Multi-resolution Image Registration

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Abstract

The computation cost of image registration is affected by searching data size and space. This paper proposes an efficient image registration algorithm that uses multi-resolution wavelet decomposed image to reduce the data size search. The algorithm determines the correlation detection at low resolution on low-pass sub bands of wavelet and generate mask for higher resolution as part of a coarse to fine registration algorithm. The correlation matching is defined for coarse resolution similarity measurement, while mutual information (MI) is used at fine resolution. The results show that the new efficient mask-based algorithm improves computational efficiency and yields robust and consistent image registration results.

Keywords: Image registration, multi-resolution processing.

1. Introduction

Image registration is to find the best transform between a reference and input image that may be different due to noise and change in position or altitude of sensors in both systematic and nonsystematic geometric errors. Image registration is process involving with alignment of two overlapping images of the same scene acquired from different viewpoints, different sensors or different time. The bottlenecks for improvement the accuracy and efficiency of image registration is computation cost becomes higher and higher when the area of alignment becomes larger and registration technique becomes more complex.

This work, describes a registration procedure based on a multi-resolution analysis of image that is obtained by means of a discrete wavelet transform (DWT). It reduces the computation cost by initially registering images at lowest resolution and then proceeding to higher resolution where the registration process is refined. There are several different methods for measuring the similarity of these methods to image at each resolution level. The complexity of similarity measurement metric should be limited to maintain the goal of this work.

At lower resolution level, the decomposed images contain only a few of image content and detail, but rich with with image intensity information. At this level, image will be searched through the large area of reference image. Therefore, lower complexity of computation is needed for similarity measurement. This paper purposes the correlation matching, that histogram of correlation between reference and search image is established and used as a weighting factor for adjust a mask for determine the possible area of registration. This process only requires a few of statistically computation cost because of a low amount data of low-resolution level. On the other hand, at higher resolution level, image content and detail were reserved in decomposition process. Mutual information can be used to be a similarity metric that requires higher computation cost. Anyway, this process only performs on determined area of previous lower resolution level. Optimization is needed to achieve overall computation cost and amount of search area at each resolution level. At the finest resolution, the conventional cross-correlation or improved technique such as, phase correlation, statically cross-correlation will be applied to yield the final image registration.

2. Correlation matching

This similarity measurement is based on correlation matching. Both coarse resolution images are a decomposed DWT sub-band intensity image. The matching metric can be set by first evaluate the correlation of two function f(x,y) and h(x,y), is defined as

$$r_{fh} = f(x,y) \circ h(x,y) = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f^{*}(m,n)h(x+m,y+n) \tag{1}$$

To enhance the distinction level between preserve and eliminate criterion, weighting factor (k) will be generated and applied before comparing with threshold level and mask generating, what is defined as a Gaussian equation,

$$k_{fh} = \exp\left(\frac{-(r_{ff}-r_{hh})^2}{2\sigma^2}\right) \quad \text{when,} \quad \sigma^2 = \frac{\sum\left(r_{ff}-r_{hh}\right)^2}{N} \tag{2}$$

Then the result of weighted correlation of each sub-image pair will be compared to the threshold level (ε) to generate binary mask for next level analysis. Mask is given

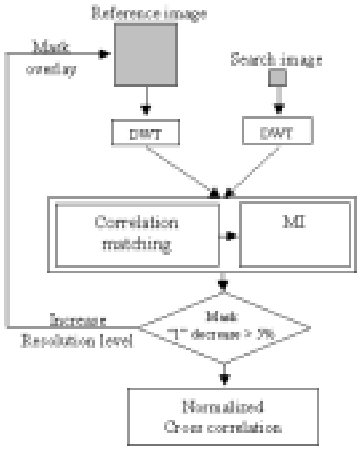


Fig.1. Proposed multi-resolution registration procedure

$$M_{corr\_match}(f,h)=\begin{cases}1 & if\ \varepsilon \le \dfrac{r_{fh}}{\sqrt{r_{ff}\,r_{hh}}}k_{fh}\\[2ex] 0 & if\ \varepsilon > \dfrac{r_{fh}}{\sqrt{r_{ff}\,r_{hh}}}k_{fh}\end{cases} \qquad (3)$$

The matched distance that greater than the threshold level will be eliminated and set as "0" in the mask. On the other hand, it will be preserved and set as "1" in the mask.

3. Mutual information

Mutual information (MI) is based on information theory concepts, measures the amount of information relation between two random variables f and h. This measurement is related with the entropy of the variable distribution and it is determined by,

$$C(f,h)=\sum_{i,j} Pfh(i,j)\log\frac{Pfh(i,j)}{Pf(i).Ph(j)} \qquad (4)$$

where Pf and Ph are the marginal distribution of the random variables f and h, respectively, and Pfh is their joint distribution.

$$M_{MI}(f,h)=\begin{cases}1 & if\ \varepsilon \le C(f,h)\\ 0 & if\ \varepsilon > C(f,h)\end{cases} \qquad (5)$$

4. Proposed multi-resolution image registration procedure

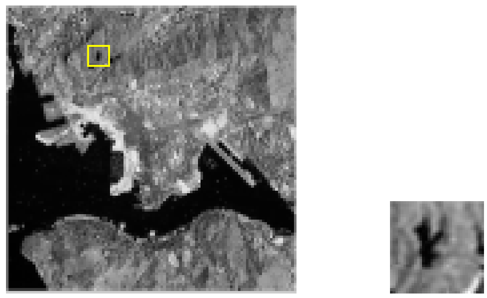
The registration process starts at lowest resolution of low frequency components of DWT (Discrete wavelet transform). The low frequency component of search image then search through the reference image with two similarities, correlation matching by correlation measurement and MI, to generate the mask. This mask used to superimpose to the reference image at higher resolution. The "1" in binary mask is used to preserve the expected registration area and "0" is used to eliminate for unexpected area for reducing the computation in next resolution level. The process starts with the correlation matching then switches to MI similarity measurement when the "1" in mask decrease less than 5% when compared with previous level. The registration process will be completed at finest resolution with normalized correlation measurement that is defined as

$$R(x_0,y_0)=\frac{\sum_{x,y} f(x,y)h(x+x_0,y+y_0)}{\sqrt{\sum_{x,y} f(x,y)^2 \sum_{x,y} h(x+x_0,y+y_0)^2}} \qquad (6)$$

The procedure is shown in fig.1.

