Simultaneous Navigation and SAR Auto-focusing

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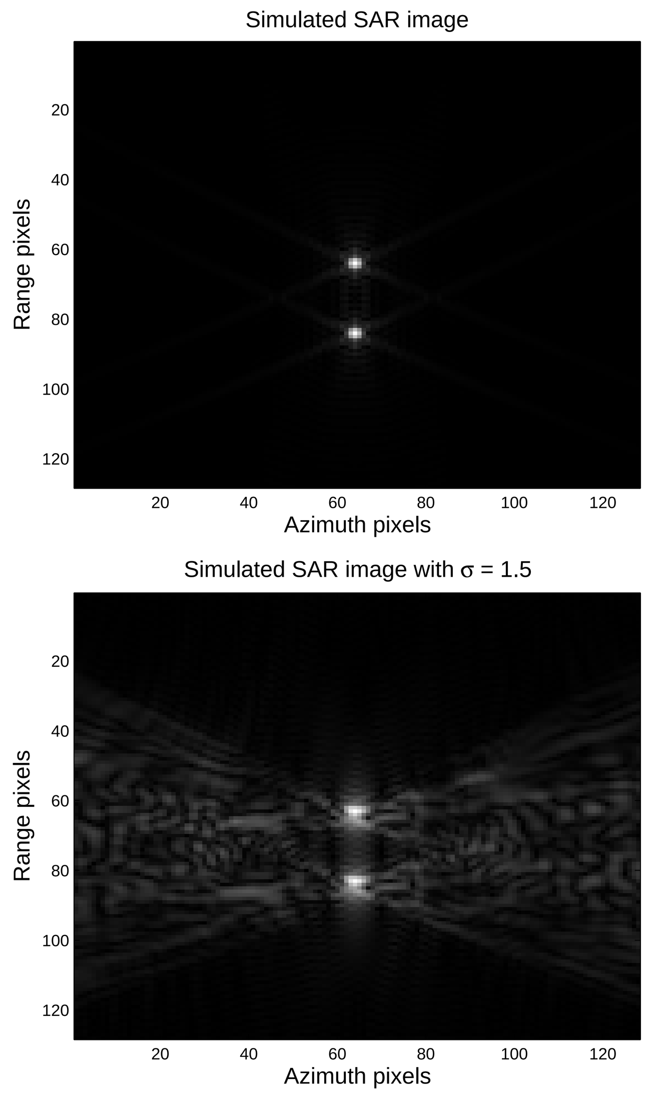
Contribution

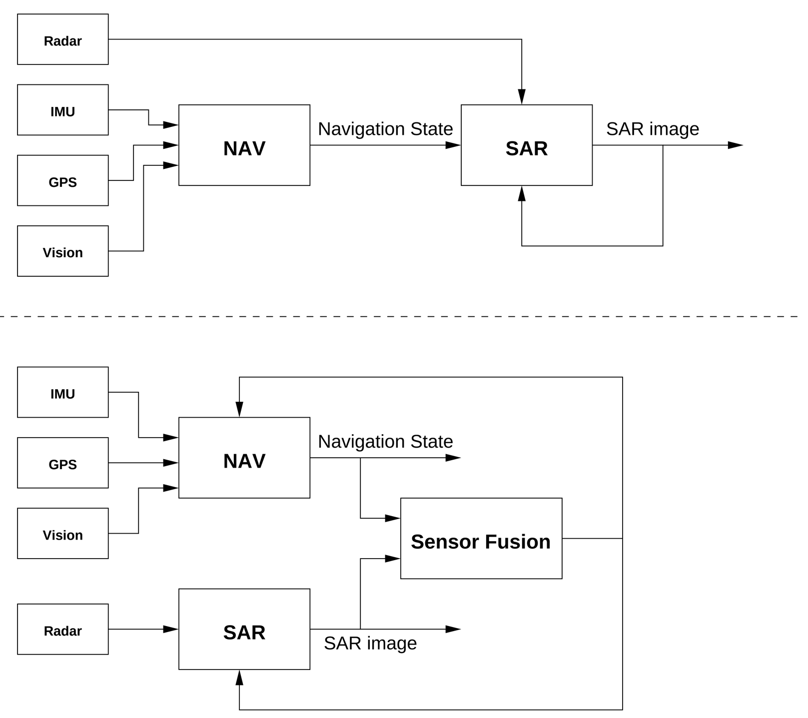
- Possibility of obtaining good images and good navigation solution
- New way of utilizing SAR as a sensor in Sensor Fusion framework

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. In order for this operation to produce high quality images, it is crucial that the flown path is known, otherwise the images will be distorded. One of the most common distortions is image defocus. This is illustrated in the figures to the left where SAR images of two point targets are simulated, one with linear unperturbed track and the other with a linear perturbed track.

