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Image stitching method and device.

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The present invention is related to an image stitching method. It is further related to an image stitching device and to a computer readable medium carrying instructions for performing such method.

The method according to the invention comprises determining a pixel value of a pixel at an interpolation position in the region to be stitched using pixel values of corresponding pixels in a plurality of sub-images. According to the invention, the interpolation position corresponds to a weighted sum of positions of the corresponding pixels, wherein the weighting factor for the position of a corresponding pixel in a given sub-image depends on a relative distance of at least one of said corresponding pixel and said interpolation position to a border of the region to be stitched associated with that sub-image.

Image stitching method and device

The present invention is related to an image stitching method. It is further related to an image stitching device and to a computer readable medium carrying instructions for performing such method.

Methods are known in the art by which multiple images each covering a different part of a scene can be combined into one panoramic image. The angle of view of such image may reach up to 360 degrees, giving a user a full impression of the surroundings of a given viewpoint. For instance, applications are known wherein vehicle-mounted cameras are used to obtain information of the surroundings. Such information can be used in e.g. surveying and measurement tasks, remote work-planning and (public) asset management. Other applications of for instance sequential panoramic images or video include entertainment, e.g. 360 degree content for virtual reality viewing devices. Typically, a plurality of cameras is used, wherein the cameras are each directed in a different direction. The images obtained by these cameras must be combined into a panoramic image. This process comprises image stitching.

When creating a high-quality seamless panoramic image from multiple sub-images, one typically aims to minimize parallax errors. This improves the geometrical correctness of the result and reduces the visibility of stitching artefacts such as seams or ghosting. Parallax errors can be minimized by keeping the optical centre of the camera(s) recording the images on the same spatial position. In practice however, this is prevented by inaccurate alignment, e.g. when manually capturing without a tripod and panoramic rotator, physical restrictions, e.g. in getting the optical centre of multiple cameras to align, or multi-perspective requirements, e.g. some parallax may be required to construct a depth map or stereo views. To improve the quality of the panoramic image when (residual) parallax is present, algorithms are needed that minimize the visibility of artefacts.

Figure 1 illustrates the general stitching problem of combining two images 1, 2 into a single image. Hereinafter, the images that are to be stitched are referred to as sub-images, wherein the result of the stitching, e.g. the panoramic image, is referred to as final image.

Sub-images 1, 2 have been globally aligned and overlap in an overlapping region 3. After global alignment, the sub-images are normally no longer rotated or shifted with respect to each other when using these images to construct the final image. Global alignment is known in the art and comprises finding a suitable relative position and orientation of the sub-images based on corresponding features in the sub-images. Alternatively, the positioning or orientation can be determined using the geometrical relationship between the cameras responsible for obtaining the cameras or between the entrance pupils of those cameras or camera at the time of recording the sub-images.

Due to the global alignment, a reference frame can be introduced by means of which positions in the sub-images and final image can be expressed as vectors relative to a common origin O .

The final image has a shape that may correspond to the sum of the contours of sub-images 1, 2. To determine the content of this final image, three regions can be identified. In the first region I, the pixels of the final image are determined using pixels of only sub-image 1. In the second region II, the pixels of the final image are determined using pixels of only sub-image 2. In the third region III, the pixels of the final image are determined using pixels of both sub-image 1 and sub-image 2. This latter region, hereinafter referred to as the region to be stitched, may correspond to the overlapping region 3, but it may also be smaller or larger than this region.

In figure 1, vectors \mathbf{p}_1 and \mathbf{p}_2 indicate positions of corresponding pixels in sub-images 1 and 2, respectively. For instance, these vectors point to pixels that represent or are part of the same feature in both sub-images. Accordingly, these vectors point to pixels in the respective sub-images that are associated with features that appear in both sub-images. In case when parallax is absent, vector \mathbf{p}_1 and vector \mathbf{p}_2 should ideally coincide. It is noted that both vector \mathbf{p}_1 and vector \mathbf{p}_2 relate to a common origin denoted by O , and may refer to pixels that are outside of the overlapping region and/or region to be stitched.

Corresponding pixels in two or more sub-images can be found using techniques that are known in the art, such as optical flow, motion estimation, and/or (dense) (stereo) matching. In most techniques, not only the pixels themselves but also the surrounding pixels are examined to determine whether a pair or combination of pixels is found to constitute a pair or group of corresponding pixels.

The stitching problem can be summarized as how to determine the pixel values for the pixels in the region to be stitched, e.g. region III in figure 1. For instance, in figure 1 the pixel value of the pixel at a position corresponding to vector \mathbf{p}_i needs to be determined using the information from sub-images 1 and 2. In such case it is important to determine a) which pixels in sub-images 1, 2 should be used to determine the value of the pixel at \mathbf{p}_i , and b) if these pixels are known, how the pixel value at position \mathbf{p}_i is determined using the pixel values of these pixels.

A known technique for addressing this problem is known as alpha blending. In this technique the value of the pixel at position \mathbf{p}_i in the final image is determined using the pixel values at this same position in sub-images 1 and 2, i.e. $\mathbf{p}_i = \mathbf{p}_1 = \mathbf{p}_2$. A weighting factor may be used to impart more or less weight to a particular pixel value of a pixel in a given sub-image. A drawback of this known approach is that ghosting may occur in the final image.

In US5986668A and US6097854A a local alignment step is described as a de-ghosting method in which pairwise correspondences are used to calculate a warping to a (virtual) average position. This known method can handle n overlapping input images, warping each image to the

same average interpolation position, which removes the ghosting in the overlap region. However, as the overlap region is warped to an average interpolation position and the non-overlapping parts are not warped, this approach can yield visual artefacts on this boundary.

Further methods for stitching images have been disclosed in US7006709B2 and
 5 US2014307045A1.

It is an object of the present invention to provide a solution to the abovementioned stitching problem wherein the occurrence of artefacts is minimized.

This object is achieved with the method as defined in claim 1, which is characterized in that the interpolation position corresponds to a weighted sum of positions of the corresponding
 10 pixels, wherein the weighting factor for the position of a corresponding pixel in a given sub-image depends on a relative distance of at least one of said corresponding pixel and said interpolation position to a border of the region to be stitched associated with that sub-image.

According to the present invention, corresponding pixels are used to determine the pixel value of a pixel at the interpolation position in the final image. The invention further stipulates that
 15 the distance between each pixel among the corresponding pixels and the interpolation position depends on the relative distance of said each pixel to a border of the region to be stitched associated with that sub-image and/or on the relative distance of the interpolation position to a border of the region to be stitched associated with the sub-image corresponding to said each pixel.

The relative distance may correspond to a distance of at least one of said corresponding
 20 pixel and said interpolation position to a border of the region to be stitched associated with that sub-image relative to the sum of those relative distances for all sub-images. For example, the relative distance is given by:

Equation 1
$$\frac{d_i}{\sum_{n=1}^N d_n}$$

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wherein d_i is the distance of at least one of said corresponding pixel and said interpolation position to a border of the region to be stitched associated with sub-image i , and wherein N is the total number of sub-images.

The weighting factor for the position of a corresponding pixel in a given sub-image may
 30 equal the relative distance associated with that sub-image.

In an embodiment, the weighting factor decreases if the distance of the pixel or the interpolation position to the border decreases.

The distance to the border may generally be computed as the shortest distance to the border. Furthermore, the border may comprise an arbitrary curve or a collection of curves, which
 35 are connected to form a larger curve or contour.

The corresponding pixels in the plurality of sub-images may be pixels that relate to the same region or point of an object or feature that is imaged in the plurality of sub-images. For instance, the feature may comprise a house that is visible in each of the sub-images. However, the position of this house appears to be different after globally aligning the sub-images. Pixels may then be identified in each of the sub-images that relate to the same spot on the house. These pixels can be identified using known techniques such as motion estimation.

The border of the region to be stitched associated with a sub-image may correspond to an edge of that sub-image in the aligned plurality of sub-images. Here, the aligned plurality of sub-images may refer to an imaginary composite image of the plurality of sub-images. The edge of the sub-image refers to the edge of that sub-image that is present in the composite image. The region to be stitched may correspond to an entire region in which at least two or more sub-images are overlapping.

Alternatively, the region to be stitched could be centred about a curve through a region in said plurality of images in which at least two of said sub-images are overlapping. In this manner, the overlapping region may not be entirely used for stitching. In such case, the method may further comprise determining a correction benchmark using the differences in pixel values between the respective corresponding pixels for a plurality of pixels in the region to be stitched, comparing the correction benchmark to a predefined threshold, and if the correction benchmark exceeds the predefined threshold, extending the region to be stitched.

For instance, the region to be stitched comprises 100 pixels corresponding to 100 interpolation positions. The pixel values for these pixels are determined using two sub-images. For each pixel in the region to be stitched, two pixel values are available from the two sub-images by which a pixel value can be determined. When a large difference exists between these pixel values, it may be expected that a large parallax correction has occurred. In such case, it may be advantageous to use a broader region to be stitched. To that end, the differences for each of the 100 pixels may be combined into a single correction benchmark that can be compared to a threshold.

The method may additionally or alternatively comprise determining a displacement vector field in the region to be stitched that indicates a difference in position between corresponding pixels in different sub-images, and calculating the curve using the displacement vector field. Here, the displacement vector field is a vector field comprising vectors between corresponding pixels. The curve could for instance be calculated using a least cost optimization technique and/or wherein the curve is configured to avoid regions in which the displacement vectors are relatively large. Hence, the region to be stitched may be chosen such that it excludes regions in the global alignment of sub-images that are characterized by large differences in position between corresponding pixels. It may therefore exclude regions that comprise features indicative of a large parallax artefact. In such case, it may be advantageous to only use pixel information from one of

the sub-images to determine the pixels in the final image. It may be possible to vary, preferably gradually, the width of the region to be stitched, for instance depending on the magnitude of the displacement vectors.

The method may further comprise determining an interpolation position in the region to be stitched, and finding, preferably by means of optimization, the corresponding pixels of which the pixel values are to be used for determining the pixel value of the pixel at the determined interpolation position.

