After the spot 19 has been traced and maybe its central point has been determined, the spot 19 is removed from the filtered image 17 so as not to be traced again by the then resumed scanning of the filtered image 17.

[0053] The result of scanning through the filtered image 17 and tracing all the spots 19 found therein is shown in Fig. 4. This Figure shows the filtered image 17 of Fig. 2 overlayed by the determined contours of respective spots 19. As can be seen from Fig. 4, the spots 19 are reliably identified, though structures in the background of the calibration pattern 13 (cf. Fig. 1) lead to false positives, especially in a periphery of the filtered image 17. Nevertheless, the described method allows identifying candidate points which are at least possible characteristic points of the calibration pattern 13, with these candidate points being identifiable with sub-pixel position by averaging a respective spot 19. Therefore the method, which requires comparatively little computing power, can be used as an important preprocessing of the image 11 for a method which subsequently selects from the set of candidate points the true characteristic points of the calibration pattern 13.

<u>List of reference signs</u>

[0054]

11	image
13	calibration pattern
15	first sub-pattern
15'	second sub-pattern
17	filtered image
19	spot
21	contour

Claims

1. Method for identification of candidate points as possible characteristic points of a calibration pattern (13) within an image (11) of the calibration pattern (13), the method comprising the steps of

   - determining spots (19) within a filtered image (17) derived from the image (11) of the calibration pattern (13), with a spot (19) being defined as a coherent set of pixels of the filtered image (17) having pixel values exceeding a threshold,
   - for each determined spot (19) calculating a central point of the determined spot, and
   - identifying as candidate points all calculated central points. wherein the step of determining the spots (19) comprises scanning the filtered image (17) one pixel of the filtered image (17) after another,
   wherein, if a scanned pixel has a pixel value exceeding the threshold, the scanning is paused and a spot contour tracing is executed starting with the last scanned pixel as current pixel and the second last pixel as previous pixel, the spot contour tracing comprising as a tracing step the steps of
   - logging the current pixel as a contour pixel,
   - for neighboring pixels adjacent to the current pixel, evaluating the condition, whether both the neighboring pixel has a pixel value exceeding the threshold and another neighboring pixel, which immediately precedes this neighboring pixel with respect to a sense of rotation around the current pixel, has a pixel value not exceeding the threshold,
   - selecting from all neighboring pixels, for which the condition is fulfilled, the neighboring pixel farthest from the previous pixel with respect to said sense of rotation, and
   - defining the current pixel as previous pixel and defining the selected neighboring pixel as current pixel;
   the spot contour tracing further comprising the steps of
   - repeating the tracing step until the current pixel is again equal to the last scanned pixel,
   - determining the spot (19) as the set of pixels comprising the logged contour pixels and the pixels surrounded by the logged contour pixels.

2. Method in accordance with claim 1,
   wherein calculating the central point of a determined spot (19) comprises the steps of

   - determining a first coordinate of the central point by calculating the sum of the products of a respective first coordinate and a respective pixel value of each of the pixels of the spot and dividing this sum by the sum of the pixel values of the pixels of the spot, and
   - determining a second coordinate of the central point by calculating the sum of the products of a respective second coordinate and a respective pixel value of each of the pixels of the spot and dividing this sum by the sum of the pixel values of the pixels of the spot.

3. Method in accordance with at least one of the preceding claims, wherein the filtered image (17) is derived from a smoothed image obtained from the image (11) of the calibration pattern (13) by, for each pixel of the image (11) of the calibration pattern (13), replacing a pixel value of the pixel by an average over the pixel values of pixels in a vicinity of the pixel.

4. Method in accordance with at least one of the preceding claims, wherein the filtered image (17) is obtained from the image (11) of the calibration pattern (13) or a smoothed image derived from the image (11) of the calibration pattern (13) by convolution of the image (11) or the smoothed image, respectively, with a filter kernel specific to the calibration pattern (13) or to a sub-pattern (15, 15') of the calibration pattern (13).

5. Method in accordance with claim 4,
   wherein the convolution of the image (11) or the smoothed image comprises the steps of

   - obtaining an integral image from the image or the smoothed image by, for each pixel of the image (11) or the smoothed image, replacing the pixel value of the respective pixel by the sum of the pixel values of pixels having smaller first and second coordinates than the respective pixel; and
   - convolving the integral image with a modified filter kernel specific to the calibration pattern (13) or to the sub-pattern (15, 15') of the calibration pattern (13).

6. Method in accordance with at least one of the preceding claims, wherein the calibration pattern (13) comprises a sub-pattern (15, 15') formed by two equally oriented squares contrasting with a background of the calibration pattern

(13), with a corner of one of the squares coinciding with a corner of the other of the squares.

7. Method in accordance with claims 4 or 5 and claim 6, wherein the filter kernel comprises a field of kernel values corresponding to said sub-pattern (15, 15') by the kernel value of a point of the field being

    - equal to one, if the point corresponds to any of the squares of the sub-pattern (15, 15'), and
    - equal to zero otherwise.