Problem Formulation



Many methods for auto-focusing of SAR images are present today and they are usually based on phase error estimation or image processing type methods. Since the computational systems and SAR processing algorithms are getting better, on-line, real time SAR image creation is becoming possible. Then it becomes natural to use SAR images in the sensor fusion framework. The information from the image defocusing and navigation system can be fused and utilised to obtain the best solution to both focusing and navigation simultaneously.

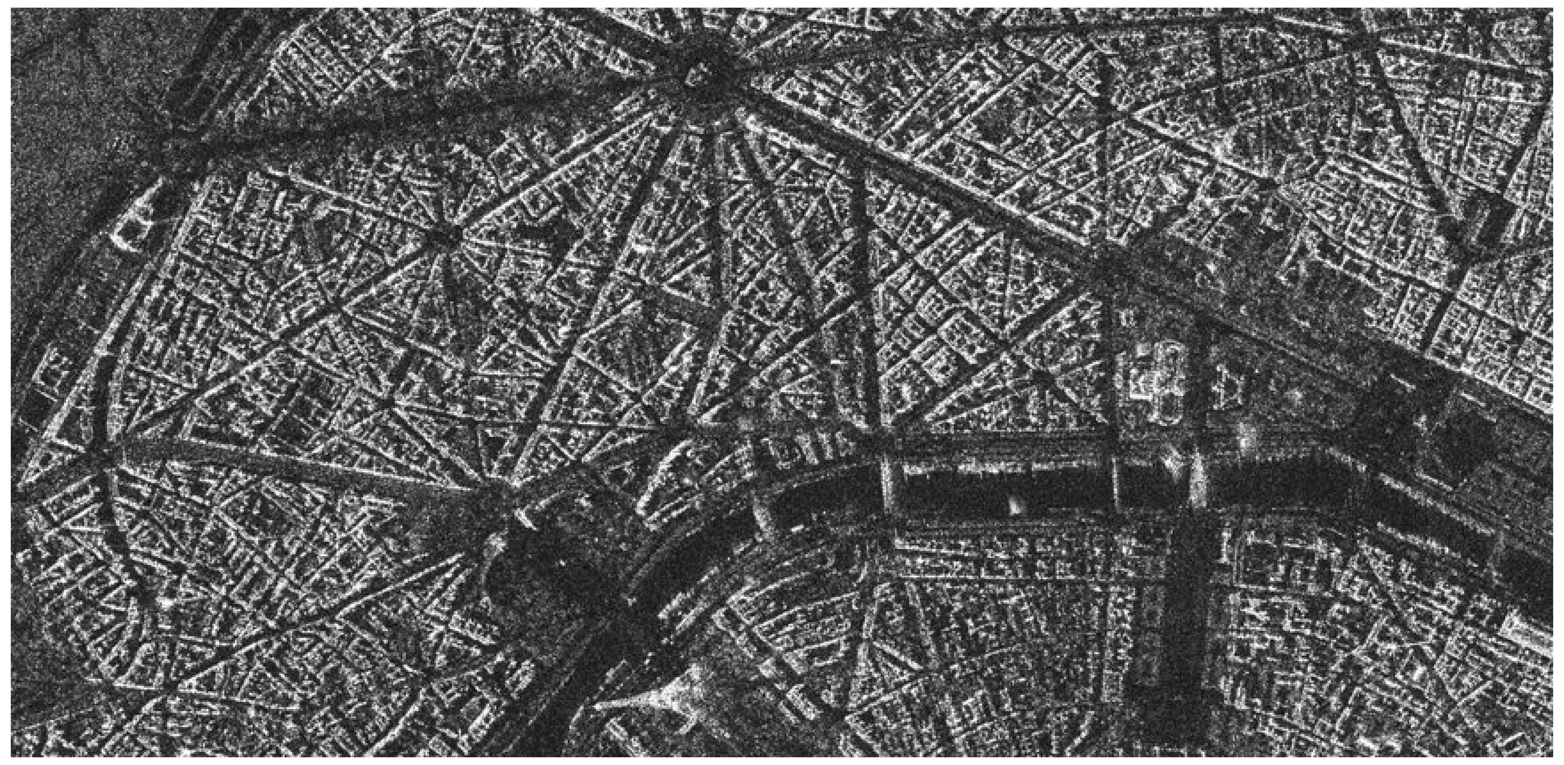
The following minimisation problem can be formulated