The finding of corresponding pixels may in this case comprise a) guessing a set of positions of the corresponding pixels, b) determining the weighting factors for the corresponding pixels, c) calculating an estimated interpolation position by applying the weighted sum of the guessed positions of the corresponding pixels, and d) determining an error between the estimated interpolation position and the determined interpolation position and repeating the steps a)-d) if the error exceeds a predefined threshold. Alternatively, the weighting factors may solely depend on the determined interpolation position. In this case, the method may further comprise calculating the weighting factors using the determined interpolation position. Alternatively, the method may comprise finding a set of corresponding pixels in the plurality of globally aligned sub-images, and determining, preferably by means of optimization, an interpolation position that corresponds to the weighted sum of the positions of the set of corresponding pixels.

The interpolation position may be determined using the steps of a) guessing an interpolation position, b) determining the weighting factors for the corresponding pixels, c) calculating an estimated interpolation position by applying the weighted sum of the positions of the corresponding pixels using the determined weighting factors, and d) determining an error between the estimated interpolation position and the guessed interpolation position, and repeating steps a)-d) if the error exceeds a predefined threshold. Alternatively, the weighting factors may solely depend on the positions of the corresponding pixels. In this case, the method may further comprise calculating the weighting factors using the determined positions of the corresponding pixels.

The pixel value of the pixel at the interpolation position in the region to be stitched may be determined by weighting the pixel values of the corresponding pixels associated with that interpolation position. Such weighting may comprise applying further weighting factors to the pixel values of the corresponding pixels. These weighting factors may be chosen such that weighting factors, which are applied to pixels among the corresponding pixels that lie far from the border, are relatively large. This reflects the notion that pixels that lie far away from the border may be more appropriate candidates for stitching than pixels that lie close to the border. This allows a gradual transition from one image to the other. In a preferred embodiment, these further weighting factors are identical to the weighting factors.

According to a second aspect, the present invention provides a device for stitching a plurality of globally aligned sub-images in a region to be stitched, which comprises a memory for holding said plurality of sub-images, a stitching region determining unit to determine the region to be stitched, and a processor configured to construct a final image using the plurality of sub-images, said constructing comprising performing the method as defined in any of the previous claims to
 5 stitch the sub-images in the region to be stitched.

According to a third aspect, the present invention provides a computer readable medium comprising instructions that, when run on a processor, instruct this processor to perform the method as described above.

10 Next, the present invention will be described in more detail referring to the appended drawings, wherein:

Figure 1 illustrates the problem of image stitching;

Figure 2 illustrates the general concept of the present invention using two sub-images;

Figure 3 illustrates different regions to be stitched when three sub-images overlap;

15 Figure 4 illustrates a region to be stitched based on a curve;

Figure 5 illustrates a region to be stitched based on a displacement vector field;

Figure 6 illustrates a first method to perform the image stitching according to the present invention;

20 Figure 7 illustrates a second method to perform the image stitching according to the present invention; and

Figure 8 illustrates an embodiment of a device according to the present invention.

Figure 2 illustrates the general concept of the present invention in case two sub-images need to be stitched. The pixel value at an interpolation position \mathbf{p}_i in the final image needs to be determined using sub-images 1, 2. Vectors \mathbf{V}_{i1} and \mathbf{V}_{i2} point to corresponding pixels in sub-images
 25 1 and 2, respectively, which pixels are used to determine the pixel value of the pixel at interpolation position \mathbf{p}_i in the final image. Hence:

$$\begin{aligned} \text{Equation 2} \quad \mathbf{p}_1 &= \mathbf{p}_i + \mathbf{V}_{i1} \\ \mathbf{p}_2 &= \mathbf{p}_i + \mathbf{V}_{i2} \end{aligned}$$

30

According to the present invention, the distance between each of the corresponding pixels and the interpolation position depends on:

a distance from the interpolation position to a respective border associated with a respective sub-image (distance method 1);

35 a distance from each of the corresponding pixels to a respective border associated with the respective sub-image (distance method 2);

a mixture of these distances (distance method 3).

The distances indicated under methods 1 and 2 above are illustrated on the right hand side of figure 2. Here, d_n indicates a distance from the corresponding pixel with position \mathbf{p}_n to the border B_n associated with sub-image n. On the other hand, d_n' indicates a distance from the interpolation position with position \mathbf{p}_i to the border B_n associated with sub-image n.

Hereinafter, the distance that is used during the stitching is referred to as d_n , regardless the distance method used. In this case, the general concept of the present invention, when applied to two sub-images, can be described by the following equation:

$$\text{Equation 3} \quad \left| \frac{\mathbf{V}_{i1}}{d_2} \right| = \left| \frac{\mathbf{V}_{i2}}{d_1} \right|$$

In other words, when distance d_1 increases, the corresponding vector \mathbf{V}_{i1} will decrease in length. Ultimately, when d_1 becomes zero, e.g. when a corresponding pixel lies on the border B_1 (distance method 2), \mathbf{V}_{i2} becomes zero. The latter indicates that the interpolation position \mathbf{p}_i corresponds to the position of the corresponding pixel in sub-image 2, i.e. \mathbf{p}_2 .

Figure 2 on the left hand side illustrates a distance d_1 from a corresponding pixel at position \mathbf{p}_1 in sub-image 1 to the border of this sub-image, which border is indicated by the dashed line. Here it is noted that in figure 2 the region to be stitched comprises the entire region in which sub-images 1, 2 are overlapping.

Assuming that vectors \mathbf{V}_{i1} and \mathbf{V}_{i2} are oppositely arranged, i.e. $d_1\mathbf{V}_{i1} = -d_2\mathbf{V}_{i2}$, Equation 2 and Equation 3 can be combined into:

$$\text{Equation 4} \quad \mathbf{p}_i = w_1 \cdot \mathbf{p}_1 + w_2 \cdot \mathbf{p}_2$$

wherein w_1 and w_2 are weighting factors given by:

$$\text{Equation 5} \quad w_1 = \frac{d_1}{d_1 + d_2}$$

$$\text{Equation 6} \quad w_2 = \frac{d_2}{d_1 + d_2}$$

where it is noted that the weighting factors may depend on the interpolation position (e.g. distance method 1) and/or on the positions of the corresponding pixels (e.g. distance method 2). Hence, according to the present invention, the interpolation position corresponds to a sum of weighted positions of the corresponding pixels that are used to determine the pixel value of the pixel at the interpolation position, wherein the weighting factor for the position of each corresponding pixel depends on the relative distance of at least one of the corresponding pixel and

the interpolation position to a border of the region to be stitched associated with that sub-image. This concept can easily be generalized for N overlapping images into:

$$\text{Equation 7} \quad \mathbf{p}_i = \sum_{n=1}^N w_n \cdot \mathbf{p}_n$$

5

wherein

$$\text{Equation 8} \quad w_i = \frac{d_i}{\sum_{n=1}^N d_n}$$

10

If a combination of corresponding pixels \mathbf{p}_n and interpolation position \mathbf{p}_i is found that satisfies Equation 7, than those corresponding pixels can be used to determine the pixel value of the pixel at that interpolation position.

Figure 3 illustrates the situation wherein three sub-images 1, 2, 4 show partial overlap. The following table shows which sub-images are overlapping in which region after global alignment.

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Region	Sub-images
I	1
II	2
III	1+2
IV	1+2+4
V	1+4
VI	2+4
VII	4

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Sub-image 1 is relevant to four different regions. In region I, the weighting factors for pixels in sub-image 1 can be set to 1 as the other sub-images do not contain image information for that position. In region III, the weighting factors for pixels in sub-images 1 and 2 are determined by comparing the distance from those pixels and/or the interpolation position to the border associated with sub-image 1 and to the border associated with sub-image 2, respectively. For region IV, three sub-images are taken into account. If a corresponding pixel in a given sub-image is found that is outside of the relevant region to be stitched, the associated weighting factor can be set to zero. For instance, pixel position 5 in sub-image 4 is associated with a weighting factor equal to zero when this position indicates a pixel that corresponds to another pixel in sub-image 1 or 2 when trying to interpolate inside region IV.

25

In addition to using the full overlapping region, bounded regions can be used. In such case, only a limited region can be used in which image stitching is applied. Such region can for instance be defined around a centre line or curve \mathcal{C} in the overlapping region, as shown in figure 4. Here, weighting factors for sub-image 1 in region A are set to one and in region C to zero. In region B, the weighting factors depend on the distance to the border associated with sub-image 1.

Figure 4 illustrates a straight line \mathcal{C} as an example of a curve. However, the invention is not limited thereto.

Alternative methods exist to define the region to be stitched. For instance, the region to be stitched may be formed based on a displacement vector field, as illustrated in figure 5. Here, a displacement vector indicates the vector from a pixel in a given sub-image to a corresponding pixel in another sub-image. A curve \mathcal{C} may be found through this field based on a least cost approach wherein the sum of the displacements of the pixels crossed by the curve, or crossed by the curve and a certain region, is minimized. Once this curve is found, a certain region surrounding the curve can be used to perform the image stitching. Additionally or alternatively, the construction of the region to be stitched can be performed adaptively. For instance, for a given starting region the average amount of correction per pixel can be computed. Such correction can be computed using the difference between the pixel values of the corresponding pixels in the different sub-images. If the average correction per pixel is too high, the region to be stitched can be expanded and the image stitching process can be repeated.

To find a combination of corresponding pixels $\mathbf{p}_1.. \mathbf{p}_n$ and interpolation position \mathbf{p}_i that satisfies Equation 7, two different methods will be discussed. In the second method, the interpolation position is chosen and the corresponding pixels that should be used for that interpolation position are sought, whereas in the first method, the corresponding pixels are first determined after which an interpolation position is sought.

An advantage of first determining the interpolation position \mathbf{p}_i (second method), is that \mathbf{p}_i can be chosen to align with the regular pixel grid of the composite image one wants to create, i.e. every integer pixel position in the stitch region of the composite image. Its corresponding pixel positions $\mathbf{p}_1.. \mathbf{p}_n$ are real valued when using subpixel accurate matching techniques to derive the correspondences. One can use known sampling/interpolation techniques, e.g. bi-linear, bi-cubic, or Lanczos sampling, to fetch the pixel or vector values in images 1..n based on these real valued position vectors. This method resembles inverse warping.