8. Method in accordance with claims 5 and 6, wherein the modified filter kernel comprises a field of kernel values corresponding to said sub-pattern (15, 15') by the kernel value of a point of the field being

    - equal to one, if the point corresponds to a corner of any of the squares and the sum of first and second coordinates of the corner is smaller or greater than each sum of first and second coordinates of the other corners of the same square,
    - equal to minus one, if the point corresponds to a corner of any of the squares and the sum of first and second coordinates of the corner is neither smaller nor greater than each sum of first and second coordinates of the other corners of the same square, and
    - equal to zero otherwise.

9. Method in accordance with at least one of the claims 1 to 3, wherein the calibration pattern (13) is an arrangement of sub-patterns (15, 15') comprising at least a first sub-pattern (15) and a second sub-pattern (15'), in particular with the second sub-pattern (15') being an inverse of the first sub-pattern (15).

10. Method in accordance with claim 9, wherein the filtered image (17) is obtained from the image (11) of the calibration pattern (13) or a smoothed image derived from the image (11) of the calibration pattern (13) by

    - convolution of the image (11) or the smoothed image with a filter kernel specific to a superposition of the first sub-pattern (15) and the second sub-pattern (15'); and
    - after convolution, for each pixel of the image (11) or the smoothed image, replacing a pixel value of the pixel by the absolute value of the pixel value.

11. Method in accordance with claim 10, wherein the convolution of the image (11) or the smoothed image comprises the steps of

    - obtaining an integral image from the image (11) or the smoothed image by, for each pixel of the image (11) or the smoothed image, replacing a pixel value of the pixel by the sum of the pixel values of pixels having smaller first and second coordinates than the pixel; and
    - convolving the integral image with a modified filter kernel specific to the superposition of the first sub-pattern (15) and the second sub-pattern (15').

12. Method in accordance with at least one of the claims 9 to 11, wherein each of the first and second sub-patterns (15, 15') is formed by two equally oriented squares contrasting with a background of the calibration pattern (13), with a corner of one of the squares coinciding with a corner of the other of the squares, wherein the relative orientation of the two squares of the first sub-pattern (15) is perpendicular to the relative orientation of the two squares of the second sub-pattern (15').

13. Method in accordance with claim 10 or 11 and claim 12, wherein the filter kernel comprises a field of kernel values corresponding to the superposition of the first sub-pattern (15) and the second sub-pattern (15') by the kernel value of a point of the field being

    - equal to one, if the point corresponds to any of the squares of the first sub-pattern (15),
    - equal to minus one, if the point corresponds to any of the squares of the second sub-pattern (15'), and
    - equal to zero otherwise.

14. Method in accordance with claims 11 and 12,

wherein the modified filter kernel comprises a field of kernel values corresponding to the superposition of the first sub-pattern (15) and the second sub-pattern (15') by the kernel value of a point of the field being

- equal to one, if the point corresponds to a corner of any of the squares of the first sub-pattern (15) and the sum of first and second coordinates of the corner is smaller or greater than each sum of first and second coordinates of the other corners of the same square,
- equal to minus one, if the point corresponds to a corner of any of the squares of the first sub-pattern (15) and the sum of first and second coordinates of the corner is neither smaller nor greater than each sum of first and second coordinates of the other corners of the same square,
- equal to minus one, if the point corresponds to a corner of any of the squares of the second sub-pattern (15') and the sum of first and second coordinates of the corner is smaller or greater than each sum of first and second coordinates of the other corners of the same square,
- equal to one, if the point corresponds to a corner of any of the squares of the second sub-pattern (15') and the sum of first and second coordinates of the corner is neither smaller nor greater than each sum of first and second coordinates of the other corners of the same square, and
- equal to zero otherwise.

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

Patentansprüche

1. Verfahren zur Identifizierung von Kandidatenpunkten als mögliche charakteristische Punkte eines Kalibrierungsmusters (13) in einem Bild (11) des Kalibrierungsmusters (13), wobei das Verfahren die Schritte umfasst, dass

- Flecken (19) in einem gefilterten Bild (17), das aus dem Bild (11) des Kalibrierungsmusters (13) abgeleitet ist, bestimmt werden, wobei ein Fleck (19) als zusammenhängender Satz von Pixeln des gefilterten Bildes (17) definiert ist, die Pixelwerte aufweisen, die einen Schwellenwert überschreiten,
- für jeden bestimmten Fleck (19) ein Mittelpunkt des bestimmten Flecks berechnet wird, und
- alle berechneten Mittelpunkte als Kandidatenpunkte identifiziert werden,

wobei der Schritt des Bestimmens der Flecken (19) umfasst, dass das gefilterte Bild (17) ein Pixel des gefilterten Bilds (17) nach dem anderen abgetastet wird,

wobei, wenn ein abgetastetes Pixel einen Pixelwert aufweist, der den Schwellenwert überschreitet, das Abtasten unterbrochen wird und eine Fleckenkonturverfolgung beginnend mit dem zuletzt abgetasteten Pixel als aktuellem Pixel und dem vorletzten Pixel als vorherigem Pixel ausgeführt wird,

wobei die Fleckkonturverfolgung als Verfolgungsschritt die Schritte umfasst, dass

