LINK-SIC

Navigation and SAR Auto-focusing in Filtering Framework

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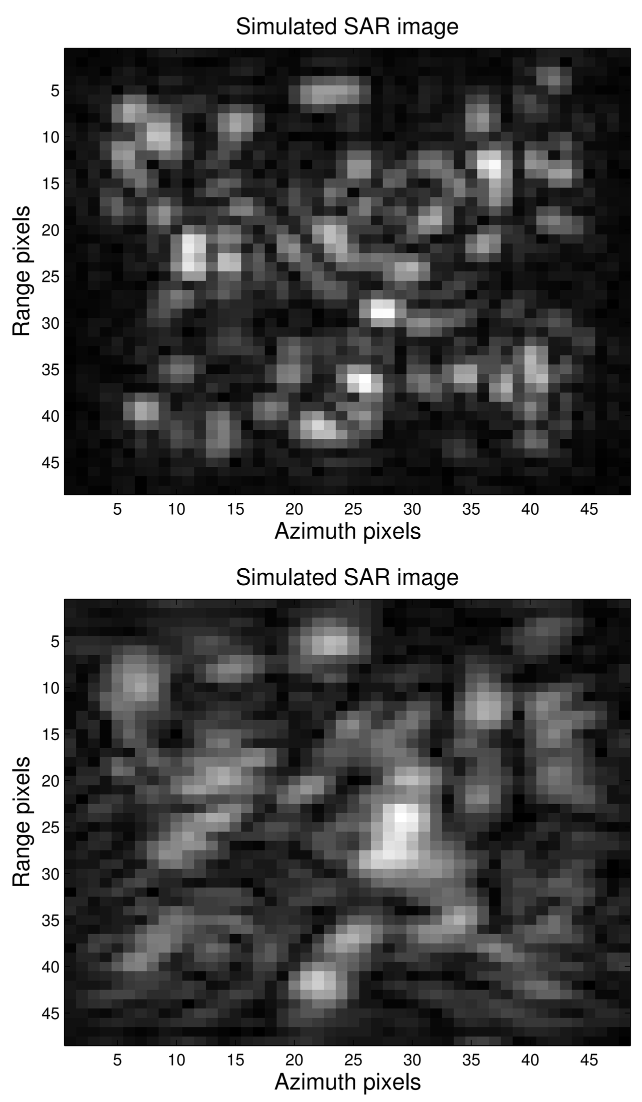
Contribution

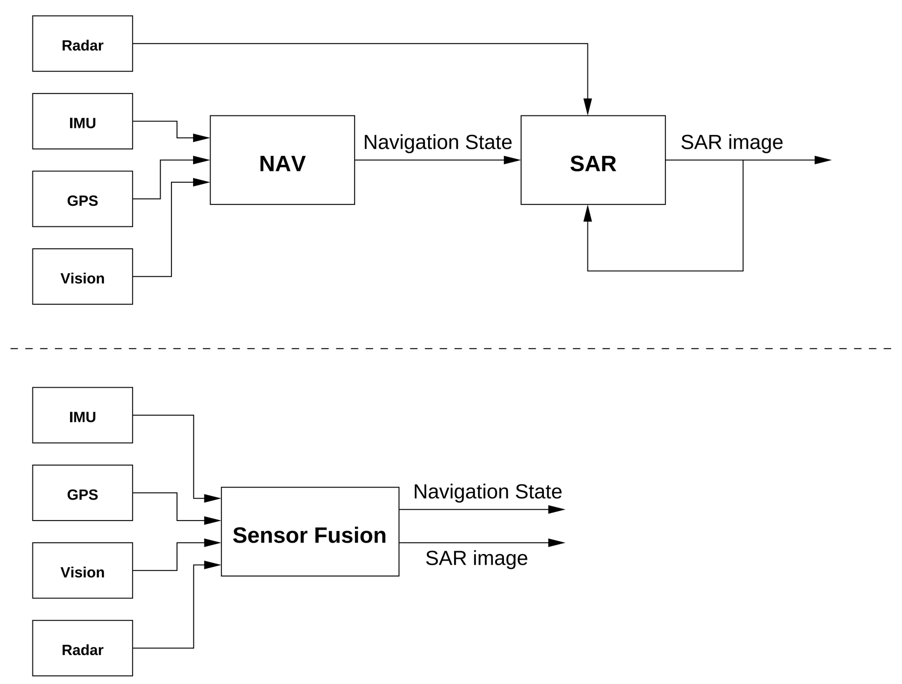
- New way of utilizing SAR data in the sensor fusion framework
- Possibility of obtaining good images and good navigation solution simultaneously