If one first determines $\mathbf{p}_1.. \mathbf{p}_n$ and then derives a real valued position \mathbf{p}_i (first method), the latter might not be aligned with the pixel grid of the composite image. To get alignment with the regular grid of the composite image, one can use forward warping (or “splating”) techniques. E.g. calculating for each pixel or vector at a real valued position \mathbf{p}_i its (distance) weighted contributions to the surrounding regular/integer grid pixels or vectors. This is usually done in a contribution pass,

where a separate weight map is kept, and a normalization pass where the weights are used to normalize the values in the regular grid.

In both methods known techniques are used to find corresponding pixels. In the following section an important aspect of these techniques is detailed, namely the originating position.

5 Following this explanation the two methods are further detailed.

Finding correspondences

10 Techniques to find dense pixel correspondences such as motion estimation, optical flow estimation and (stereo) disparity estimation typically yield their result in the form of a vector field containing a displacement vector for each pixel or block of pixels. For instance, a full search block matching motion estimation technique can be used to test (for each pixel or block of pixels) all possible displacement vectors by means of block correlation and assign the vector with the best correlation value.

15 In practice, a lot of techniques are based on more refined (and faster) optimization and combine a matching term (e.g. pixel/block/feature correlation, gradient constraint equations) with extra terms/constraints, such as a smoothness term that prevents the vector from deviating too much from vectors estimated at neighboring positions.

20 When applying these techniques, it is important to consider the “position” the vectors or the vector field originate(s) at. For example, it is possible to estimate a displacement vector field \mathbf{vf}_{12} valid at the “position” of image 1, containing for a pixel position \mathbf{p}_1 the displacement vector to a matching pixel position \mathbf{p}_2 in image 2 in accordance with Equation 9. Image 1 and 2 are assumed to be overlapping images with the same coordinate system.

25 Equation 9
$$\mathbf{p}_2 = \mathbf{p}_1 + \mathbf{v}_{12} = \mathbf{p}_1 + \mathbf{vf}_{12}(\mathbf{p}_1)$$

Similarly, it is possible to estimate a vector field originating at the “position” of image b in accordance with Equation 10.

30 Equation 10
$$\mathbf{p}_1 = \mathbf{p}_2 + \mathbf{v}_{21} = \mathbf{p}_2 + \mathbf{vf}_{21}(\mathbf{p}_2)$$

With some techniques, it is also possible to estimate a vector field originating at an “in-between” virtual image position x . For example in the middle of images 1 and 2:

35 Equation 11
$$\mathbf{p}_1 = \mathbf{p}_x + 0.5 * \mathbf{v}_x = \mathbf{p}_x + 0.5 * \mathbf{vf}_x(\mathbf{p}_x)$$

Equation 12
$$\mathbf{p}_2 = \mathbf{p}_x - 0.5 * \mathbf{v}_x = \mathbf{p}_x - 0.5 * \mathbf{vf}_x(\mathbf{p}_x)$$

Or at an arbitrary virtual image position γ , where γ lies between zero and one (indicating the position between image a and b):

$$\begin{aligned} \text{Equation 13} \quad & \mathbf{p}_1 = \mathbf{p}_x + \gamma * \mathbf{v}_x = \mathbf{p}_x + \gamma * \mathbf{vf}_x(\mathbf{p}_x) \\ \text{Equation 14} \quad & \mathbf{p}_2 = \mathbf{p}_x + (1 - \gamma) * \mathbf{v}_x = \mathbf{p}_x + (1 - \gamma) * \mathbf{vf}_x(\mathbf{p}_x) \end{aligned}$$

For a block matching motion estimator, the above equations can be used to derive for a displacement vector being tested, the set of positions on which the block correlation has to be applied. The test vectors “pivot” around the position \mathbf{p}_x .

In general, vector fields estimated at different originating image positions γ contain the same vector values but at shifted spatial positions. In practice they can differ somewhat due to numerical, occlusion and other (estimation) effects such as ill-posed conditions.

Alternatively or additionally, the forward warping technique discussed in conjunction with the first method can be used to “project” a vector field to a different originating position. Due to occlusion effects holes and overlaps can occur in this projection, this effect can be targeted with known occlusion handling techniques.

The first method; distance method 1

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In a variant of the first method, illustrated in figure 6A, the first distance method is used. Consequently, direct computation of the interpolation position is not possible due to the fact that the required weighting factors depend on the unknown interpolation position. In this case, the interpolation position \mathbf{p}_i can be found by optimization using Equation 15:

25

$$\text{Equation 15} \quad \min_{\mathbf{p}_i} \left| \mathbf{p}_i - \sum_{n=1}^N w_n \cdot \mathbf{p}_n \right|$$

In detail, after determining the corresponding pixels in step S60, the interpolation position can be found by first guessing an interpolation position in step S61. Next, in step S62 the weighting factors are determined. In step S63, an estimated interpolation position can be found by applying Equation 7 using the determined weighting factors and the corresponding pixels that were already found. In step S64, this estimated interpolation position is compared to the guessed interpolation position. The resulting error is compared to a threshold in step S65. If the error is above a certain threshold, the process returns to guessing the interpolation position.

35

For three sub-images 1-3, Equation 15 can be re-written as:

Equation 16
$$\min_{\mathbf{p}_i} |\mathbf{p}_i - \mathbf{p}_1 - w_2 \cdot \mathbf{V}_{12} - w_3 \cdot \mathbf{V}_{13}|$$

wherein \mathbf{p}_1 , \mathbf{V}_{12} , and \mathbf{V}_{13} are known as these parameters relate to corresponding pixels, which in the first method have already been found. Depending on the distance method used, weighting factors w_2 and w_3 are already known (distance method 2) and the interpolation position can be calculated directly, or the weighting factors depend on the interpolation position (distance methods 1 and 3) and the interpolation position is computed by optimization. A generic optimization algorithm, such as stochastic hill climbing, can be used to find the best solution for \mathbf{p}_i .

For two sub-images 1 and 2, Equation 15 reduces to:

Equation 17
$$\min_{\mathbf{p}_i} |\mathbf{p}_i - \mathbf{p}_1 - w_2 \cdot \mathbf{V}_{12}|$$

Optimization of this equation, when required if distance method 1 or 3 is used, is generally performed along the line from \mathbf{p}_1 to \mathbf{p}_2 .

The first method is well suited, but not limited to, finding the corresponding pixels by means of estimating the pairwise vector fields (e.g. \mathbf{vf}_{12} , \mathbf{vf}_{21} in the previous section).

In the first method, the calculated interpolation position may be off grid. In such case, a pixel value can nevertheless be computed. A distance weighting can be used to determine how the pixels in the final image surrounding the off grid interpolation position are influenced by this pixel value.

The first method; distance method 2

In a variant of the first method, illustrated in figure 6B, corresponding pixels are found using known techniques in step S66. In figure 6B, distance method 2 is used so the weighting factors can be calculated directly in step S67, after which the interpolation position can be calculated in step S68 using Equation 7.

The second method; distance method 1

In the second method, the interpolation position is determined and the corresponding pixels are sought, such that Equation 7 is satisfied. The weighted positions of the corresponding pixels should be equal to the interpolation position. Equivalently, by Equation 2, the vectors $\mathbf{v}_{i1} \dots \mathbf{v}_{in}$, are sought that satisfy Equation 7.

In a variant of the second method, distance method 1 is used as shown in figure 7A. In this case, the weighting factors can be computed directly in step S71 after determining the interpolation position in S70. The corresponding pixels are determined thereafter in step S72.

The second method is well suited, but not limited to, finding the corresponding pixels by motion estimation with the interpolation position as originating position (e.g. by determining \mathbf{v}_{i1} , \mathbf{v}_{i2} , \mathbf{v}_{i3}). In this case, the estimation follows the same symmetry principle as the “in-between” estimation explained earlier in connection with Equations 11-14. The “pivot” point is based on Equation 7 and can be generalized for N images. More in particular, Equation 7 can be used to express the position \mathbf{p}_j of corresponding pixel j in the interpolation position \mathbf{p}_i and the positions \mathbf{p}_n of the other corresponding pixels:

$$\text{Equation 18} \quad \mathbf{v}_{in} = \mathbf{p}_n - \mathbf{p}_i = \sum_{m=1, m \neq n}^M w_m \cdot \mathbf{p}_m + (1 - w_n) \cdot \mathbf{p}_n$$

For three images, Equation 18 can be re-written into:

$$\text{Equation 19} \quad \mathbf{v}_{i1} = (1 - w_1)\mathbf{p}_1 + w_2\mathbf{p}_2 + w_3\mathbf{p}_3$$

$$\text{Equation 20} \quad \mathbf{v}_{i2} = w_1\mathbf{p}_1 + (1 - w_2)\mathbf{p}_2 + w_3\mathbf{p}_3$$

$$\text{Equation 21} \quad \mathbf{v}_{i3} = w_1\mathbf{p}_1 + w_2\mathbf{p}_2 + (1 - w_3)\mathbf{p}_3$$

where \mathbf{v}_{in} are test vectors that originate at the interpolation position \mathbf{p}_i . To find suitable test vectors to initiate a search, it may be advantageous to use information from an interpolation at an adjacent interpolation position \mathbf{p}_i' that used the position vectors \mathbf{p}_1' , \mathbf{p}_2' , \mathbf{p}_3' . These vectors point to known corresponding pixels. The weighting for interpolation position \mathbf{p}_i can be applied to these vectors to find vectors \mathbf{v}_{in}' :

$$\text{Equation 22} \quad \mathbf{v}_{in}' = \sum_{m=1, m \neq n}^M w_m \cdot \mathbf{p}_m' + (1 - w_n) \cdot \mathbf{p}_n'$$

Next, vectors \mathbf{v}_{ij}' are translated to interpolation position \mathbf{p}_i to find suitable test position vectors:

$$\text{Equation 23} \quad \mathbf{p}_n = \mathbf{p}_i + \mathbf{v}_{in}'$$

Thereafter, variations can be applied to these test position vectors to search for the best matching set of corresponding pixels (or blocks) for which the weighted sum of the position vectors corresponds to interpolation position

The second method; distance method 2

In a variant of the second method, distance method 2 is used as illustrated in figure 7B. The interpolation position is determined in step S73 and the corresponding pixels must be found. In this case, Equation 7 equally applies. However, in this case the positions of the corresponding pixels are guessed in step S74.