- das aktuelle Pixel als Konturpixel protokolliert wird,
- für benachbarte Pixel angrenzend an das aktuelle Pixel die Bedingung ausgewertet wird, ob sowohl das benachbarte Pixel einen Pixelwert aufweist, der den Schwellenwert überschreitet, als auch ein weiteres benachbartes Pixel, welches diesem benachbarten Pixel bezüglich einer Drehrichtung um das aktuelle Pixel herum unmittelbar vorausgeht, einen Pixelwert aufweist, der den Schwellenwert nicht überschreitet,
- aus allen benachbarten Pixeln, für welche die Bedingung erfüllt ist, das benachbarte Pixel gewählt wird, das mit Bezug auf die Drehrichtung von dem vorherigen Pixel am weitesten entfernt ist, und
- das aktuelle Pixel als vorheriges Pixel definiert wird und das gewählte benachbarte Pixel als aktuelles Pixel definiert wird;

wobei die Fleckenkonturverfolgung ferner die Schritte umfasst, dass

- der Verfolgungsschritt wiederholt wird, bis das aktuelle Pixel wieder gleich dem zuletzt abgetasteten Pixel ist,
- der Fleck (19) als der Satz von Pixeln bestimmt wird, der die protokollierten Konturpixel und die Pixel umfasst, die von den protokollierten Konturpixeln umgeben sind.

2. Verfahren nach Anspruch 1,
wobei das Berechnen des Mittelpunkts eines bestimmten Flecks (19) die Schritte umfasst, dass

- eine erste Koordinate des Mittelpunkts bestimmt wird, indem die Summe der Produkte aus einer jeweiligen ersten Koordinate und einem jeweiligen Pixelwert von jedem der Pixel des Flecks berechnet wird und diese Summe durch die Summe der Pixelwerte der Pixel des Flecks dividiert wird, und
- eine zweite Koordinate des Mittelpunkts bestimmt wird, indem die Summe der Produkte aus einer jeweiligen

zweiten Koordinate und einem jeweiligen Pixelwert von jedem der Pixel des Flecks berechnet wird und diese Summe durch die Summe der Pixelwerte der Pixel des Flecks dividiert wird.

3. Verfahren nach einem der vorstehenden Ansprüche, wobei das gefilterte Bild (17) aus einem geglätteten Bild abgeleitet wird, das aus dem Bild (11) des Kalibrierungsmusters (13) erhalten wird, indem für jedes Pixel des Bilds (11) des Kalibrierungsmusters (13) ein Pixelwert des Pixels durch einen Mittelwert über die Pixelwerte der Pixel in einer Umgebung des Pixels ersetzt wird.

4. Verfahren nach einem der vorstehenden Ansprüche, wobei das gefilterte Bild (17) aus dem Bild (11) des Kalibrierungsmusters (13) oder aus einem geglätteten Bild erhalten wird, das aus dem Bild (11) des Kalibrierungsmusters (13) durch Falten des Bilds (11) oder des geglätteten Bilds mit einem für das Kalibrierungsmuster (13) oder ein Teilmuster (15, 15') des Kalibrierungsmusters (13) spezifischen Filterkern abgeleitet ist.

5. Verfahren nach Anspruch 4,
wobei das Falten des Bilds (11) oder des geglätteten Bilds die Schritte umfasst, dass

- ein integrales Bild aus dem Bild oder dem geglätteten Bild erhalten wird, indem für jedes Pixel des Bilds (11) oder des geglätteten Bilds der Pixelwert des jeweiligen Pixels durch die Summe der Pixelwerte von Pixeln ersetzt wird, welche kleinere erste und zweite Koordinaten als das jeweilige Pixel aufweisen; und
- das integrale Bild mit einem modifizierten Filterkern linear überlagert wird, der für das Kalibrierungsmuster (13) oder für das Teilmuster (15, 15') des Kalibrierungsmusters (13) spezifisch ist.

6. Verfahren nach einem der vorstehenden Ansprüche, wobei das Kalibrierungsmuster (13) ein Teilmuster (15, 15') umfasst, das durch zwei gleich orientierte Quadrate gebildet wird, die in Kontrast zu einem Hintergrund des Kalibrierungsmusters (13) stehen, wobei eine Ecke von einem der Quadrate mit einer Ecke des anderen der Quadrate übereinstimmt.

7. Verfahren nach Anspruch 4 oder 5 und Anspruch 6,
wobei der Filterkern ein Feld aus Kernwerten umfasst, die dem Teilmuster (15, 15') dadurch entsprechen, dass der Kernwert eines Punkts des Felds

- gleich eins ist, wenn der Punkt einem der Quadrate des Teilmusters (15, 15') entspricht, und
- ansonsten gleich null ist.

