Karhunen Loève Transformation algorithm for automatic image registration

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Given two satellite images (X and Y) sharing some geographic area, we have developed an automatic registration algorithm that finds the relation of correspondence among pixels from X to Y. Classic registration algorithms are based on cross correlation measures or Fourier analysis (see [1]) and also more advanced techniques have been recently introduced (see for example [2] or [3]).

In this work, a pattern recognition technique based on KLT (Karhunen Loève Transformation) is used to perform a registration of two satellite images coming from different sources reaching to a novel aproach.

Outline of our algorithm:

Using a regular grid, the primary image (X) is subdivided in M sub images called patterns. These patterns are searched within the secondary image (Y) running a slide window and calculating distances between each of the patterns and the subimage of the slide window. Points of minima distance means positions of patterns.
Distances and similarity measures in images

Sub images are considered as vectors in $\mathbb{R}^n$. The natural distance measure is the Euclidean distance. Additionally, if we consider the subspace generated by patterns (subimages of $X$) we can measure new euclidean distances which are related with this subspace $S_p$. Also a new measure of similarity is introduced (AFPS):

- **DIPS$_i$($y$)**: Distance In Pattern Subspace between the projection of $y$ and Pattern $i$
- **DFPS($y$)**: Distance From Pattern Subspace
- **AFPS($y$)**: Angle From Pattern Subspace

**Pythagoras formula:**

$$\left\| y - x_j \right\|^2 = DIPS^2_j + DFPS^2$$

The search of patterns within secondary image ($Y$) is performed in a fast way using the Fast Fourier Transform algorithm (FFT) since measures can be written in a convolutive form.
Results

Two images captured by the same satellite sensor (MERIS note 1) in two different days were used to show the efficiency of the algorithm. Here, the results of using the AFPS measure are presented. Primary image X was divided in 16 patterns. The following Figure shows the AFPS calculated as a function of the position of the sliding window in the secondary image and post processed with a point detector filter. Note that 14 of 16 patterns were correctly detected.

Conclusions

An efficient algorithm for registration of satellite images were presented based on KLT and AFPS similarity measure. A fast calculation of distances is available through the FFT algorithm. The algorithm showed excellent results also in cases where visual identification is almost impossible (see Pattern 6 and 7 examples above).

Note1: Satellite Image source: ESA (European Space Agency)