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 the 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

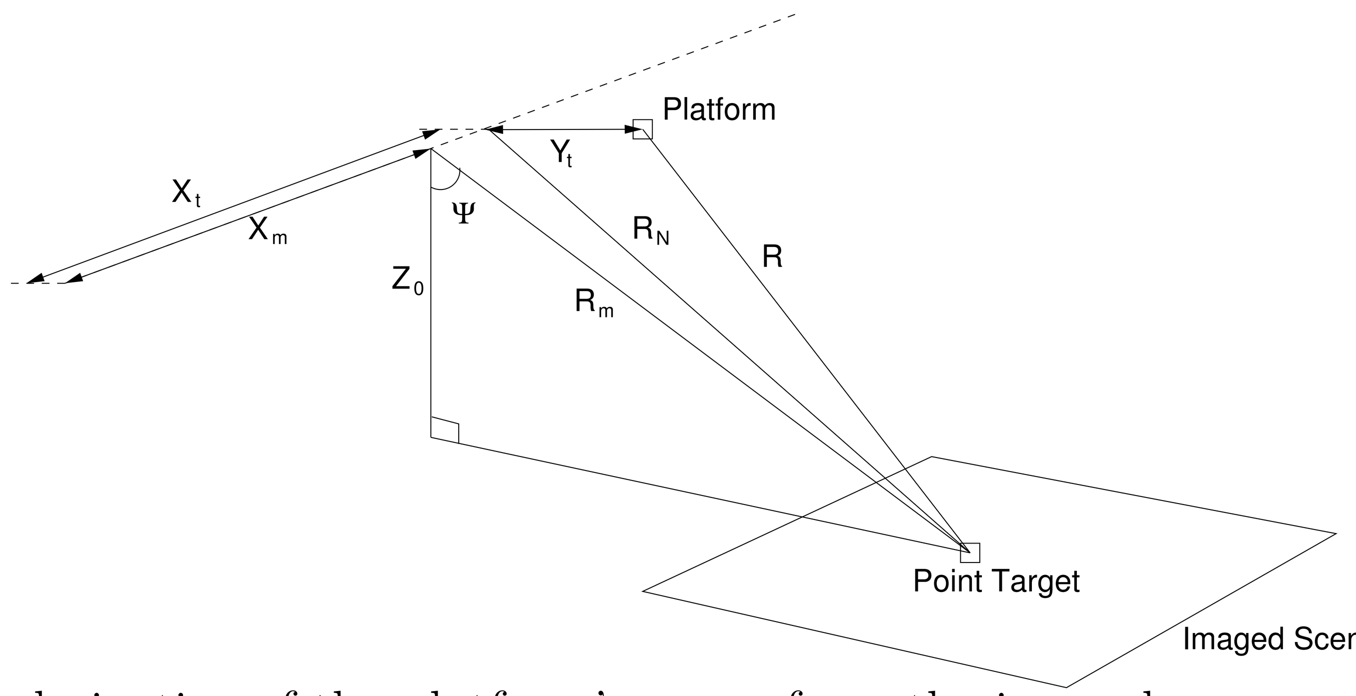


Many methods for auto-focusing of SAR images are present today and they are usually based on phase error estimation or image processing type methods. Since the computational systems and SAR processing algorithms are getting better, on-line, real time SAR image creation is becoming possible. Then it becomes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

