Fusion of Information from SAR and Optical Images

Zoran Sjanic*,** Fredrik Gustafsson*
*Linköping University **Saab Aeronautics

Contribution

- Utilising of SAR as a pose sensor in the sensor fusion framework
- A robust method for matching SAR and optical images

Background

The method for creating high resolution Synthetic Aperture Radar (SAR) images is to integrate all the low resolution Real Aperture Radar images taken along the synthetic aperture by the flying platforms, such as aircraft or satellites. These images are very similar to the optical images, although some differences can appear, since these images are based on the radar reflectivity of the scene. The big advantage of the SAR is that it can produce the images in all weather conditions, while an optical sensor will be occluded by the clouds or darkness. The idea is to match the SAR images to the optical map images and in that way obtain position updates. The method will be illustrated on the SAR and the optical map image of the Capitol Hill with surroundings in Washington DC shown below. The SAR image is both rotated and translated relative to the optical image. The patches which are matched are marked in the SAR image.

Images: Sandia National Labs. & Google Maps

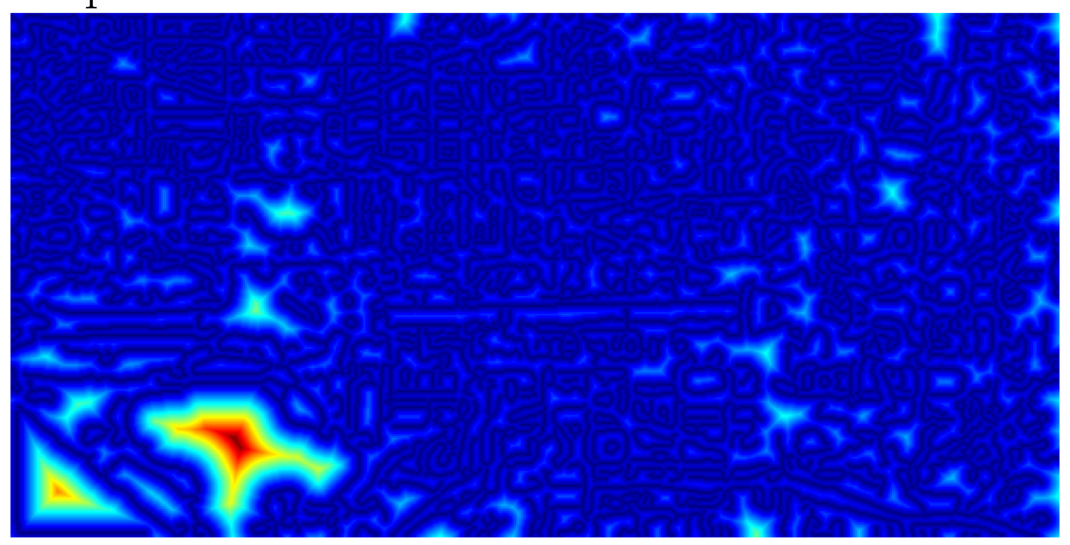
Method

Chamfer Matching

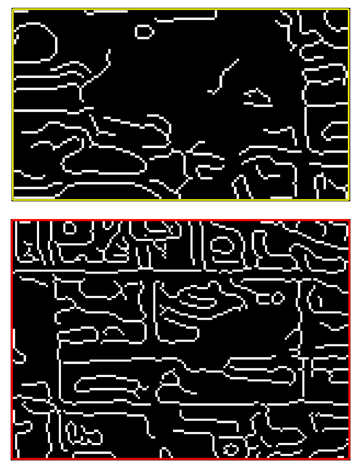
The method for matching images used is Chamfer matching. The Chamfer matching is a robust parametric method for matching template images to the source images. It utilises distance transformed source (map) image, D, and calculates the translation, represented with the range, r, and the azimuth, a, and the rotation, χ, of the template (binary edge SAR) image patch, T, as

$$(\hat{r}, \hat{a}, \hat{\chi}) = \arg\min_{r,a,\chi} f(D \odot T(r, a, \chi))$$

$\odot$ is the elementwise matrix multiplication and $f : \mathbf{R}^{\text{size}(D)} \rightarrow \mathbf{R}_+$, is some positive and monotone function.



Distance transformed optical image.



Binary edge SAR image patches.

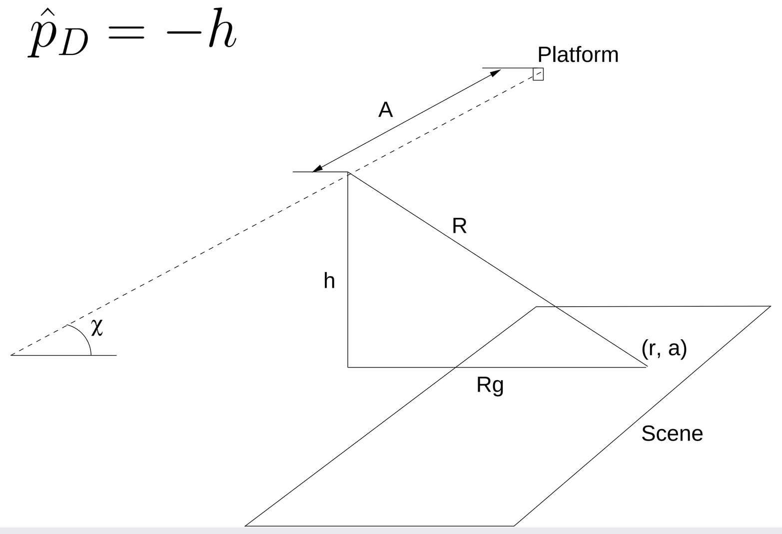
Pose Estimation

After obtaining the matching pixel values $(\hat{r}, \hat{a})$ the geographical coordinates (r_T, a_T) are extracted from the map image. The relative platform's position (R_g, A, h) can be found with the triangulation from several patches and the following relations (see also geometry figure below)

$$R = r_S \Delta_R, \quad A = a_S \Delta_A$$

where r_S and a_S are the coordinates of the upper left corner of the SAR patch and Δ_R and Δ_A are the SAR image resolutions. These parameters are then used to estimate the platform's geographical position $(\hat{p}_N, \hat{p}_E, \hat{p}_D)^T$ as

$$\begin{aligned}
\hat{p}_N &= a_T + A\cos(\hat{\chi}) + R_g \sin(\hat{\chi}) \\
\hat{p}_E &= r_T + A\sin(\hat{\chi}) - R_g \cos(\hat{\chi}) \\
\hat{p}_D &= -h
\end{aligned}$$



Results and Conclusions

Results from the matching procedure with two different SAR image patches are shown below. The SAR patches are overlayed on the optical images and the match is very accurate, both in position and rotation.

- Robust parametric estimation method
- No GNSS is used
- Method works better when the scene is structured
- Better results with a high frequency SAR
- Can easily be combined with several sensors, *e.g.* vision

Future Work

- Applying method to the low frequency SAR – CARABAS
- Characterise the noise in the produced measurements