8. Verfahren nach Anspruch 5 und 6,
wobei der modifizierte Filterkern ein Feld von Kernwerten umfasst, die dem Teilmuster (15,15') dadurch entsprechen, dass der Kernwert eines Punkts des Felds

- gleich 1 ist, wenn der Punkt einer Ecke eines der Quadrate entspricht und die Summe aus ersten und zweiten Koordinaten der Ecke kleiner oder größer als jede Summe aus ersten und zweiten Koordinaten der anderen Ecken des gleichen Quadrats ist,
- gleich minus 1 ist, wenn der Punkt einer Ecke eines der Quadrate entspricht und die Summe aus ersten und zweiten Koordinaten der Ecke weder kleiner noch größer als jede Summe aus ersten und zweiten Koordinaten der anderen Ecken des gleichen Quadrats ist, und
- ansonsten gleich null ist.

9. Verfahren nach einem der Ansprüche 1 bis 3,
wobei das Kalibrierungsmuster (13) eine Anordnung aus Teilmustern (15, 15') ist, die mindestens ein erstes Teilmuster (15) und ein zweites Teilmuster (15') umfasst, wobei insbesondere das zweite Teilmuster (15') eine Umkehrung des ersten Teilmusters (15) ist.

10. Verfahren nach Anspruch 9,
wobei das gefilterte Bild (17) aus dem Bild (11) des Kalibrierungsmusters (13) oder einem geglätteten Bild, das aus dem Bild (11) des Kalibrierungsmusters (13) abgeleitet wird, dadurch erhalten wird, dass

- das Bild (11) oder das geglättete Bild mit einem Filterkern, der für eine Überlagerung des ersten Teilmusters (15) und des zweiten Teilmusters (15') spezifisch ist, gefaltet wird; und
- für jedes Pixel des Bilds (11) oder des geglätteten Bilds ein Pixelwert des Pixels nach der Faltung durch den

Absolutwert des Pixelwerts ersetzt wird.

11. Verfahren nach Anspruch 10,
wobei das Falten des Bilds (11) oder des geglätteten Bilds die Schritte umfasst, dass

- ein integrales Bild aus dem Bild (11) oder dem geglätteten Bild erhalten wird, indem für jedes Pixel des Bilds (11) oder des geglätteten Bilds ein Pixelwert des Pixels durch die Summe der Pixelwerte von Pixeln ersetzt wird, die kleinere erste und zweite Koordinaten als das Pixel aufweisen; und
- das integrale Bild mit einem modifizierten Filterkern gefaltet wird, der spezifisch für die Überlagerung des ersten Teilmusters (15) und des zweiten Teilmusters (15') ist.

12. Verfahren nach einem der Ansprüche 9 bis 11, wobei jedes der ersten und zweiten Teilmuster (15, 15') durch zwei gleich orientierte Quadrate gebildet wird, die mit einem Hintergrund des Kalibrierungsmusters (13) in Kontrast stehen, wobei eine Ecke von einem der Quadrate mit einer Ecke des anderen der Quadrate übereinstimmt,
wobei die relative Orientierung der zwei Quadrate des ersten Teilmusters (15) rechtwinklig zu der relativen Orientierung der zwei Quadrate des zweiten Teilmusters (15') ist.

13. Verfahren nach Anspruch 10 oder 11 und Anspruch 12,
wobei der Filterkern ein Feld von Kernwerten umfasst, die der Überlagerung des ersten Teilmusters (15) und des zweiten Teilmusters (15') dadurch entsprechen, dass der Kernwert eines Punkts des Felds

- gleich eins ist, wenn der Punkt einem der Quadrate des ersten Teilmusters (15) entspricht,
- gleich minus 1 ist, wenn der Punkt einem der Quadrate des zweiten Teilmusters (15') entspricht, und
- ansonsten gleich null ist.

14. Verfahren nach Anspruch 11 und 12,
wobei der modifizierte Filterkern ein Feld von Kernwerten umfasst, die der Überlagerung des ersten Teilmusters (15) und des zweiten Teilmusters (15') dadurch entsprechen, dass der Kernwert eines Punkts des Felds

- gleich eins ist, wenn der Punkt einer Ecke eines der Quadrate des ersten Teilmusters (15) entspricht und die Summe aus ersten und zweiten Koordinaten der Ecke kleiner oder größer als jede Summe aus ersten und zweiten Koordinaten der anderen Ecken des gleichen Quadrats ist,
- gleich minus 1 ist, wenn der Punkt einer Ecke eines der Quadrate des ersten Teilmusters (15) entspricht und die Summe aus ersten und zweiten Koordinaten der Ecke weder kleiner noch größer als jede Summe aus ersten und zweiten Koordinaten der anderen Ecken des gleichen Quadrats ist,
- gleich minus 1 ist, wenn der Punkt einer Ecke eines der Quadrate des zweiten Teilmusters (15') entspricht und die Summe aus ersten und zweiten Koordinaten der Ecke kleiner oder größer als jede Summe aus ersten und zweiten Koordinaten der anderen Ecken des gleichen Quadrats ist,
- gleich eins ist, wenn der Punkt einer Ecke eines der Quadrate des zweiten Teilmusters (15') entspricht und die Summe aus ersten und zweiten Koordinaten der Ecke weder kleiner noch größer als jede Summe aus ersten und zweiten Koordinaten der anderen Ecken des gleichen Quadrats ist, und
- ansonsten gleich null ist.