As a next step, the weighting factors are determined in step S75. Because distance method 2 is used, the weighting factors can only be calculated after guessing the corresponding pixels. Next, an estimated interpolation position is calculated based on the guessed positions of the corresponding pixels and the determined weighting factors in step S76. In step S77, this estimated interpolation position is compared to the interpolation position that was determined in step S73. The resulting error is compared to a threshold in step S78. If the error is above a certain threshold, the process returns to guessing the positions of the corresponding pixels.

For all methods described above, wherein an optimization step is used, such as guessing vectors or positions, it may be beneficial to use a previous combination of an interpolation position and corresponding pixels, preferably relating to an adjacent interpolation position, as a starting point for the optimization process.

In the examples above, methods have been described to interpolate between more than two images simultaneously. Alternatively, the interpolation process could be performed by cascading a two image interpolation process. For instance, assume that 4 images need to be combined into a single image. As a first step, a first intermediate image can be constructed by interpolating between the first and second image. Next, a second intermediate image can be constructed by interpolating between the first intermediate image and the third image. The final image can then be constructed by interpolating between the second intermediate image and the fourth image

Pixel value determination at the interpolation position

The process of finding a combination of interpolation position and corresponding pixels as described above has to be repeated for each position in the region to be stitched. Once the combination of interpolation position and corresponding pixels is known the pixel values of the final image can be computed. To this end, a weighting using further weighting factors v_n may be used:

$$I(\mathbf{p}_i) = \sum_{n=1}^N v_n \cdot I_n(\mathbf{p}_n)$$

wherein I_n is the pixel value of sub-image n at position \mathbf{p}_n . As an example, the weighting factors w_n mentioned above may be used as further weighting factors, i.e. $v_n = w_n$. Alternatively, the further weighting factors may be determined using a given distance method that is different from the distance method used for determining the weighting factors w_n .

5 It should be noted that the pixel value may relate to an intensity value, and/or a colour channel value such as a RGB value. Furthermore, in case more than one pixel value exists for each pixel, the stitching method described here can be applied to each pixel value separately. However, it is preferred to determine a suitable combination of interpolation position and corresponding pixels for one pixel value, such as the intensity, and to use this same combination to determine the
10 other pixel values.

Figure 8 illustrates an embodiment of a device 100 according to the present invention. It comprises a memory 101 for holding a plurality of sub-images and a stitching region 102 determining unit to determine the region to be stitched. Device 100 also comprises a processor 103 configured to construct a final image using the plurality of sub-images, said constructing
15 comprising performing the method as defined above to stitch the sub-images in the region to be stitched. Additionally, processor 103 may also be configured to perform global alignment on the stored sub-images. The result of this global alignment and/or the final image resulting from the stitching may also be stored in memory 101.

Although the present invention has been described using embodiments thereof, it should be
20 apparent to the skilled person that various modifications to those embodiments are possible without deviating from the scope of the invention which is defined by the appended claims.

As an example, the present invention is related to interpolating images that have been globally aligned. Within the context of the present invention, global alignment comprises a first alignment of the images. This alignment may comprise a coordinate transformation to transform
25 the coordinates of the raw images to the coordinates of the final image. For instance, two images each having 3000 x 2000 pixels, may be combined into a single image comprising 5500 x 2000 pixels. In this case, the pixels of the first image, corresponding to a left part, may not be transformed. The pixels of the second image, corresponding to a right part, may be transformed by using the translation (2500, 0). Accordingly, a region of overlap will be generated that extends
30 between (2500, 0) – (3000, 2000).

In the description above, references have been made to position vectors of corresponding pixels that are relative to an origin that is common for all the images to be stitched. It should be apparent to the skilled person that these vectors can also be expressed in the coordinates of the underlying raw images in combination with the transformation related to that image. In the
35 example above, a vector pointing to position (500, 0) relative to the origin of the raw second image is identical to a vector pointing at a pixel of the second image at position (3000, 0) relative to the

common origin of the first and second image after the transformation associated with global alignment.

CONCLUSIES

1. Werkwijze voor het stikken van een veelvoud aan globaal uitgelijnde sub-afbeeldingen in een te stikken gebied, de werkwijze omvattende:

5 het bepalen van een pixelwaarde van een pixel op een interpolatiepositie in het te stikken gebied met gebruik van pixelwaardes van corresponderende pixels in het genoemde veelvoud aan sub-afbeeldingen;

met het kenmerk dat

10 de interpolatiepositie overeenkomt met een gewogen som van posities van de corresponderende pixels, waarbij de weegfactor voor de positie van een corresponderende pixel in een gegeven sub-afbeelding afhangt van een relatieve afstand van ten minste één van de genoemde corresponderende pixel en de genoemde interpolatiepositie tot een grens van het te stikken gebied welke geassocieerd is met die sub-afbeelding.

15 2. Werkwijze volgens conclusie 1, waarbij de genoemde relatieve afstand overeenkomt met een afstand van ten minste één van de genoemde corresponderende pixel en de genoemde interpolatiepositie tot een grens van het te stikken gebied welke geassocieerd is met die sub-afbeelding, relatief tot de som van die afstanden voor alle sub-afbeeldingen.

20 3. Werkwijze volgens conclusie 2, waarbij de relatieve afstand gegeven wordt door:

$$\frac{d_i}{\sum_{n=1}^N d_n}$$

25 waarbij d_i de afstand is van ten minste één van de genoemde corresponderende pixel en de genoemde interpolatiepositie tot een grens van het te stikken gebied welke geassocieerd is met sub-afbeelding i , en waarbij N het totale aantal sub-afbeeldingen is.

30 4. Werkwijze volgens een van de voorgaande conclusies, waarbij de weegfactor voor de positie van een corresponderende pixel in een gegeven sub-afbeelding gelijk is aan de relatieve afstand welke geassocieerd is met die sub-afbeelding.

5. Werkwijze volgens een van de voorgaande conclusies, waarbij de weegfactor afneemt als de afstand van de genoemde pixel of de genoemde interpolatiepositie tot de grens afneemt.

6. Werkwijze volgens een van de voorgaande conclusies, waarbij de genoemde afstand de kortste afstand tot de grens is.

5 7. Werkwijze volgens een van de voorgaande conclusies, waarbij de corresponderende pixels in het veelvoud aan sub-afbeeldingen pixels zijn welke betrekking hebben op hetzelfde gebied of punt van een object of kenmerk welke afgebeeld wordt in het veelvoud aan sub-afbeeldingen.

10 8. Werkwijze volgens conclusie 7, verder omvattende het gebruiken van een bewegingsschattingstechniek om corresponderende pixels te vinden in het genoemde veelvoud aan sub-afbeeldingen, of een techniek om dichte correspondenties te vinden, zoals bewegingsschatting, optische stroomschatting en/of stereo-dispariteitschatting.

15 9. Werkwijze volgens een van de voorgaande conclusies, waarbij de grens van het te stikken gebied welke geassocieerd is met een sub-afbeelding overeenkomt met een rand van die sub-afbeelding in het uitgelijnde veelvoud aan sub-afbeeldingen.

20 10. Werkwijze volgens conclusie 9, waarbij het te stikken gebied overeenkomt met een geheel gebied waarin ten minste twee of meer sub-afbeeldingen overlappen.

11. Werkwijze volgens een van de conclusies 1-9, waarbij het te stikken gebied een gebied is welke gecentreerd is rond een kromme door een gebied in het genoemde veelvoud aan afbeeldingen waarin ten minste twee van de genoemde sub-afbeeldingen overlappen.

25 12. Werkwijze volgens conclusie 11, verder omvattende het bepalen van een correctie-benchmark met gebruik van de verschillen in pixelwaarden tussen de respectievelijke corresponderende pixels voor een veelvoud aan pixels in het te stikken gebied;

30 het vergelijken van de correctie-benchmark met een vooraf gedefinieerde drempel; als het correctie-ijkpunt de drempel overschrijdt, het uitbreiden van het te stikken gebied.

35 13. Werkwijze volgens conclusie 11 of 12, verder omvattende: het bepalen van een verplaatsingsvectorveld in het te stikken gebied welke een verschil aangeeft in positie tussen corresponderende pixels in verschillende sub-afbeeldingen; het berekenen van de kromme met gebruik van het verplaatsingsvectorveld.

14. Werkwijze volgens conclusie 13, waarbij de kromme berekend wordt met gebruik van een minste kosten optimalisatietechniek.

5 15. Werkwijze volgens conclusie 14, waarbij de kromme ingericht is om gebieden te vermijden waarin verplaatsingsvectoren relatief groot zijn.

16. Werkwijze volgens een van de voorgaande conclusies, omvattende:
 het bepalen van een interpolatiepositie in het te stikken gebied;
 het vinden, bij voorkeur door middel van optimalisatie, van de corresponderende pixels
 10 waarvan de pixelwaardes gebruikt dienen te worden voor het bepalen van de pixelwaarde van de pixel bij de bepaalde interpositiepositie.

17. Werkwijze volgens conclusie 16, waarbij het genoemde vinden omvat:
 a) het raden van een set posities van corresponderende pixels;
 15 b) het bepalen van de weegfactoren voor de corresponderende pixels;
 c) het berekenen van een geschatte interpolatiepositie door het toepassen van de gewogen som van de geraden posities van de corresponderende pixels;
 d) het bepalen van een fout tussen de geschatte interpolatiepositie en de bepaalde interpolatiepositie en het herhalen van stappen a)-d) als de fout een vooraf gedefinieerde drempel
 20 overschrijdt.