$$\min_{x_0,\ w_{1:N}} \gamma_F F(x_{0:N}) + \gamma_s \sum_{k=1}^{N} ||y_k - h(x_k, u_k)||^2_{R_k}$$

subject to

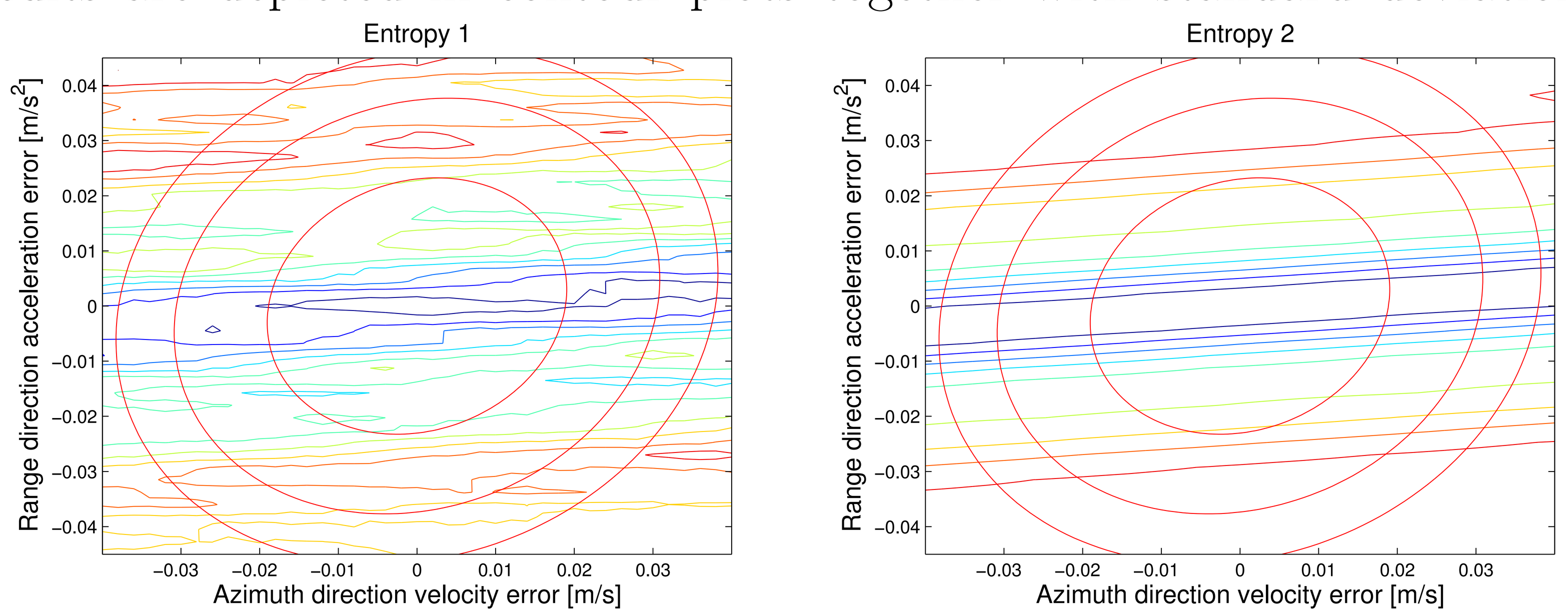
$$x_{t+1} = f(x_t, u_t, w_t), \quad w_t \sim \mathcal{N}(0, Q_t)$$

where the scalar function $F(x_{0:N})$ is a measure of how focused the image is and it depends on the whole trajectory $x_{0:N}$, and in particular on the velocity in the along-track (azimuth) direction, v_t^X, and the acceleration in the cross-track (range) direction, a_t^Y.