15. Computerprogrammprodukt mit einem Computerprogramm, das Softwaremittel aufweist, um ein Verfahren in Übereinstimmung mit mindestens einem der vorstehenden Ansprüche auszuführen, wenn das Computerprogramm in einer Rechenvorrichtung ausgeführt wird.

Revendications

1. Procédé d'identification de points candidats en tant que points caractéristiques possibles d'un motif d'étalonnage (13) dans une image (11) du motif d'étalonnage (13), le procédé comprenant les étapes consistant à

- déterminer des secteurs (19) dans une image filtrée (17) dérivée de l'image (11) du motif d'étalonnage (13), un secteur (19) étant défini comme un ensemble cohérent de pixels de l'image filtrée (17) ayant des valeurs de pixels dépassant un seuil,
- pour chaque secteur déterminé (19) calculer un point central du secteur déterminé et
- identifier comme points candidats tous les points centraux calculés,

dans lequel l'étape consistant à déterminer des secteurs (19) consiste à balayer l'image filtrée (17) un pixel de l'image filtrée (17) après l'autre,
dans lequel, si un pixel balayé a une valeur de pixel dépassant le seuil, le balayage est mis en pause et un traçage de contour de secteur est exécuté en commençant par le dernier pixel balayé comme pixel courant et l'avant-dernier pixel comme pixel précédent,
le traçage de contour de secteur comprenant en tant qu'étape de traçage les étapes consistant à
- enregistrer le pixel courant en tant que pixel de contour,
- pour des pixels voisins adjacents au pixel courant, évaluer la condition selon laquelle à la fois le pixel voisin a une valeur de pixel dépassant le seuil et un autre pixel voisin, qui précède immédiatement ce pixel voisin par rapport à un sens de rotation autour du pixel courant, a une valeur de pixel ne dépassant pas le seuil,
- sélectionner parmi tous les pixels voisins pour lesquels la condition est remplie, le pixel voisin le plus éloigné du pixel précédent par rapport audit sens de rotation et
- définir le pixel courant comme pixel précédent et définir le pixel voisin sélectionné comme pixel courant ;
le tracé de contour de secteur comprenant en outre les étapes consistant à
- répéter l'étape de traçage jusqu'à ce que le pixel courant soit à nouveau égal au dernier pixel balayé,
- déterminer le secteur (19) comme l'ensemble des pixels comprenant les pixels de contour enregistrés et les pixels entourés par les pixels de contour enregistrés.

2. Procédé selon la revendication 1,
dans lequel l'étape consistant à calculer le point central d'un secteur déterminé (19) comprend les étapes consistant à

- déterminer une première coordonnée du point central en calculant la somme des produits d'une première coordonnée respective et d'une valeur de pixel respective de chacun des pixels du secteur et en divisant cette somme par la somme des valeurs de pixel des pixels du secteur, et
- déterminer une deuxième coordonnée du point central en calculant la somme des produits d'une deuxième coordonnée respective et une valeur de pixel respective de chacun des pixels du secteur et en divisant cette somme par la somme des valeurs de pixel des pixels du secteur.

3. Procédé selon au moins l'une des revendications précédentes,
dans lequel l'image filtrée (17) est dérivée d'une image lissée obtenue à partir de l'image (11) du motif d'étalonnage (13) en remplaçant, pour chaque pixel de l'image (11) du motif d'étalonnage (13), une valeur de pixel du pixel par une moyenne des valeurs de pixel des pixels dans un voisinage du pixel.

4. Procédé selon au moins l'une des revendications précédentes,
dans lequel l'image filtrée (17) est obtenue à partir de l'image (11) du motif d'étalonnage (13) ou d'une image lissée dérivée de l'image (11) du motif d'étalonnage (13) par convolution de l'image (11) ou de l'image lissée, respectivement, avec un noyau de filtre spécifique au motif d'étalonnage (13) ou à un sous-motif (15, 15') du motif d'étalonnage (13).

5. Procédé selon la revendication 4,
dans lequel la convolution de l'image (11) ou de l'image lissée comprend les étapes consistant à

- obtenir une image intégrale de l'image ou de l'image lissée en remplaçant, pour chaque pixel de l'image (11) ou de l'image lissée, la valeur de pixel du pixel respectif par la somme des valeurs de pixel des pixels ayant des première et deuxième coordonnées inférieures à celles du pixel respectif ; et
- convoluer l'image intégrale avec un noyau de filtre modifié spécifique au motif d'étalonnage (13) ou au sous-motif (15, 15') du motif d'étalonnage (13).

6. Procédé selon au moins l'une des revendications précédentes,
dans lequel le motif d'étalonnage (13) comprend un sous-motif (15, 15') formé par deux carrés orientés de la même manière et contrastant avec un fond du motif d'étalonnage (13), un coin de l'un des carrés coïncidant avec un coin de l'autre des carrés.

7. Procédé selon les revendications 4 ou 5 et la revendication 6,
dans lequel le noyau de filtre comprend un champ de valeurs de noyau correspondant audit sous-motif (15, 15') par la valeur de noyau d'un point du champ étant

- égale à un si le point correspond à l'un quelconque des carrés du sous-motif (15, 15') et

- égale à zéro sinon.