18. Werkwijze volgens conclusie 16, waarbij de weegfactoren alleen afhangen van de bepaalde interpolatiepositie, de werkwijze verder omvattende het berekenen van de weegfactoren met gebruik van de bepaalde interpolatiepositie.
 25

19. Werkwijze volgens een van de voorgaande conclusies, omvattende:
 het vinden van een set corresponderende pixels in het veelvoud aan globaal uitgelijnde sub-afbeeldingen;
 het bepalen, bij voorkeur door middel van optimalisatie, van een interpolatiepositie welke
 30 overeenkomt met de gewogen som van de posities van de set corresponderende pixels.

20. Werkwijze volgens conclusie 19, waarbij het genoemde bepalen omvat:
 a) het raden van een interpolatiepositie;
 b) het bepalen van weegfactoren voor de corresponderende pixels;

c) het berekenen van een geschatte interpolatiepositie door het toepassen van de gewogen som van de posities van de corresponderende pixels met gebruik van de bepaalde weegfactoren;

5 d) het bepalen van een fout tussen de geschatte interpolatiepositie en de geraden interpolatiepositie en het herhalen van stappen a)-d) als de fout een vooraf gedefinieerde drempel overschrijdt.

10 21. Werkwijze volgens conclusie 19, waarbij de weegfactoren alleen afhangen van de posities van de corresponderende pixels, de werkwijze verder omvattende het berekenen van de weegfactoren met gebruik van de bepaalde posities van de corresponderende pixels.

15 22. Werkwijze volgens een van de voorgaande conclusies, verder omvattende het bepalen van een pixelwaarde van de pixel bij de interpolatiepositie in het te stikken gebied door het wegen van de pixelwaarden van de corresponderende pixels welke geassocieerd zijn met die interpolatiepositie met gebruik van verdere weegfactoren.

23. Werkwijze volgens conclusie 22, waarbij de verdere weegfactoren identiek zijn aan de weegfactoren.

20 24. Inrichting voor het stikken van een veelvoud aan globaal uitgelijnde sub-afbeeldingen in een te stikken gebied, omvattende:

een geheugen voor het bewaren van het genoemde veelvoud aan sub-afbeeldingen;

een stikgebiedbepalingseenheid voor het bepalen van het te stikken gebied; en

25 een verwerkingseenheid ingericht voor het construeren van een eindafbeelding met gebruik van het veelvoud aan sub-afbeeldingen, waarbij het construeren het uitvoeren omvat van de werkwijze volgens een van de voorgaande conclusies voor het stikken van de sub-afbeeldingen in het te stikken gebied.

30 25. Door de computer te lezen opslagmedium omvattende instructies welke, wanneer uitgevoerd door een verwerkingseenheid, deze verwerkingseenheid instrueren om de werkwijze volgens een van de conclusies 1-23 uit te voeren.