$$x_{t+1} = f(x_t, w_t), \qquad w_t \sim \mathcal{N}(0, Q_t),$$
$$y_t = h(x_t) + e_t, \qquad e_t \sim \mathcal{N}(0, R_t),$$

where y_t contains measurements from inertial system and radar data, any nonlinear filter, like Extended Kalman Filter (EKF), can be applied to estimate the navigation states.

Measuring the Range Derivative



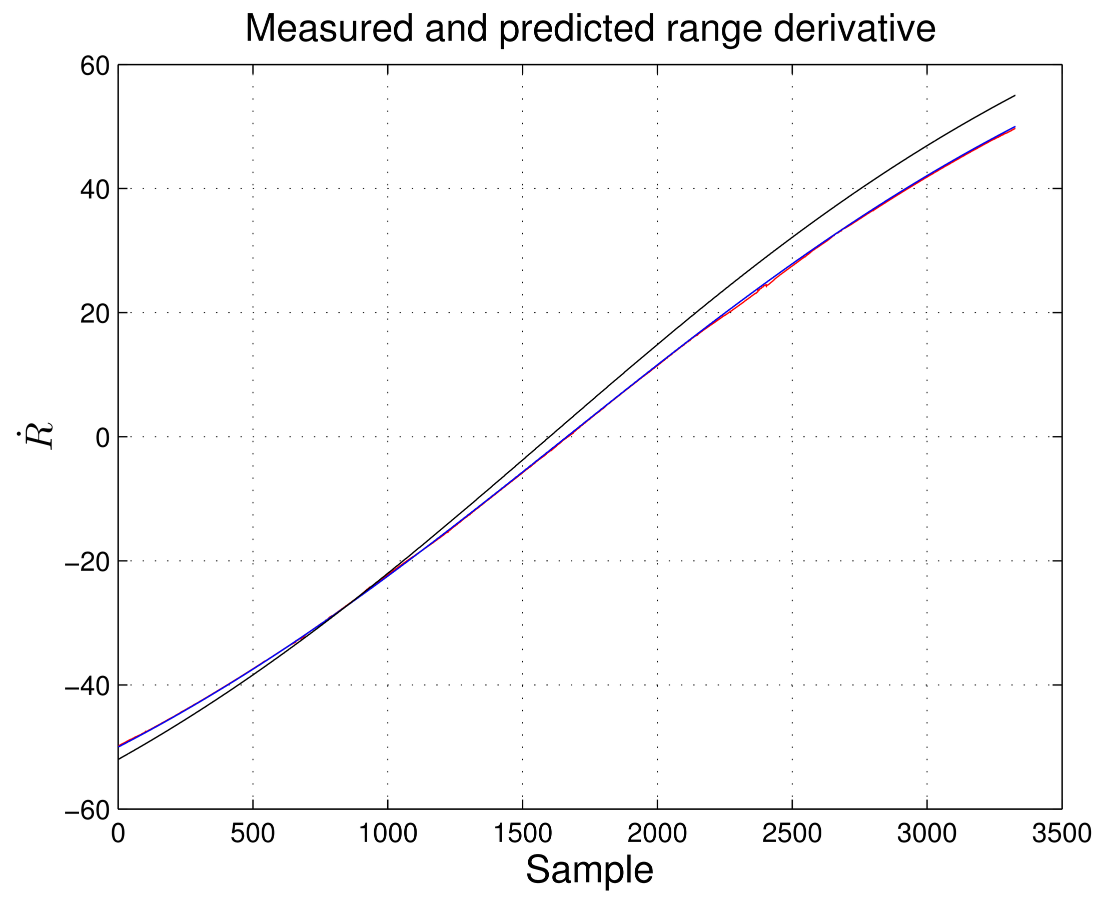
Time derivative of the platform's range from the imaged scene can both be estimated from raw radar data

$$y_t^{\dot{R}} = -\frac{\lambda}{4\pi M^2}\sum_{i,j}\text{Im}\left\{\frac{\ln I_t^{ij} - \ln I_{t-T}^{ij}}{T}\right\}, \; i = 1,\dots,M, \; j = 1,\dots,M$$