8. Procédé selon les revendications 5 et 6,
dans lequel le noyau de filtre modifié comprend un champ de valeurs de noyau correspondant audit sous-motif (15, 15') par la valeur de noyau d'un point du champ étant

- égale à un si le point correspond à un coin d'un quelconque des carrés et que la somme des première et deuxième coordonnées du coin est inférieure ou supérieure à chaque somme des première et deuxième coordonnées des autres coins du même carré,
- égale à moins un si le point correspond à un coin d'un quelconque des carrés et que la somme des première et deuxième coordonnées du coin n'est ni inférieure ni supérieure à chaque somme des première et deuxième coordonnées des autres coins du même carré et
- égale à zéro sinon.

9. Procédé selon au moins l'une des revendications 1 à 3,
dans lequel le motif d'étalonnage (13) est un agencement de sous-motifs (15, 15') comprenant au moins un premier sous-motif (15) et un deuxième sous-motif (15'), en particulier le deuxième sous-motif (15') étant un inverse du premier sous-motif (15).

10. Procédé selon la revendication 9,
dans lequel l'image filtrée (17) est obtenue à partir de l'image (11) du motif d'étalonnage (13) ou d'une image lissée dérivée de l'image (11) du motif d'étalonnage (13) par

- convolution de l'image (11) ou de l'image lissée avec un noyau de filtre spécifique à une superposition du premier sous-motif (15) et du deuxième sous-motif (15') ; et
- après convolution, pour chaque pixel de l'image (11) ou de l'image lissée, remplacer une valeur de pixel du pixel par la valeur absolue de la valeur de pixel.

11. Procédé selon la revendication 10,
dans lequel la convolution de l'image (11) ou de l'image lissée comprend les étapes consistant à

- obtenir une image intégrale à partir de l'image (11) ou de l'image lissée en remplaçant, pour chaque pixel de l'image (11) ou de l'image lissée, une valeur de pixel du pixel par la somme des valeurs de pixel des pixels ayant des première et deuxième coordonnées inférieures à celles du pixel ; et
- convoluer l'image intégrale avec un noyau de filtre modifié spécifique à la superposition du premier sous-motif (15) et du deuxième sous-motif (15').

12. Procédé selon au moins l'une des revendications 9 à 11,
dans lequel chacun des premier et deuxième sous-motifs (15, 15') est formé par deux carrés orientés de la même manière et contrastant avec un fond du motif d'étalonnage (13), un coin de l'un des carrés coïncidant avec un coin de l'autre des carrés,
dans lequel l'orientation relative des deux carrés du premier sous-motif (15) est perpendiculaire à l'orientation relative des deux carrés du deuxième sous-motif (15').

13. Procédé selon la revendication 10 ou 11 et la revendication 12,
dans lequel le noyau de filtre comprend un champ de valeurs de noyau correspondant à la superposition du premier sous-motif (15) et du deuxième sous-motif (15') par la valeur de noyau d'un point du champ étant

- égale à un si le point correspond à l'un quelconque des carrés du premier sous-motif (15),
- égale à moins un si le point correspond à l'un quelconque des carrés du deuxième sous-motif (15') et
- égale à zéro sinon.

14. Procédé selon les revendications 11 et 12,
dans lequel le noyau de filtré modifié comprend un champ de valeurs de noyau correspondant à la superposition du premier sous-motif (15) et du deuxième sous-motif (15') par la valeur de noyau d'un point du champ étant

- égale à un si le point correspond à un coin d'un quelconque des carrés du premier sous-motif (15) et que la somme des première et deuxième coordonnées du coin est inférieure ou supérieure à chaque somme des

première et deuxième coordonnées des autres coins du même carré,
- égale à moins un si le point correspond à un coin d'un quelconque des carrés du premier sous-motif (15) et que la somme des première et deuxième coordonnées du coin n'est ni inférieure ni supérieure à chaque somme des première et deuxième coordonnées des autres coins du même carré,
- égale à moins un si le point correspond à un coin d'un quelconque des carrés du deuxième sous-motif (15') et que la somme des première et deuxième coordonnées du coin est inférieure ou supérieure à chaque somme des première et deuxième coordonnées des autres coins du même carré,
- égale à un si le point correspond à un coin d'un quelconque des carrés du deuxième sous-motif (15') et que la somme des première et deuxième coordonnées du coin n'est ni inférieure ni supérieure à chaque somme des première et deuxième coordonnées des autres coins du même carré et
- égale à zéro sinon.

15. Produit programme d'ordinateur comportant un programme d'ordinateur qui présente des moyens logiciels pour mettre en œuvre un procédé selon au moins l'une des revendications précédentes si le programme d'ordinateur est exécuté dans un dispositif informatique.

