Efficient Feature Correspondence for Image Registration

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Abstract: - Feature correspondence is an important step in image registration. Chamfer matching is a process of establishing the feature correspondence of an object (subimage) in an image where both the subimage and the image are binary. Chamfer matching establishes correspondence based on low level features. It is the process of locating the template within the image by shifting the template within the image and at each shift position determining the sum of distances of closest object points in the template and the image. The smaller the sum, the closer object points in the template and the image. Correspondence is achieved by calculating the minimum distance out of all the translations which is computationally expensive. The problem is further aggravated if reference image is of much greater dimensions as compared to template image. Since the reference image consists of objects and background, calculating the minimum distance for all the pixel locations becomes time consuming. In this paper a method to decrease the computation time of existing technique is presented, to make existing schemes suitable for real time registration.

Key-Words: - Image registration, Feature correspondence, Distance transformations, Chamfer matching, Edge matching, Reference image, Template image.

1 Introduction

Feature correspondence is an important step in image registration; this can be achieved either by selecting features in the reference image and searching for them in the sensed image or by selecting features in both images independently and then determining the correspondence between them. The former method is chosen when the features contain considerable information, such as image regions or templates. The later method is used when individual features, such as points and lines, do not contain sufficient information. Chamfer matching is the process of finding the position of an object (subimage) in an image where both the subimage and the image are binary. The sum of distances between corresponding object and image points is used as the match-rating. The amount of shifts where the images best align is determined using the sum of distances between closest points in the images.

Chamfer matching [1] can be used to determine the position of regions in the sensed image with respect to reference image when local geometric differences between images are small, although global geometric difference between the images can be large. Given a template and an image, the process of locating the template within the image involves shifting the template within the image and at each shift position determining the sum of distances of closest object points in the template and the image. The smaller the sum, the closer object points in the template and the image. The process therefore, involves starting from an initial position in the image, determining the sum of distances of points in the template to the points in the image closest to them and shifting the template in the image in the gradient-descent direction of sum until a minimum is reached in the sum. If the template perfectly matches the image at a shift position, the sum of distances obtained as a result will be zero.

Depending upon the starting position of the template in the image and the contents of the image, the process may converge to a local minimum rather than a global one and miss the true match position. On the contrary exhaustive search is computationally expensive, since most of the computation time is spent on finding the sum of distances at various shift positions; considerable effort has gone into finding ways to speed up the computation of distances. If the distances are computed ahead of time and reused when calculating the sum of distances, considerable computational saving can be achieved. This paper presents a technique to further reduce the computational complexity of the existing techniques to make the more suitable for real time image registration.

The outline of the paper is as follows. Section 2 reviews previous work on distance transform, distance measures and matching strategies. Section 3 is on problem formulation. Section 4 gives the problem solution. Finally we conclude in Section 5.

2. Previous Work

Chamfer matching [1] is a low level correspondence technique for finding the best fit of edge points from two different images, by minimizing a generalized distance between them. The edge points of one image are transformed by a set of parametric transformation equations that describes how the image can be geometrically distorted in relation to one another. Measure of correspondence between patterns to be matched has been improved to have fewer false matches [2]. As the correspondence problem is computation intensive, a multi resolution approach [3], and hierarchical chamfer matching algorithm [4] was proposed to speed up the computation considerably, so much so that correspondence problem that could not be solved with single resolution algorithm (as computational load was too heavy), could be solved using moderate computation time.

Comparing images using Hausdorff distances was proposed [5] claiming three advantages: relative insensitivity to small perturbations; simplicity and speed of computations; natural allowance for portions of one shape to be compared with another. Hausdorff distance is a shape comparison metric based on binary image. It is a distance defined between two sets of points. Unlike most shape comparison methods that build a one-to-one correspondence between a model and a test image, Hausdorff distance can be calculated without explicit point correspondence. Hausdorff distance for binary image matching is more tolerant to perturbations on the locations of points than binary correlation techniques, since it measures proximity rather than exact superposition. Hausdorff matching is the only robust method of the known literature for occluded images to an extent. Various variants of Hausdorff matching are: the upper envelope of Voronoi surfaces and its applications [6], getting around a lower bound for the minimum Hausdorff distance [7], a guided image matching approach using Hausdorff distance with interesting points detection [8], a modified Hausdorff distance between fuzzy sets [9], efficient algorithms for robust feature matching [10], robust Hausdorff distance matching algorithms using pyramidal structures [11] and line segment Hausdorff distance on face matching [12] was proposed.

Other known available matching scheme is wavelet decomposition method [13], where input image is decomposed into different multi resolution levels in the wavelet transformed domain and use only the pixels with high wavelet coefficients in the decomposed detailed sub image at a lower resolution level to compute the normalized correlation between two compared patterns. Ring projection transform [14] is used to make the matching scheme rotation invariant.

Robust image matching algorithm [15] is low level feature based correspondence method, in which edge points or low level feature points are extracted from digital images, converted to binary images, which are distance transformed, which is used for matching. The distance transform (DT) of template is superimposed on the DT of the model and values are subtracted pixel wise and matching is found as per the metric. Four matching measures were proposed: ranked highest numbers of zeros, range, minimum average and RMS value.