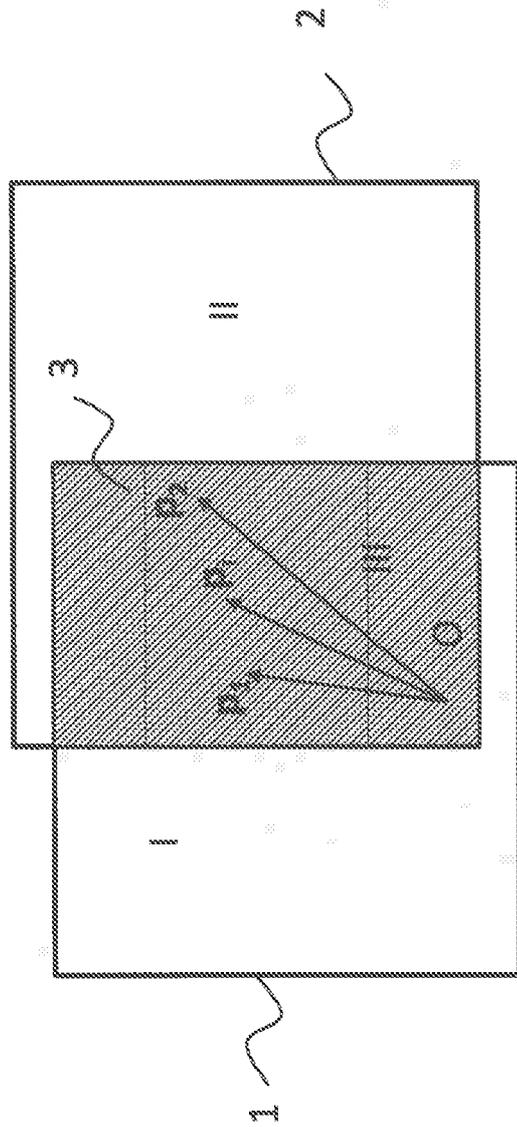


FIG.1

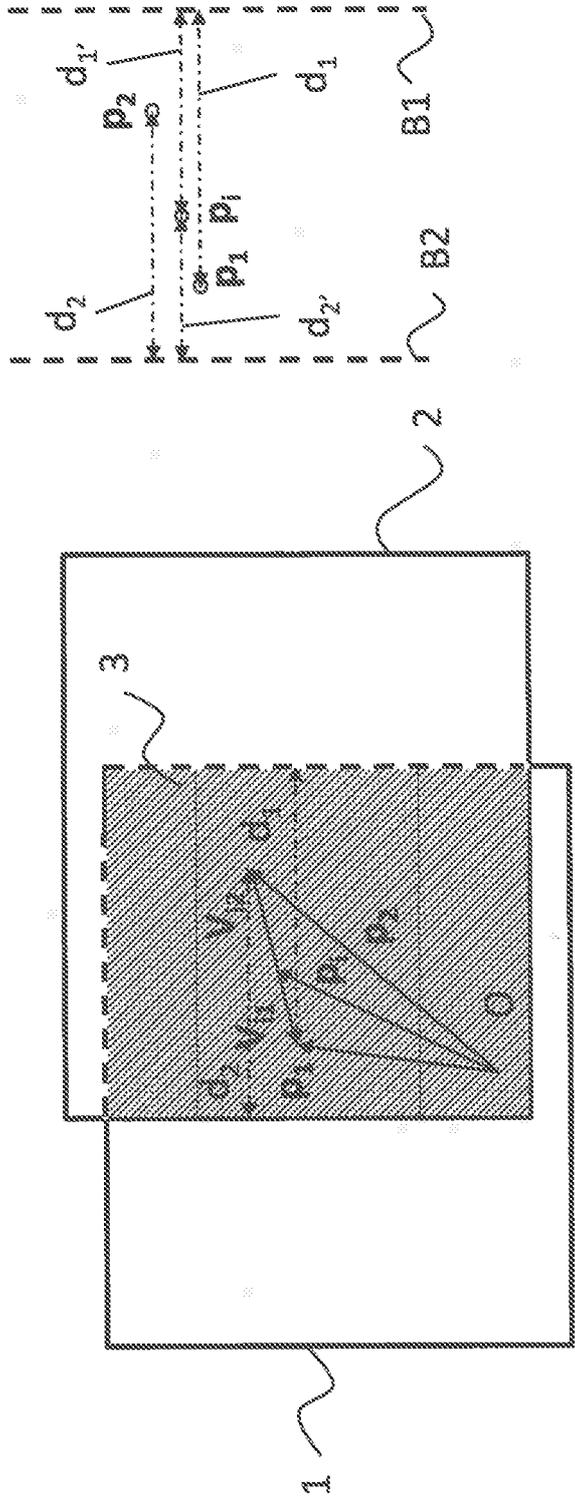


FIG.2

3/10

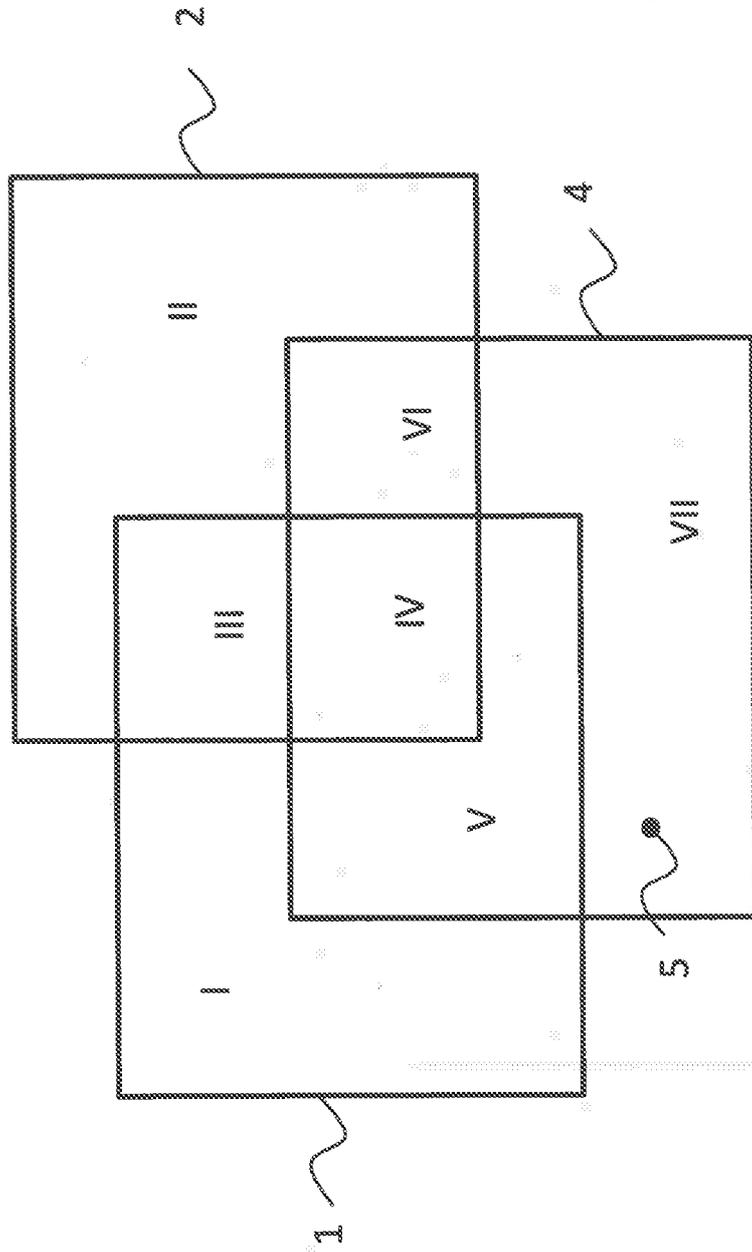


FIG.3

4/10

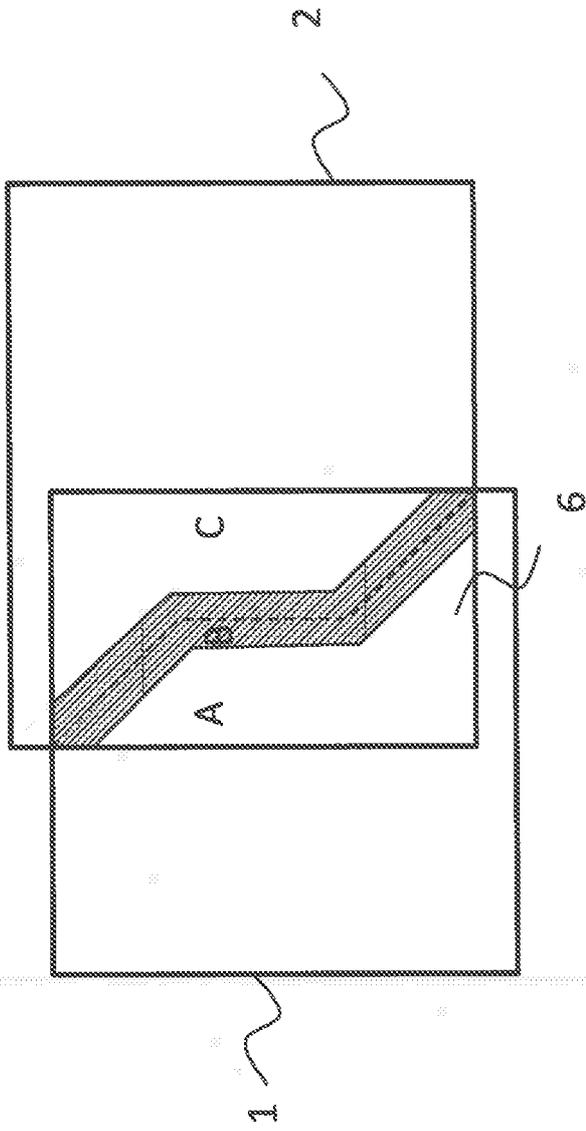


FIG.4

5/10

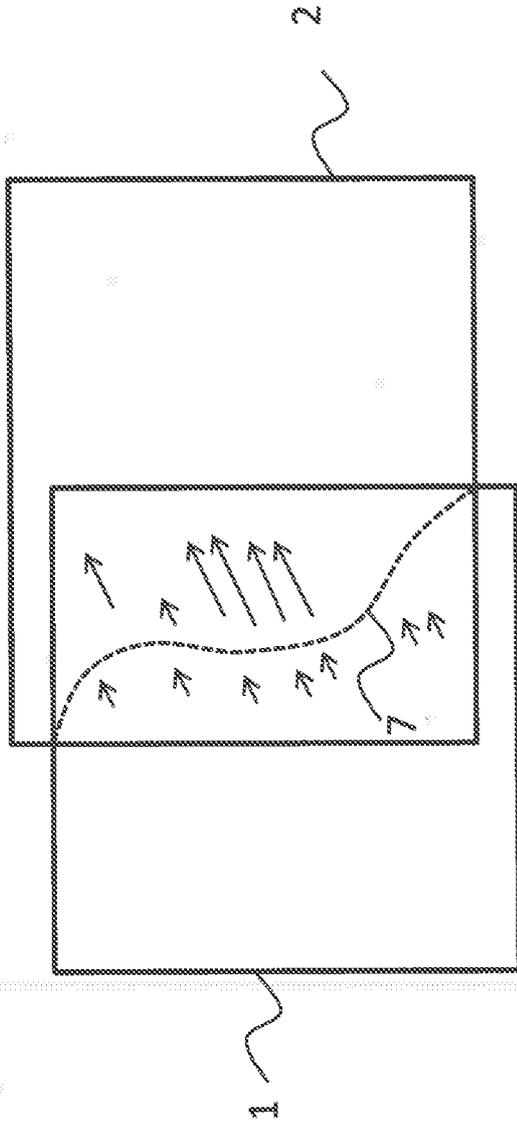


FIG.5

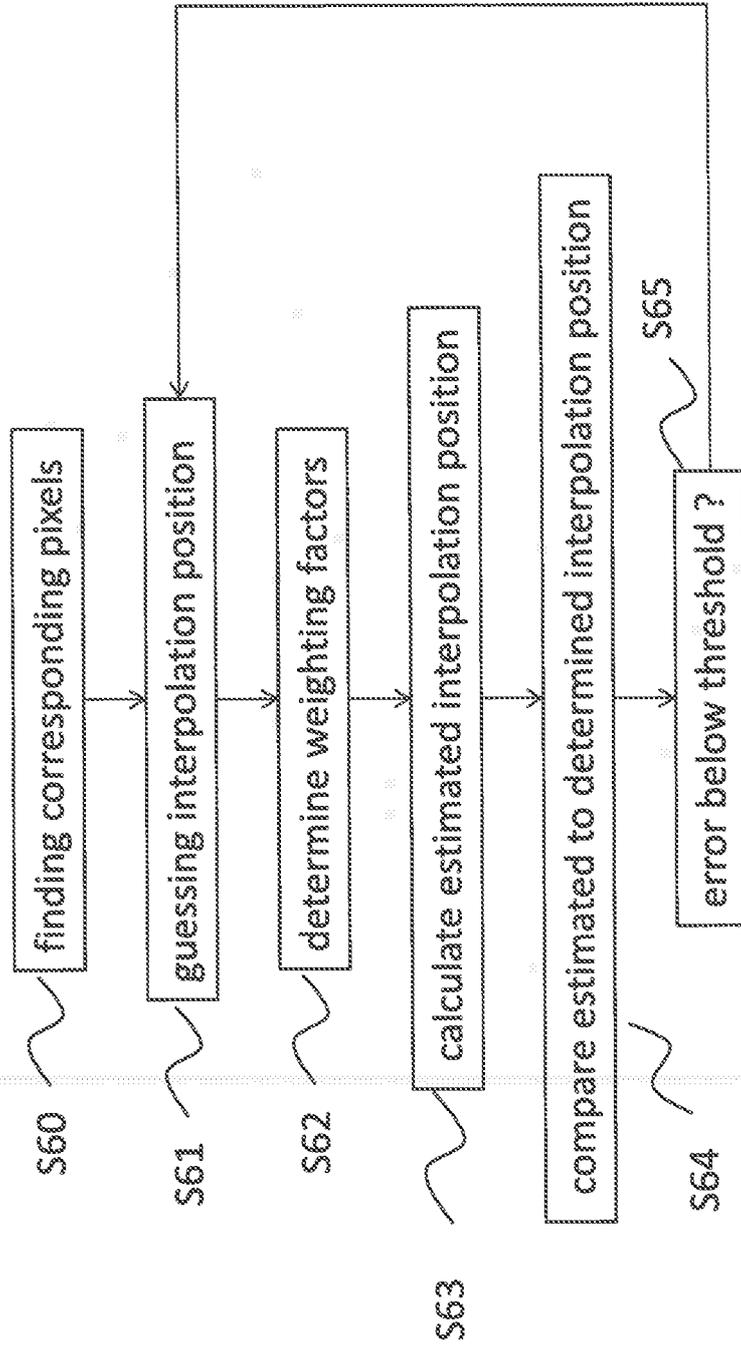


FIG.6A

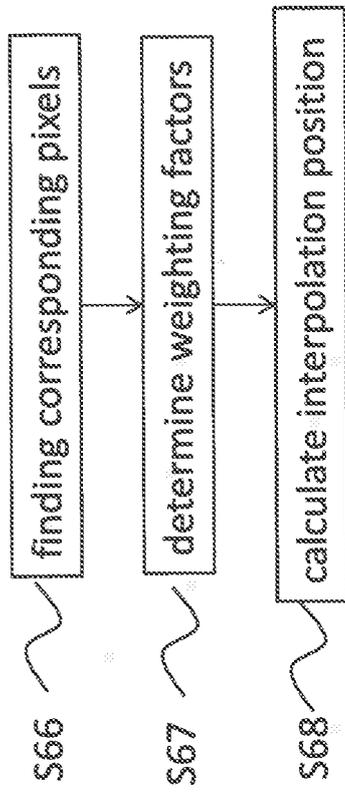


FIG.6B

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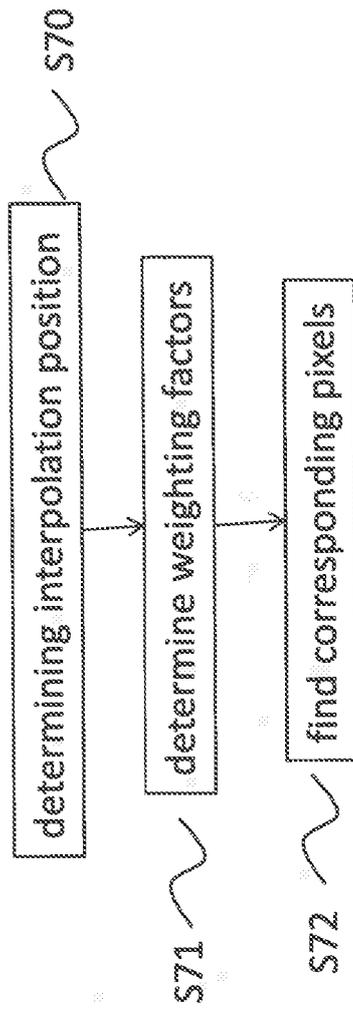


