Structure Driven SAR Image Registration

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The Problem:

Even though it is an easy task for a human observer to register two SAR images with different viewing geometries, it is very difficult problem for the techniques that currently exist for automating this process.

Motivation:

To build maps of extremely large areas using synthetic aperture radar (SAR) it is impractical to attempt to sweep the entire region in a single pass. Instead images generated from small regions must be accurately "stitch" together to generate a target image. To ensure that during this stitching process the "seams" between the images must be carefully aligned to account for variations in heading, altitude, squint angle and a host of other variations which can occur during the imaging process. To do this the images must be accurately registered to one another.

A second use for accurate SAR image registration, is that it would allow for accurate change detection. Allowing for the monitoring of the movement of vehicles, missiles and temporary structures.

Previous Work:

SAR image registration techniques such as mutual information [3] maximization, which attempt to recover a precise pixel-by-pixel registration are plagued with local minima, and therefore must be "seeded" with an initial guess which is close to the final registration.

Approach:

By reasoning at the level of objects, or recognizable regions, human observers greatly simplify the matching problem. In this research, we attempt to mimic this notion of using recognizable regions to produce an approximate "object-level" (as opposed to pixel-level) registration. Using a multi-scale image representation, unique regions are identified in one of the images. These regions then serve as "landmarks" for aligning the second image.

Distinctive regions provide significant constraint on the correct registration, while more recurrent areas provide little or no useful information. Localized objects, such as structures or vehicles match only few locations, (such as the green regions in Figure 1) thus providing strong constraints on registration. Extended elements, roads or tree-lines match a small area (shown in blue) providing a one dimensional constraint. Common elements, e.g. grass or forest, match large portions of the image (shown in red), and provide almost no useful information. Using the only the most distinctive regions as landmarks, reduces the computational requirements and increases the performance of most registration algorithms.

By determining those regions which have low expected mutual information with other regions in the image, given a predictive model, landmarks are found automatically.

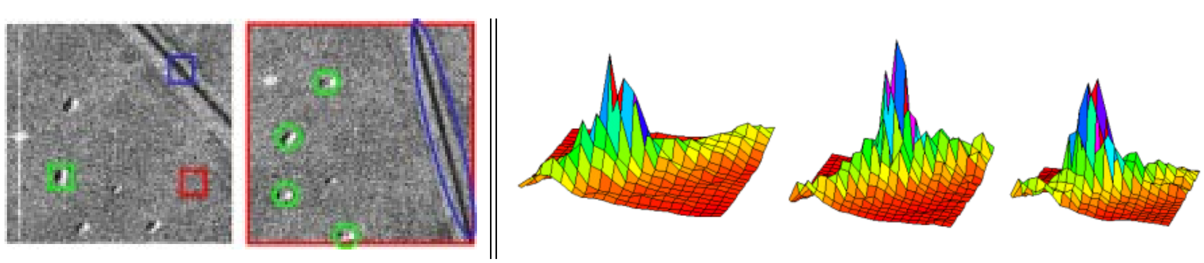

Figure 1: Left: Distinctive regions (green and somewhat less so, blue) provide significant constraint on the correct registration, while more recurrent areas (red) provide little or no useful information. Right: Match-similarity space for multiple resolution matches for the left image pair in Figure 2.

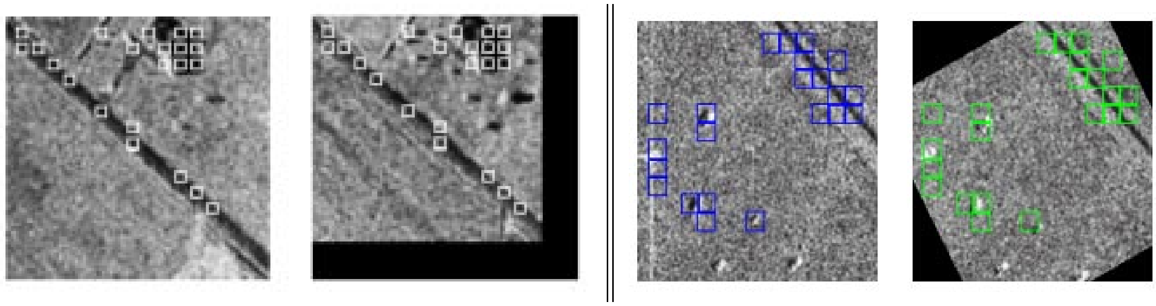

Figure 2: Two typical registrations.

To perform the underlying landmark determination and match operations, a we measure the joint occurrence of local features at multiple resolutions to measure the likelihood that landmarks contain the same textures as the corresponding regions in the match-image [2, 1]. This approach results in a match-similarity space that is far smoother than those of local pixel based techniques, and as a result, the global optimum can be easily found; shown by the surfaces in Figure 1 for coarse to fine matches.

Thus, accurate registration of two images is found regardless of the imaging geometry or initial "seeding."

Difficulty:

Because of artifacts in the SAR imaging process, such as speckle and shadowing, registration techniques which are reasonably robust for optical images fail dramatically. This is due to the creation of local minima cause by the drowning out of true features, such as roads and trees, by the SAR artifacts.

Using region texture similarity measure results in a much smoother search space, in which multiresolution gradient based optimization approaches can be successfully applied. Two typical registrations are shown in Figure 2.

Impact:

Experiments indicate that precise registration can be obtained. Furthermore, the performance is robust and fully automatic, and can be successfully applied to images which vary greatly in physical imaging conditions, region of overlap and scene complexity.

Future work:

From this research, a full scale SAR image registration system will be developed and deployed. Further, these techniques can be directly applied to other sensor types, and can be used with highly cluttered optical images for which simpler methods typically fail.

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References:

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