5. Experimental results

The image under this experiment is a part of Hong Kong. This reference image size is 256*256 pixel^2, and the search area is a lake with size 32*32 pixel^2, as shown in fig 2. The coarse resolution level is based on the search image size, here is $5 = \log_2(32)$.



(a) (b)

Fig.2. (a).Reference (base) image (b). search image

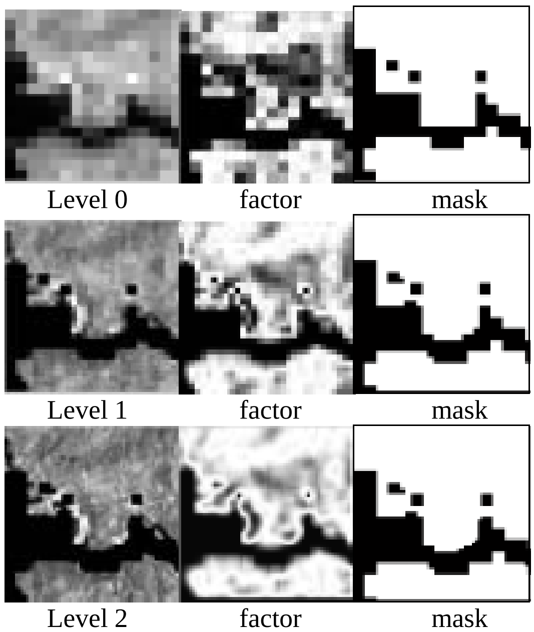


Fig.3. Multi resolution image registration with correlation matching

The process begins at the coarsest resolution (level 0) by correlation matching. The fig.2 shows the experimental result of superimposed reference image, enhancement factor and mask the generation of each level. The process will be repeated through level 3 that "1" in mask increase lower 5% when compared with the previous level. Then, the process switches to use MI similarity measurement to process. Figure 4 shows the result of MI process. The final result of image registration and calculation cost summary are shown in fig.5.

6. Conclusion

These two combined similarity measurement procedure give the efficient of computation. The proposed technique also provides the robust of multi-resolution image registration in the sense of geometric distorted image independent due to non-pixel-wise process. The correlation matching is based on gray level computation, while the MI is based on the statistically computation. Only last step at finest resolution has to be considered for final registration.

. 7. Reference

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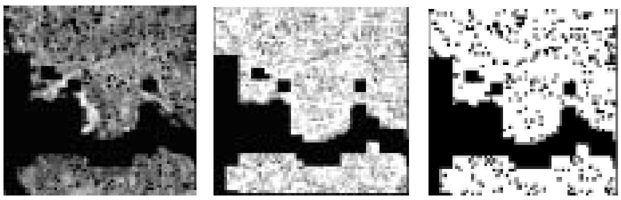
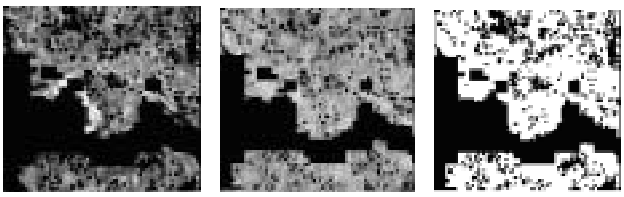
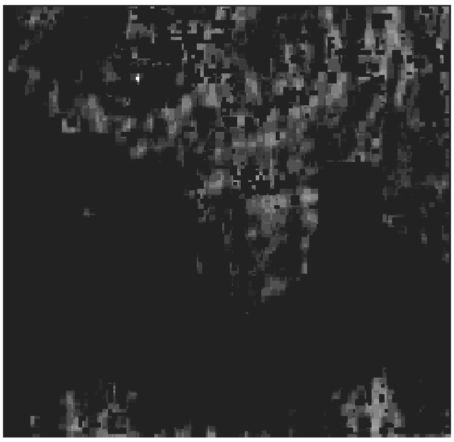


Level 3 MI Mask

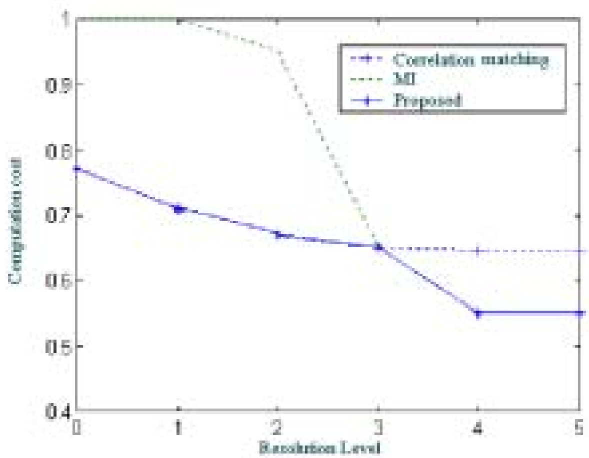


Level 4 MI Mask

Fig.4 Multi-resolution image registration with MI



(a). Normalize cross correlation (Level 5)



(b). Calculation cost

Fig.5 The final image registration and calculation cost