FIG.7A

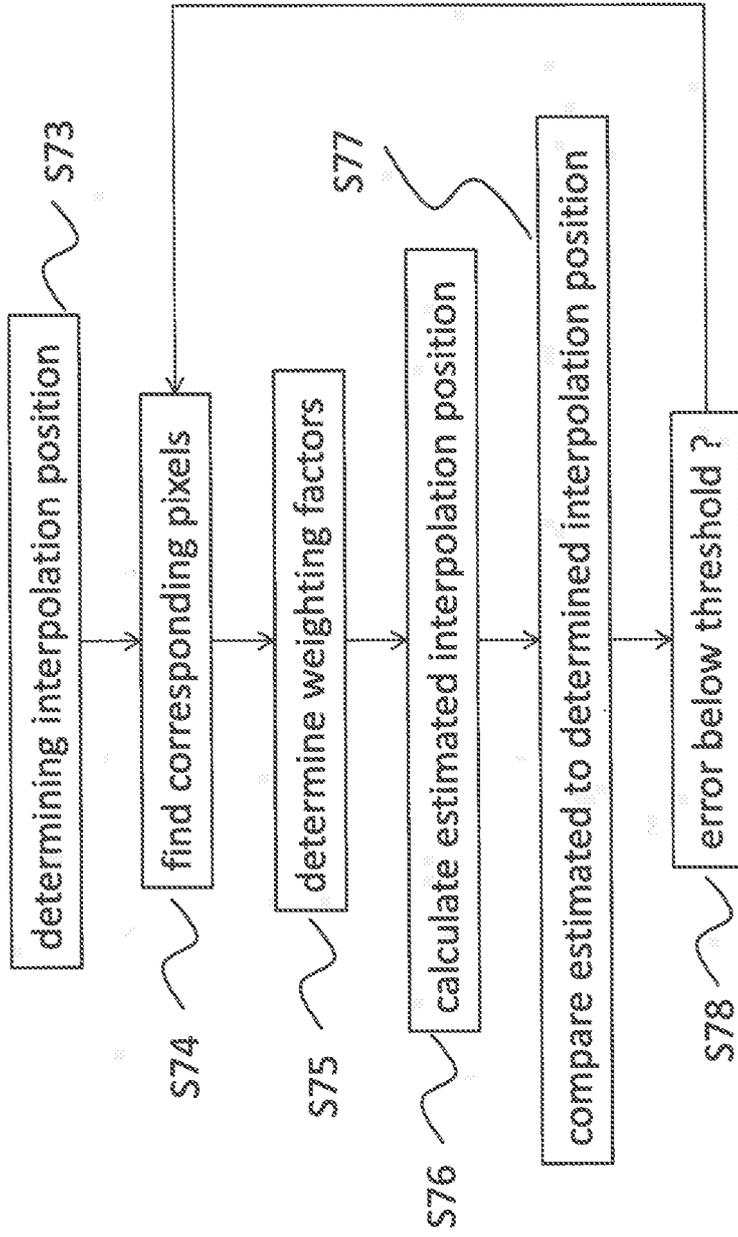


FIG.7B

10/10

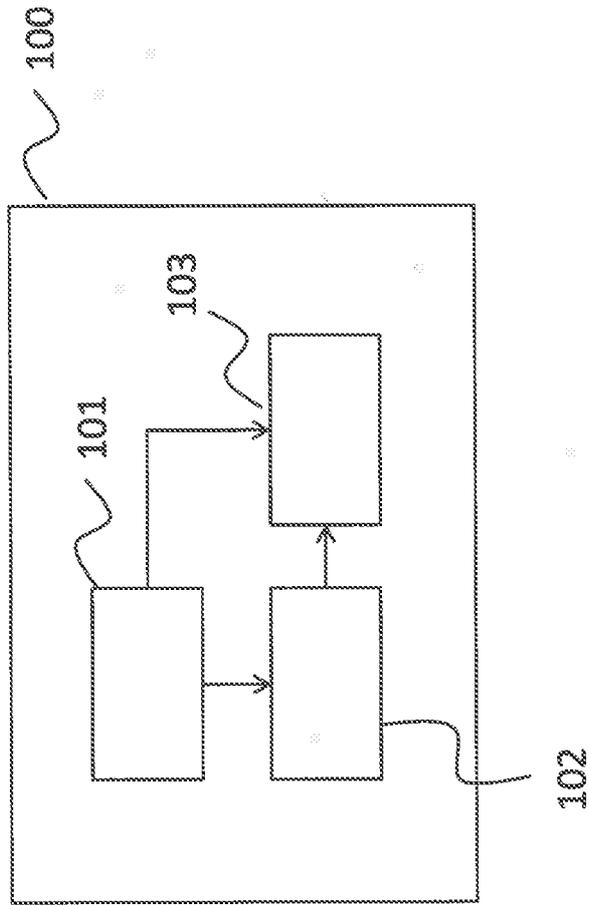


FIG.8

ABSTRACT

5 The present invention is related to an image stitching method. It is further related to an image stitching device and to a computer readable medium carrying instructions for performing such method.

10 The method according to the invention comprises determining a pixel value of a pixel at an interpolation position in the region to be stitched using pixel values of corresponding pixels in a plurality of sub-images. According to the invention, the interpolation position corresponds to a weighted sum of positions of the corresponding pixels, wherein the weighting factor for the position of a corresponding pixel in a given sub-image depends on a relative distance of at least one of said corresponding pixel and said interpolation position to a border of the region to be stitched associated with that sub-image.

15

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	3B/2QZ76/BD/9
Nederlands aanvraag nr.	Indieningsdatum
2016660	22-04-2016
	Ingeroepen voorrangsdatum
Aanvrager (Naam)	
Cyclomedia Technology B.V.	
Datum van het verzoek voor een onderzoek van internationaal type	Door de instantie voor internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr.
01-10-2016	SN67460
I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)	
Volgens de internationale classificatie (IPC)	
G06T3/40	
II. ONDERZOCHE GEBIEDEN VAN DE TECHNIEK	
Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC	G06T
Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen	
III. <input type="checkbox"/>	GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)
IV. <input checked="" type="checkbox"/>	GEBREK AAN EENHEID VAN UITVINDING (opmerkingen op aanvullingsblad)

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Nummer van het verzoek om een onderzoek naar
de stand van de techniek

NL 2016660

A. CLASSIFICATIE VAN HET ONDERWERP

INV. G06T3/40

ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHETE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)

G06T

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	EENHEID VAN UITVINDING ONTBREEKT zie aanvullingsblad B ----- LHUILIER M ET AL: "Relief mosaics by joint view triangulation", PROCEEDINGS 2001 IEEE CONFERENCE ON COMPUTER VISION AND PATTERN RECOGNITION. CVPR 2001. KAUAI, HAWAII, DEC. 8 - 14, 2001; [PROCEEDINGS OF THE IEEE COMPUTER CONFERENCE ON COMPUTER VISION AND PATTERN RECOGNITION], IEEE COMPUTER SOCIETY, LOS ALAMITOS, C, deel 1, 8 december 2001 (2001-12-08), bladzijden 785-790, XP010583825, ISBN: 978-0-7695-1272-3	1-11, 19, 21-25
A	* sectie 2, alinea 2 * * sectie 3, sub-sectie "Two-view compositing" * -----	12



Verdere documenten worden vermeld in het vervolg van vak C.



Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

*** Speciale categorieën van aangehaalde documenten**

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvraag vermeld

"E" eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvraag, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"Z" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

25 januari 2017

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie

European Patent Office, P.B. 5818 Patentlaan 2
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Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Kollreider, Klaus

GEBREK AAN EENHEID VAN UITVINDING

Octrooiaanvraag Nr.:

SN 67460

NL 2016660

AANVULLINGSBLAD B

De instantie belast met het uitvoeren van het onderzoek naar de stand van de techniek heeft vastgesteld dat deze aanvraag meerdere uitvindingen bevat, te weten:

1. conclusies: 1-12, 19, 21-25
 adapt the size of the stitching region

2. conclusies: 13-15
 avoid stitching at regions of large positional deviation

3. conclusies: 16-18, 20
 determine interpolation position and corresponding pixels

Het vooronderzoek werd tot het eerste onderwerp beperkt.

With reference to D1 (Lhuillier et al., "Relief Mosaics by Joint View Triangulation", Dec. 2001), the subject-matter of claims 1-5, 7-10, 19, 21-25 is disclosed and is thus not novel (see cited passages in the search report). In addition, the subject-matter of claims 6, 11, although novel, is obvious with respect to the common knowledge of the skilled person: Re. claim 6, considering the section/border at shortest distance is one of several straightforward possibilities in order to calculate $d(u, B_i)$ in D1 (sec. 3, list item 2). Re. claim 11, stitching around a curve (usually called "seam") belongs to the common general knowledge in the field readily available for analogous use in D1.

The subject-matter of claim 12 differs from D1 in that a correction benchmark is determined using pixel value difference in the region to be stitched, wherein the region to be stitched is extended if the correction benchmark exceeds a threshold. This distinguishing aspect represents the special technical feature STF1 of the first group of claims. This feature solves the problem of how to adapt the size of the stitching region to the local misalignment (cf. descr., p. 4, l. 20-26).

The subject-matter of claim 13-15 differs from D1 in that a curve is determined based on a displacement field between corresponding pixels in the region to be stitched. This distinguishing aspect represents the special technical feature STF2. It solves the problem of how to avoid stitching at regions of large positional deviation (p. 4, l. 31-36).

The subject-matter of claims 16-18, 20 differ from D1 in that either the interpolation position is set (known), and thus the corresponding pixels are sought optionally involving optimisation (cl. 16-18), or, alternatively the corresponding pixels are set (known), and the interpolation position is sought by optimisation (cf. 20). This distinguishing aspect represents the special technical feature STF3. It solves the problem of how to determine the interpolation position and corresponding pixels.