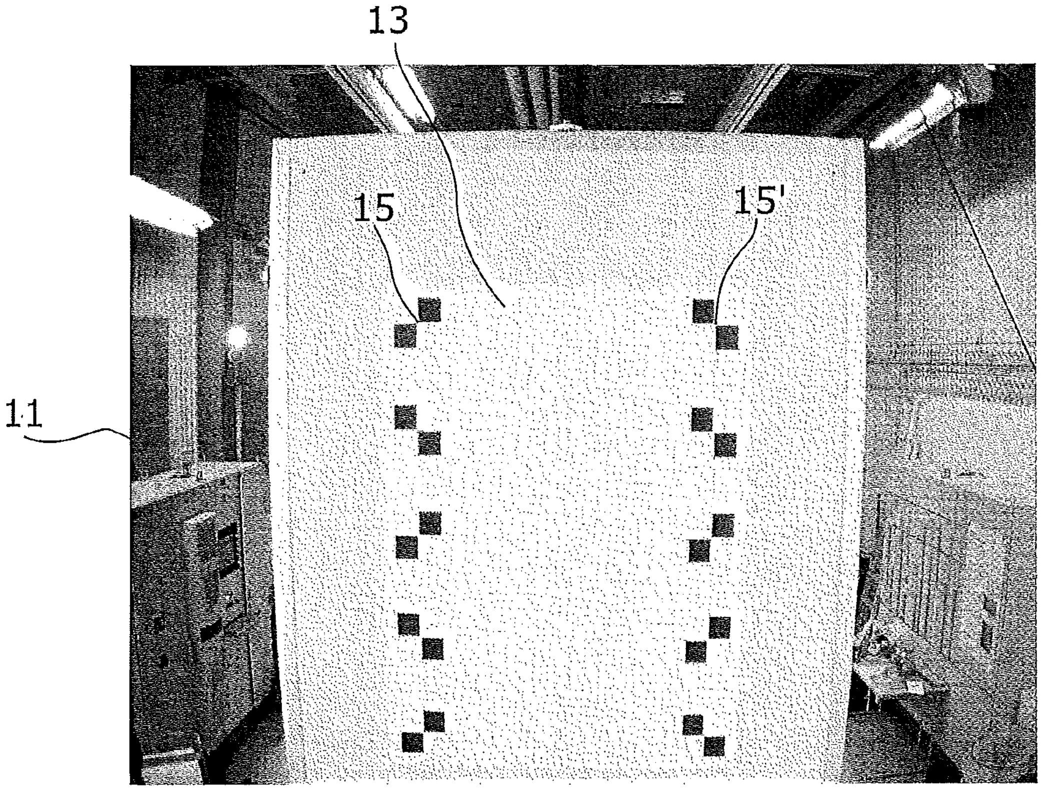

Fig. 1

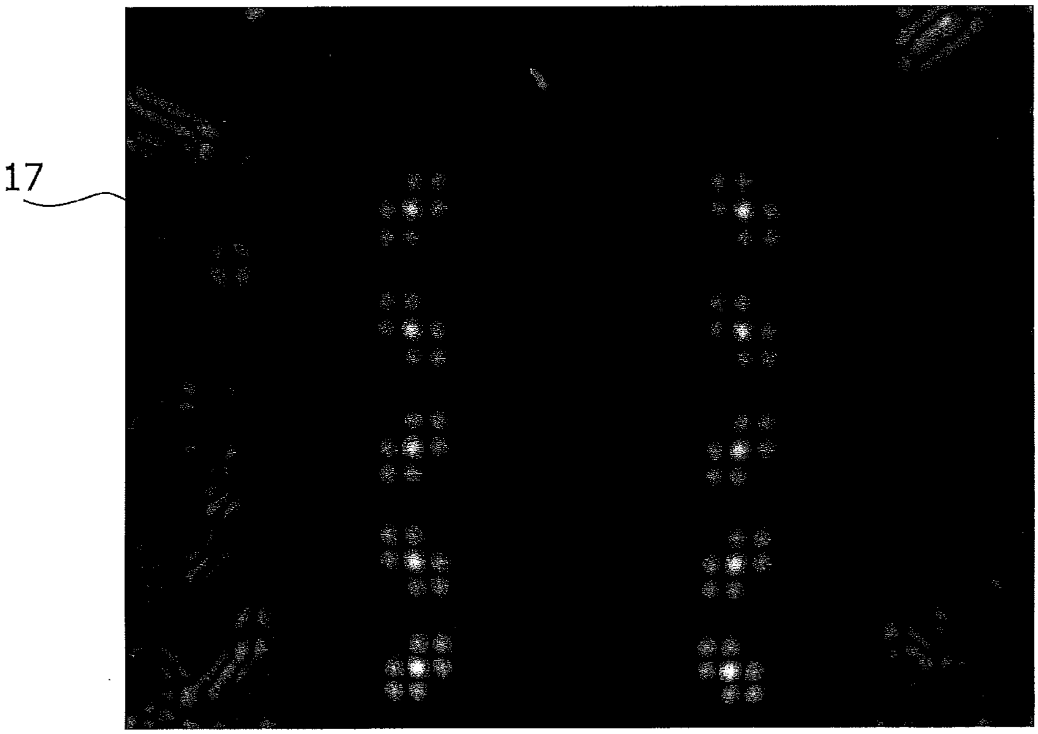

Fig. 2

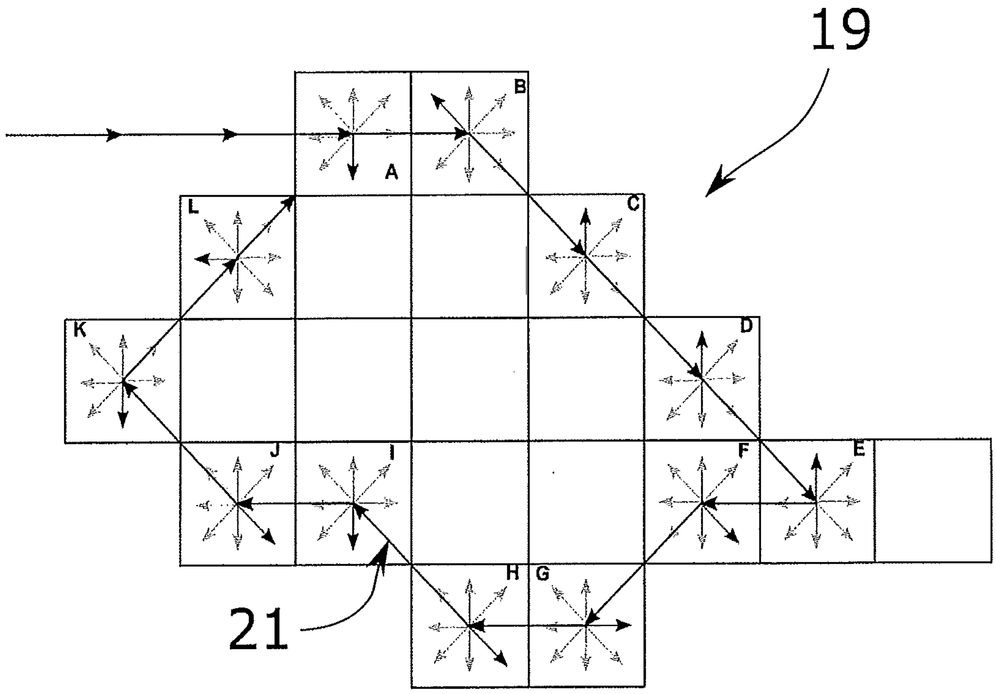

Fig. 3

