

IMAGE PROCESSING METHOD AND SYSTEM

FIELD OF THE INVENTION

The present invention relates to the field of image processing. In one
5 form, the invention relates to a method and system of matching regions of a
first image and at least a second image, said regions being non-overlapping
segments of an image, to provide a fundamental algorithm in use to perform
image registration.

It will be convenient to hereinafter describe the invention in relation to
10 the use of such an algorithm for that purpose of image registration; however it
should be appreciated that the present invention is not limited to that use only.

BACKGROUND OF THE INVENTION

Image registration is a fundamental task in the area of computer vision
15 used to match two images of a same scene taken by two different cameras
from different viewpoints at different times. The main goal of the image
registration is to find a geometric transformation with which the first image can
be correlated or aligned with the second one. The registration is often
necessary for 1) integrating information taken from different sensors; 2)
20 finding changes in images taken at different times or under conditions; 3)
inferring 3D information from images; 4) for model-based object recognition.
Among the existing prior art algorithms for image registration, the approaches
based on region features are widely used, especially in multi-sensor image
registration where the two images present significant gray level disparities.
25 The images are firstly segmented into a set of non-overlapped regions by the
approaches of split-and-merge or region growing. Then a region-matching
algorithm may be performed to find region matches and further to find the
geometry transformation between the images.

Most existing approaches in the prior art for region matching measure
30 the region similarity based on the region features, such as area, diameter,
elongation and moments. For two regions in two images to be matches, their
properties should be similar enough. After the region matches are found, their

centroids will be used as the control points to compute the geometric transformation. The major problem associated with these approaches within the prior art is the case of mismatch. For example, it is common to have two regions in the first image with similar or even exactly the same properties with one corresponding region in the second image. In this case, it is hard to solve the ambiguity. Then computed transformation will be very sensitive to the mismatched regions. This means that they are not robust enough to work in most situations.

It is to be noted that the prior art discussed herein has been noted to have the difficulties, as discussed, by the inventor.

Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art base or the common general knowledge in the relevant art in Singapore or elsewhere on or before the priority date of the disclosure and claims herein.

An object of the present invention is to provide a method and system for matching image regions of a first and second image that provides a useful alternative to the prior art.

A further object of the present invention is to alleviate at least one disadvantage associated with the prior art.

SUMMARY OF THE INVENTION

In one aspect the present invention provides a method of matching regions of a first image and at least a second image, said regions being non-overlapping segments of an image, the method comprising the steps of:

a) determine a set of region properties for each region of the first and second images;

b) for each possible pair of regions in the set of all possible pairs of regions, where each said pair comprises a region from the first image and a region from the second image, perform the following;

i) determine a hypothetical transformation;

ii) transform a portion of each region of the first image into a corresponding transformed location in the second image using the hypothetical transformation;

5 iii) determine whether a region in the second image has a corresponding existing portion proximate the transformed location;

iv) allocate a support reference to the hypothetical transformation for each determined proximate portion;

c) determine a true transformation between the first and second images in accordance with the hypothetical transformation which is allocated

10 the maximal support references.

In a preferred embodiment the method may further comprise the step of determining at least one invariant region property for each region of the first and second images prior to determining a hypothetical transformation.

Accordingly, steps b) and c) may be performed only for those region pairs

15 having the same invariant region property.

In one embodiment the region properties comprise any one or more of:

region area;

region orientation; and

region centroid.

20 The at least one invariant property may be a region moment.

Preferably, the hypothetical transformation comprises an affine transformation. The affine transformation may comprise:

a scaling determined as the square root of the ratio of the first region area and the second region area;

25 a translation determined as the difference between the first region centroid and the second region centroid; and

a rotation determined as the difference between the first region orientation and the second region orientation.

In a preferred embodiment, the hypothetically transformed portion of

30 each region of the first image is a centroid.

Other aspects and preferred aspects are disclosed in the specification and / or defined in the appended claims, forming a part of the description of the invention.

In essence, the present invention stems from the realisation that it is possible to directly relate image region properties to a geometric transformation between two images used to correlate or align the first image with the second image. In this respect, when a region is translated, all of its pixels will be translated in the same direction and by the same distance. As the region centroid statistically defines the region's position, the difference of the coordinates of the region centroids prior to and after transformation may determine the translation vector. When a region is rotated, all of its pixels will be rotated in the same direction and by the same angle. Accordingly, the difference of the region orientations prior to and after transformation may determine the rotation direction and the rotation angle. Further, when a region is scaled, the length of each boundary line will be scaled by the same scaling factor. As the region area is proportional to the square of the length of each boundary line, the square root of the ratio of the region areas prior to and after transformation may determine the scaling factor.