It is evident from the above analysis that the problems underlying the special technical features STF1-STF3 are unrelated. As these special technical features are neither the same nor corresponding to each other, the separate potential inventions are not so linked as to form a single

GEBREK AAN EENHEID VAN UITVINDING

Octrooiaanvraag Nr.:

SN 67460

NL 2016660

AANVULLINGSBLAD B

De instantie belast met het uitvoeren van het onderzoek naar de stand van de techniek heeft vastgesteld dat deze aanvraag meerdere uitvindingen bevat, te weten:

general inventive concept, nor do they solve a common corresponding technical problem.

WRITTEN OPINION

File No. SN67460	Filing date (day/month/year) 22.04.2016	Priority date (day/month/year)	Application No. NL2016660
International Patent Classification (IPC) INV. G06T3/40			
Applicant Cyclomedia Technology B.V.			

This opinion contains indications relating to the following items:

- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the application
- Box No. VIII Certain observations on the application

Examiner Kollreider, Klaus

WRITTEN OPINION

Application number

NL2016660

Box No. 1 Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - a sequence listing
 - table(s) related to the sequence listing
 - b. format of material:
 - on paper
 - in electronic form
 - c. time of filing/furnishing:
 - contained in the application as filed.
 - filed together with the application in electronic form.
 - furnished subsequently for the purposes of search.
3. In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

WRITTEN OPINION

Application number
NL2016660

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step, or to be industrially applicable have not been examined in respect of

- the entire application
- claims Nos. 13-18, 20

because:

- the said application, or the said claims Nos. relate to the following subject matter which does not require a search (*specify*):
- the description, claims or drawings (*indicate particular elements below*) or said claims Nos. are so unclear that no meaningful opinion could be formed (*specify*):
- the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed (*specify*):
- no search report has been established for the whole application or for said claims Nos. 13-18, 20
- a meaningful opinion could not be formed as the sequence listing was either not available, or was not furnished in the international format (WIPO ST25).
- a meaningful opinion could not be formed without the tables related to the sequence listings; or such tables were not available in electronic form.
- See Supplemental Box for further details.

Box No. IV Lack of unity of invention

1. The requirement of unity of invention is not complied with for the following reasons:
see separate sheet
2. This report has been established in respect of the following parts of the application:
 - all parts.
 - the parts relating to claims Nos. (see Search Report)

WRITTEN OPINION

Application number

NL2016660

**Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability;
citations and explanations supporting such statement**

1. Statement

Novelty	Yes: Claims	6, 11, 12
	No: Claims	1-5, 7-10, 19, 21-25
Inventive step	Yes: Claims	12
	No: Claims	1-11, 19, 21-25
Industrial applicability	Yes: Claims	1-12, 19, 21-25
	No: Claims	

2. Citations and explanations

see separate sheet

Reference is made to the following document:

- D1 LHUILLIER M ET AL: "Relief mosaics by joint view triangulation",
PROCEEDINGS 2001 IEEE CONFERENCE ON COMPUTER VISION
AND PATTERN RECOGNITION. CVPR 2001. KAUAI, HAWAII, DEC. 8 -
14, 2001; [PROCEEDINGS OF THE IEEE COMPUTER CONFERENCE
ON COMPUTER VISION AND PATTERN RECOGNITION], IEEE
COMPUTER SOCIETY, LOS ALAMITOS, C,
deel 1, 8 december 2001 (2001-12-08), bladzijden 785-790,
XP010583825,
ISBN: 978-0-7695-1272-3

Re Item IV

Lack of unity of invention

- 1 The application does not meet the requirements of unity of invention, as the claims cover 3 potential inventions as follows:
 - I. Claim 1-12, 19, 21-25 (adapting the size of the stitching region)
 - II. Claims 13-15 (avoid stitching at regions of large positional deviation)
 - III. Claims 16-18, 20 (determine interpolation position and corresponding pixels)
- 1.1 With reference to D1, the subject-matter of claims 1-5, 7-10, 19, 21-25 is disclosed as indicated in items Error: Unable to retrieve cross-reference value! -4.7 below and is thus not novel. The subject-matter of claims 6, 11, although novel, is obvious with respect to the common knowledge of the skilled person (cf. items 5 -5.2 below).
- 1.2 The subject-matter of claim 12 differs from D1 in that a correction benchmark is determined using pixel value difference in the region to be stitched, wherein the region to be stitched is extended if the correction benchmark exceeds a threshold. This distinguishing aspect represents the special technical feature STF1 of the first group of claims. This feature solves the problem of how to adapt the size of the stitching region to the local misalignment (cf. descr., p. 4, l. 20-26).

- 1.3 The subject-matter of claim 13-15 differs from D1 in that a curve is determined based on a displacement field between corresponding pixels in the region to be stitched. This distinguishing aspect represents the special technical feature STF2. It solves the problem of how to avoid stitching at regions of large positional deviation (p. 4, l. 31-36).
- 1.4 The subject-matter of claims 16-18, 20 differ from D1 in that either the interpolation position is set (known), and thus the corresponding pixels are sought optionally involving optimisation (cl. 16-18), or, alternatively the corresponding pixels are set (known), and the interpolation position is sought by optimisation (cf. 20). This distinguishing aspect represents the special technical feature STF3. It solves the problem of how to determine the interpolation position and corresponding pixels.
- 1.5 It is evident from the above analysis that the problems underlying the special technical features STF1-STF3 are unrelated. As these special technical features are neither the same nor corresponding to each other, the separate potential inventions are not so linked as to form a single general inventive concept, nor do they solve a common corresponding technical problem.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

- 2 The application relates to image processing, in particular to image stitching (p. 1, §1). The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.
- 2.1 D1 discloses (the references in parenthesis applying to this document):
Werkwijze voor het stikken van een veelvoud aan globaal uitgelijnde sub-afbeeldingen in een te stikken gebied, de werkwijze omvattende (section 3, par. 1; sub-section "Two-view compositing", list item 1):
het bepalen van een pixel waarde van een pixel op een interpolatiepositie in het te stikken gebied met gebruik van pixelwaarcles van corresponderende pixels in het genoemde veelvoud aan sub-afbeeldingen (sec. 3, sub-section "Two-view compositing", list item 6);

met het kenmerk dat de interpolatiepositie overeenkomt met een gewogen som van posities van de corresponderende pixels, waarbij de weegfactor voor de positie van een corresponderende pixel in een gegeven sub-afbeelding afhangt van een relatieve afstand van ten minste één van de genoemde corresponderende pixel en de genoemde interpolatiepositie tot een grens van het te stikken gebied welke geassocieerd is met die sub-afbeelding (sec. 3, sub-section "Two-view compositing", list items 2-3).

3 The above applies equally to the subject-matter of claim 24 (apparatus) and claim 25 (program product), which is therefore not novel.

4 Moreover, the subject-matter of dependent claims 2-5, 7-10, 19, 21-24 is not novel since it is disclosed in D1, as detailed below:

4.1 Re. claims 2-3: cf. D1, sec. 3, sub-section "Two-view compositing", list item 2;

4.2 The subject-matter of dependent claims 4-5 (re. weighting factors) would prima facie appear to differ from D1. However, it is believed that D1 contains an obvious error, for the following reasons: According to D1, sec. 3, sub-section "Two-view compositing", list item 2, the function $s(u, u')$ is computed which should guarantee a "smooth transition". It is proportional to distance $d(u, B_1)$ from u to B_1 , where " B_i is the overlapping section of i -th image border in the composite coordinates". B_i is thus the same border as referred to in the claims/application. However, looking at function λ (which is equal to s for overlapped corresponding points) and the linear interpolation scheme for computing u in D1 (cf. sec. 3, sub-section "Two-view compositing", list item 3), function $s(u, u')$ simply cannot be proportional to $d(u, B_1)$ when the aim is a "smooth transition".

It must rather be the case that $s(u, u')$ is equal to $1 - s(u, u')$ as it stands at the moment. By this obvious correction, the weighting factors in the interpolation scheme become equal to the relative distances, i.e. proportional to $d(u, B_1)$ and $d(A(u'), B_2)$, respectively, and thus the same as in claims 4-5.

4.3 Re. claims 7-8: cf. D1, sec. 3, par. 2 and sec. 2, par. 2;

4.4 Re. claims 9-10: same as in item 4.1 above;

- 4.5 Re. claim 19: re. finding the correspondences: cf. D1, sec. 2, par. 2, l. 4-10 re. determining the weighted sum: cf. D1, sec. 3, sub-section "Two-view compositing", list items 2-3;
- 4.6 Re. claim 21: cf. D1, sec. 3, sub-section "Two-view compositing", list items 2-3;
- 4.7 Re. claims 22-23: cf. D1, sec. 3, sub-section "Two-view compositing", list item 6;
- 5 Furthermore, the subject-matter of dependent claims 6, 11 is novel, yet not considered to involve an inventive step, as detailed in the following:
- 5.1 The subject-matter of claim 6 differs from D1 in that the distance to the border is computed as the shortest distance to the border. However, given that the "overlapping section of i -th image border in the composite coordinates" (cf. D1, sec. 3, list item 2) may comprise sections in plural directions (e.g. top and side), the skilled person would be obliged to fill in with his common knowledge in order to calculate $d(u, B_i)$. Considering the section/border at shortest distance would appear to be merely one of several straightforward possibilities from which the skilled person would select, without the exercise of inventive skill.
- 5.2 The subject-matter of claim 11 differs from D1 in that the area to be stitched is centered around a curve through an overlapping image region. However, stitching around said curve (usually referred to as "seam") belongs to the *common general knowledge* in the field, and to employ this known feature starting from D1 would be obvious and representing an *analogous use*.
- 6 The additional specifications in claim 12, i.e. STF1 as identified in item 1.2 above, is not disclosed in D1, and is therefore new. The underlying technical problem would be how to adapt the size of the stitching region to the local misalignment (parallax, cf. descr., p. 4, l. 20-26). The proposed solution is to determine an correction benchmark based on pixel value differences of corresponding pixels (in particular, the average amount of correction per pixel according to p. 9, 14-19), and to expand the region in case the correction benchmark exceeds a threshold. Such a solution appears to be neither known from, nor rendered obvious by the available prior art in view of the common general knowledge, and may therefore be considered to involve an inventive step.