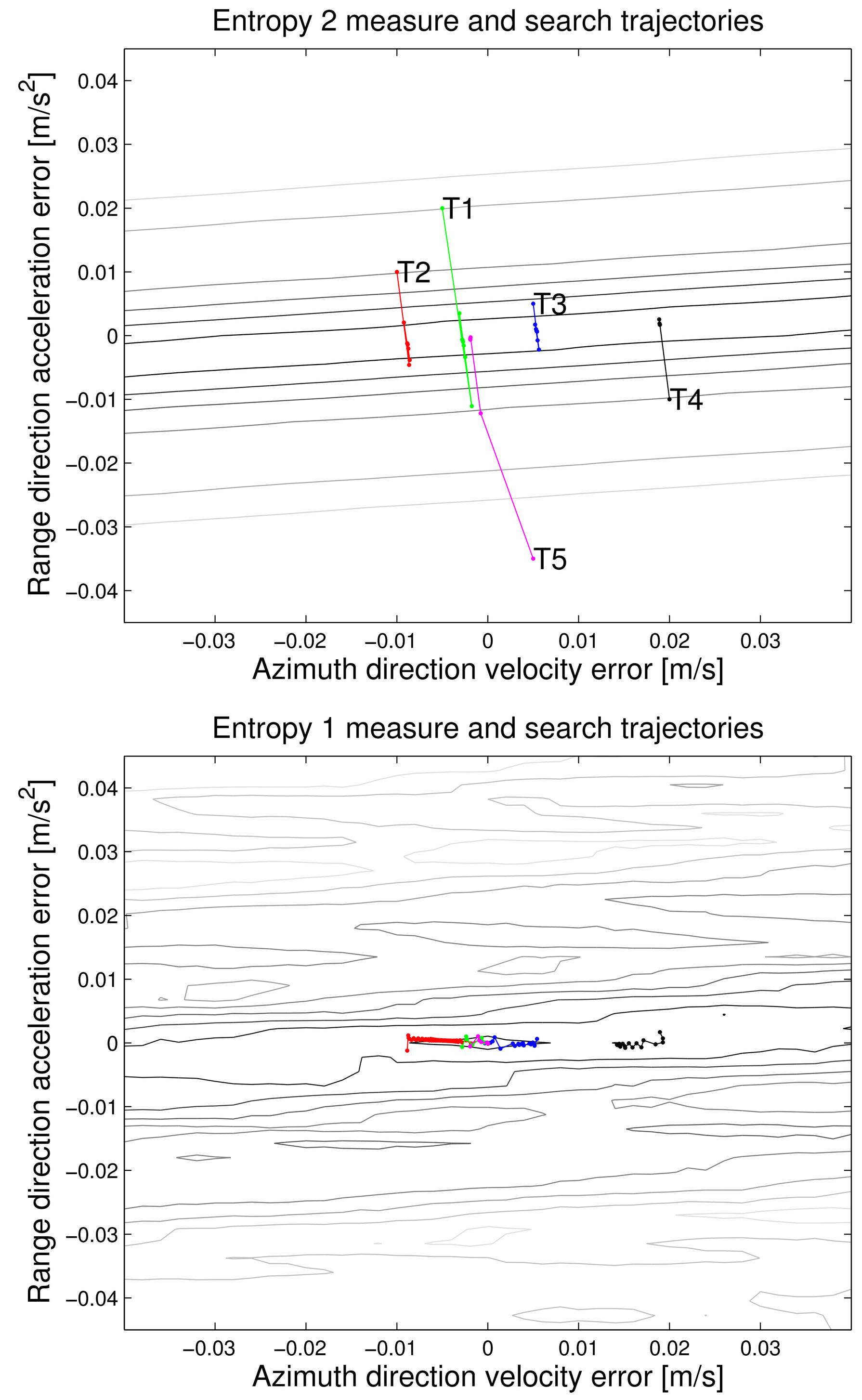


Evaluation of Focus Measures

A common and popular focus measures representing $F(x_{0:N})$ is image entropy. Two different versions of the entropy measure have been evaluated and compared for the error in initial values of the states and results are depicted in contour plots together with standard deviations.



Gradient Search



- One entropy measure is nonconvex and nonsmooth but has sharp global minimum
- Another entropy measure is convex and smooth but very flat near global minimum
- Combination of both measures has potential of obtaining good results but local minima problem still exists

Conclusions and Future Work

- Method has potential of obtaining good SAR images and fairly accurate estimates of the navigation states
- Some fundamental limitations in possibilities of obtaining good estimates
- Use raw radar data and centralised sensor fusion framework leading to filtering like methods