The present invention has been found to result in a number of advantages, such as:

It is robust. All possible transformations between two images are determined and the best one is chosen. The optimal solution if there is one may be determined by the present invention.

It is efficient. The geometric transformation between two images is determined from one single pair of region matches instead of two. By way of explanation, in general the affine transformation is described by four unknowns, one for scaling, one for rotation and two for translation. Prior art approaches compute the affine transformation between two images from the coordinates of the control points, i.e. the region centroids. In this case, four equations are required to solve for a unique affine transformation. Each pair of region centroids will provide two equations involving the unknowns of the affine transformation, so

at least two pairs of regions are required. The approach of the present invention uses the region properties to compute the affine transformation. Each unknown of the affine transformation may be solved by certain region properties. Thus, only a single pair of region matches is required in the present invention. So the total number of possible transformations between two images may be reduced hundreds of times. This may greatly reduce the algorithm complexity.

It is invariant to scaling, translation and rotation. The methodology of the present invention is inherently invariant to the effects of scaling, translation and rotation by virtue of the unknowns of the affine transformation being determined uniquely from a single pair of region matches.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

The specific algorithms derived from the present invention may be useful in application to performing the task of image registration in a computer vision environment.

BRIEF DESCRIPTION OF THE DRAWINGS

Further disclosure, objects, advantages and aspects of the present application may be better understood by those skilled in the relevant art by reference to the following description of preferred embodiments taken in conjunction with the accompanying drawing, which are given by way of illustration only, and thus are not limitative of the present invention, and in which:

Figure 1 illustrates an exemplary flow chart of the method of the present invention in accordance with a preferred embodiment.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with a preferred embodiment and with reference to figure 1, the proposed algorithm consists of four steps

1) For all the regions in both images, we compute the following region
5 properties: the region area, the region orientation and the region centroid.

2) For each pair of possible region matches, we make a hypothesis that they are corresponding regions. Thus a hypothetical transformation may be constructed or determined. According to the preferred embodiment, then a hypothetical transformation comprising a unique affine transformation may be
10 determined as following. The scaling is determined as the square root of the ratio of the first region area and the second region area. The translation is determined as the difference between the first region centroid and the second region centroid. The rotation is determined as the difference between the first region orientation and the second region orientation.

3) For the hypothesis posed or hypothetical transformation, we verify it by seeking the number of determined supports from other regions. For each region in the first image, we transform, for example, its centroid into a new location using the hypothetical transformation and determine if there is a region in the second image whose centroid is very close to or proximate the
15 computed location. If so, the hypothetical transformation gets a support. This process is performed to all the regions in the first image, and the total number of supports may be recorded.

4) Step 2 and 3 may be performed for all the possible pairs of regions. For all the hypothetical transformations, the one that gets the maximal
20 supports may be chosen as the true transformation.

In implementations of the invention, we also compute some invariant region properties, such as the region moments. When we generate the hypothetical transformation as at step 2, if two regions have different region moments, they will be regarded as impossible matches and will not be used to
30 compute a hypothetical transformation. When we seek the number of supports for a hypothetical transformation at step 3, for a pair of regions to be a support, they are also required to have similar region moments. By

incorporating the invariant region moments into the algorithm, we can achieve better accuracy and speed.

Region Matching Algorithm

1. Denote R_m ($m=1, \dots, M$) the regions in the first image and R_n ($n=1, \dots, N$) the regions in the second image.

2. Compute the region properties according to:

$\zeta_m = \{A_m, \theta_m, X_m, Y_m \mid A_m \text{ is the region area of } R_m, \theta_m \text{ is the region orientation of } R_m, X_m \text{ and } Y_m \text{ are the coordinates of the center of gravity of } R_m\}$,

$\zeta_n = \{A_n, \theta_n, X_n, Y_n \mid A_n \text{ is the region area of } R_n, \theta_n \text{ is the region orientation of } R_n, X_n \text{ and } Y_n \text{ are the coordinates of the center of gravity of } R_n\}$.

3. Starting from $m=1$ and $n=1$, we compute an affine transformation by assuming R_m and R_n are corresponding regions:

- Scaling: $s_{mn} = \sqrt{A_n / A_m}$
- Rotation: $\alpha_{mn} = \theta_n - \theta_m$
- Translation: $\begin{pmatrix} tx_{mn} \\ ty_{mn} \end{pmatrix} = \begin{pmatrix} X_n \\ Y_n \end{pmatrix} - s_{mn} \begin{pmatrix} \cos(\alpha_{mn}) & \sin(\alpha_{mn}) \\ -\sin(\alpha_{mn}) & \cos(\alpha_{mn}) \end{pmatrix} \begin{pmatrix} X_m \\ Y_m \end{pmatrix}$