Basic concepts regarding distance transform, Chamfer Matching and different similarity measures have been covered in detail in the references so these are not covered here

3. Problem Formulation

To find the position of best match in [1] and [15], if A and B are: reference and template binary images; have size MxN and PxQ respectively.

A=[m,n] m=1,2,…, M and n=1,2,…,N.

B=[p,q] p=1,2…, P and q=1,2,…,Q.

Let T and R are the number of edge points (binary value 1) in reference and template binary images respectively.

Total number of non edge points in reference image=(MxN)-R (1)

Total number of non edge points in template image=(PxQ)-T (2)

Let $T_{(p,q)}$ and $R_{(m,n)}$ define the location of edge points in template and reference binary images respectively.

To find a match in [1] and [15] schemes, we require (M-P)x(N-Q) translations of template over the reference image, figure 1 explains this calculation. Template image is superimposed and translated over the reference image, if we take one of the two extents of translations as the top left corner and the other as the bottom right corner of the reference. To raster scan the reference image completely the template image require (N-Q) horizontal and (M-P) vertical steps. Computations at most of translations are redundant, because the reference image consists of edge and non-edge points and superimposing the template over the non-edge points in reference and calculating the matching measure has no probability of finding a match.

The problem is further aggravated if reference image is of much greater dimensions as compared to template image. Here we present a method to decrease the computation time of proposed algorithm by translating the template over the selected points in the reference image.

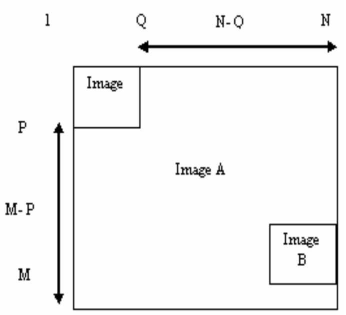

Figure 1 Calculation of Translation

4. Problem Solution

Following algorithm is proposed to save computation time.

Find all edge points in Template Image and mark them.

Find all edge points in Reference Image and mark them.

Take first marked point in Template Image as reference and translate it on all possible (except at boundary) marked points in reference image.

Find the best match using [15] approach.

Total translations require = Total number of pixels in image - Number of unmarked points in Reference Image - Number of marked points present in reference boundary (Overlapped under template) (3)

In equation (3) the third term indicates that the calculations will also be reduced for translations of the template image over the marked points in the reference image, for which the template is not completely contained in the reference.

4.1 Experimental Results

In this section we present the experimental results for evaluating the efficiency of the proposed matching algorithm. All experiments were conducted on a personal computer with Pentium IV, 3.2GHz processor. Various experiments were conducted, but only two results are shown here. The images of different sizes having 8 bit gray level were used. Edges of (reference/template) were extracted using sobel operator. After finding the DT images, templates were translated only on selected points of the reference image and matching was achieved as per the matching measures explained earlier. All results were simulated in Matlab 6.5.

4.1.1 Case 1

Figure 2[17] is a 252x238, 8bit gray level reference image. Figure 3 is a 83x79[16}, 8 bit gray level template image. Using existing schemes [1][15], 159x169 (26871) translations were required to compute the best match figure 4, only translational parameter is used for matching. In proposed time reduction scheme, we require less than 2182 translations. Saving more than approximately 91.87% of the translations. Existing schemes takes 5.9 seconds to compute the best match whereas the proposed method took .58 seconds, thereby reducing the time by 5.32 seconds (90.16%).

Figure 2 *Reference Image*

Figure 3 *Template image*

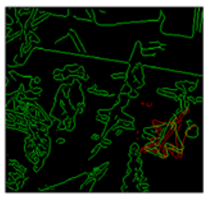

Figure 4 *Match*

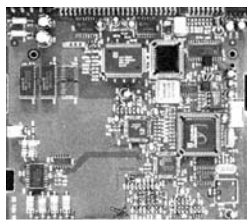

Figure 5 Reference *Image*

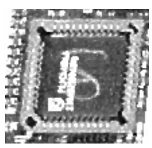

Figure 6 *Template image*

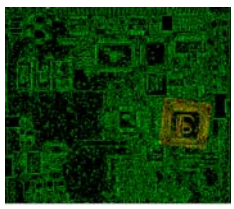

Figure 7 *Match*

4.1.2 Case 2

Figure 5 shows 470X416 reference image. Figure 6 shows 107x97 template image. Using existing schemes, 74955 translations were required to compute the best match figure 7. In proposed scheme, we require less than 13026 translations. Saving more than approximately 82.62% of the translations. However these results are dependent on size of reference/template image and density of edge points in reference image. If the size of the reference is of much higher dimension than the template the number of translations as well as computation time increases. Similarly if the density of the edge points in the reference image increases the number of translations and computation time also increases.

5. Conclusion

In this paper an efficient feature correspondence scheme is presented. We discussed the existing template techniques. Two experimental examples were presented. Experimental results show that the proposed scheme is time efficient. However these results are dependent on size of reference and template image and density of edge points in reference image the Computational time for real time system can be reduced by great amount by having a dedicated hardware and off shelf computation of distance transform.

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