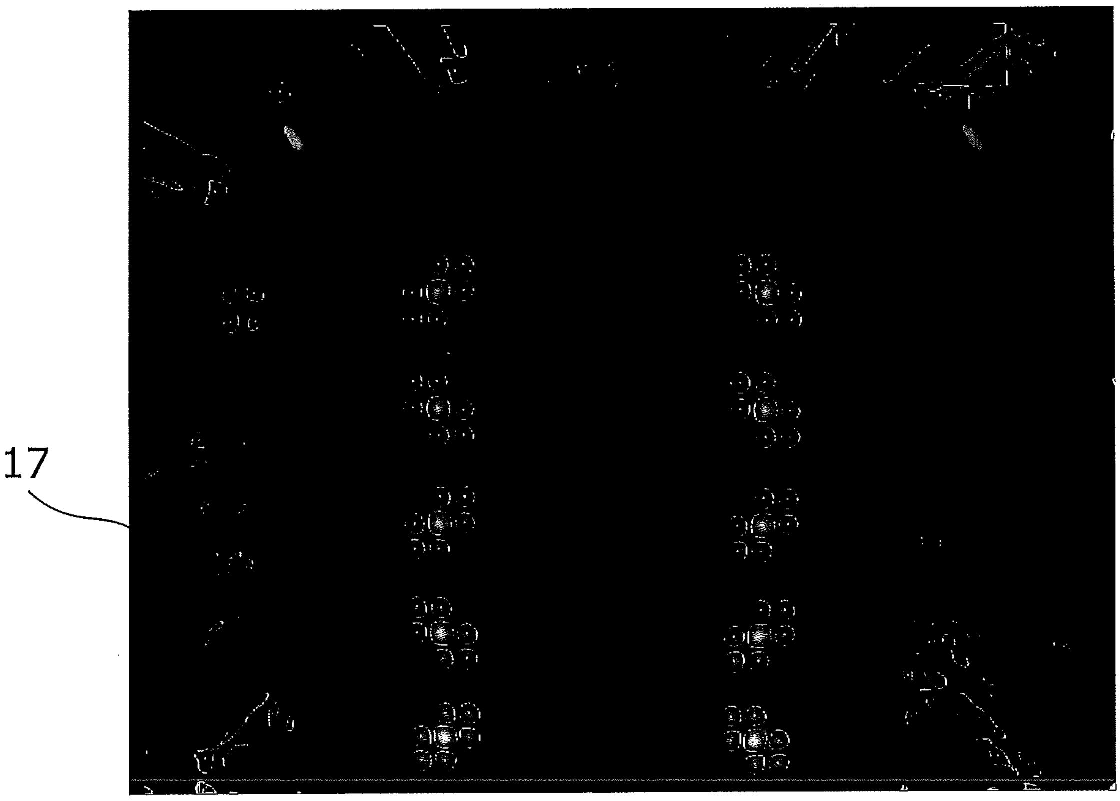

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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