4. Initialize the support variable $E_{mn}=0$. Starting from $m=1$, we transform (X_m, Y_m) into a new coordinate using the above affine transformation:

$$\begin{pmatrix} X'_m \\ Y'_m \end{pmatrix} = s_{mn} \begin{pmatrix} \cos(\alpha_{mn}) & \sin(\alpha_{mn}) \\ -\sin(\alpha_{mn}) & \cos(\alpha_{mn}) \end{pmatrix} \begin{pmatrix} X_m \\ Y_m \end{pmatrix} + \begin{pmatrix} tx_{mn} \\ ty_{mn} \end{pmatrix}$$

Define the distance threshold $r>0$. Let (X_n, Y_n) be the closest point to (X'_m, Y'_m) . If $(X_n - X'_m)^2 + (Y_n - Y'_m)^2 < r^2$, then the above transformation gets one support and $E_{mn}=E_{mn}+1$. Loop this step from $m=1$ to M .

5. Loop step 3 and 4 from $m=1$ to M and $n=1$ to N .

6. Find indexes m_0 and n_0 such that $E_{m_0 n_0} = \max(E_{mn})$. The corresponding transformation $(s_{m_0 n_0}, \alpha_{m_0 n_0}, tx_{m_0 n_0}, ty_{m_0 n_0})$ will be regarded as the true transformation between these two images.

While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification(s). This application is intended to cover any variations uses or adaptations of the invention following in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

As the present invention may be embodied in several forms without departing from the spirit of the essential characteristics of the invention, it should be understood that the above described embodiments are not to limit the present invention unless otherwise specified, but rather should be construed broadly within the spirit and scope of the invention as defined in the appended claims. Various modifications and equivalent arrangements are intended to be included within the spirit and scope of the invention and appended claims. Therefore, the specific embodiments are to be understood to be illustrative of the many ways in which the principles of the present invention may be practiced. In the following claims, means-plus-function clauses are intended to cover structures as performing the defined function and not only structural equivalents, but also equivalent structures. For example, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface to secure wooden parts together, in the environment of fastening wooden parts, a nail and a screw are equivalent structures.

“Comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.”

CLAIMS

- 1 A method of matching regions of a first image and at least a
 second image, said regions being non-overlapping segments of an image, the
 5 method comprising the steps of:
 - a) determine a set of region properties for each region of the first and
 second images;
 - b) for each possible pair of regions in the set of all possible pairs of
 regions, where each said pair comprises a region from the first image and a
 10 region from the second image, perform the following:
 - i) determine a hypothetical transformation;
 - ii) transform a portion of each region of the first image into a
 corresponding transformed location in the second image using the
 hypothetical transformation;
 - 15 iii) determine whether a region in the second image has a
 corresponding existing portion proximate the transformed location;
 - iv) allocate a support reference to the hypothetical transformation for
 each determined proximate portion;
 - c) determine a true transformation between the first and second
 20 images in accordance with the hypothetical transformation which is allocated
 the maximal support references.
2. A method as claimed in claim 1 further comprising the step of
 determining at least one invariant region property for each region of the first
 25 and second images prior to determining a hypothetical transformation.
3. A method as claimed in claim 2 wherein steps b) and c) are
 performed only for those region pairs having the same invariant region
 property.

4. A method as claimed in any one of claims 1 to 3 wherein the region properties comprise any one or more of:

region area;

region orientation; and

5 region centroid.

5. A method as claimed in any one of claims 1 to 4 wherein the at least one invariant property is a region moment.

10 6. A method as claimed in any one of claims 1 to 5 wherein the hypothetical transformation comprises an affine transformation.

7. A method as claimed in claim 6 wherein the affine transformation comprises:

15 a scaling determined as the square root of the ratio of the first region area and the second region area;

a translation determined as the difference between the first region centroid and the second region centroid; and

20 a rotation determined as the difference between the first region orientation and the second region orientation.

8. A method as claimed in any one of claims 1 to 7 wherein the hypothetically transformed portion of each region of the first image is a centroid.

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9. Apparatus adapted to match regions of a first image and at least a second image, said regions being non-overlapping segments of an image, said apparatus including:

30 processor means adapted to operate in accordance with a predetermined instruction set,

said apparatus, in conjunction with said instruction set, being adapted to perform the method as claimed in any one of claims 1 to 8.

10. A computer program product including:

a computer usable medium having computer readable program code and computer readable system code embodied on said medium for matching
5 regions of a first image and at least a second image, said regions being non-overlapping segments of an image, within a data processing system, said computer program product including:

computer readable code within said computer usable medium for performing the method steps of any one of claims 1 to 8.

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11. A method as claimed in claim 1 substantially as herein described with reference to the accompanying drawing.

12. Apparatus or a product as claimed in claim 9 or 10 substantially
15 as herein described with reference to the accompanying drawing.