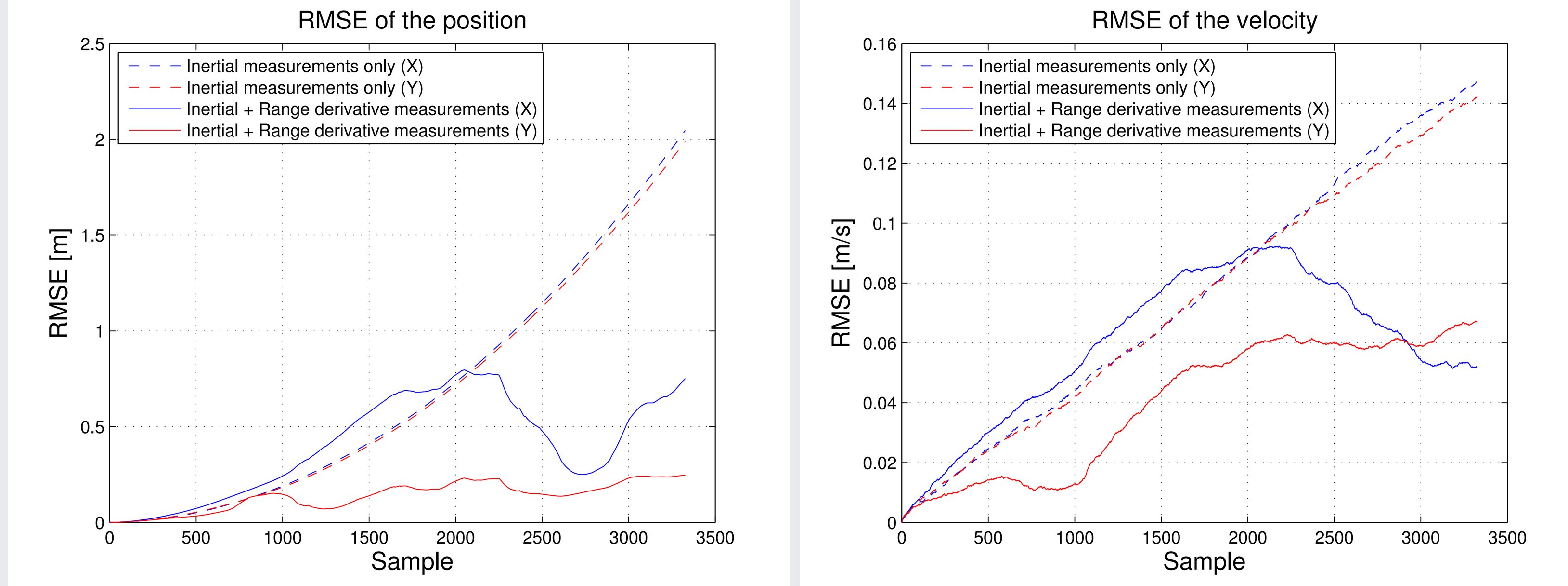
and expressed analytically as a function of the platform's states

$$h^{\dot{R}}(x_t) = \frac{-(X_m - X_t)v_t^X + Y_t v_t^Y - R_N\sin(\Psi)v_t^Y + \frac{Y_t\sin(\Psi)(X_m - X_t)v_t^X}{R_N}}{\sqrt{R_N^2 + Y_t^2 - 2R_N Y_t \sin(\Psi)}}$$

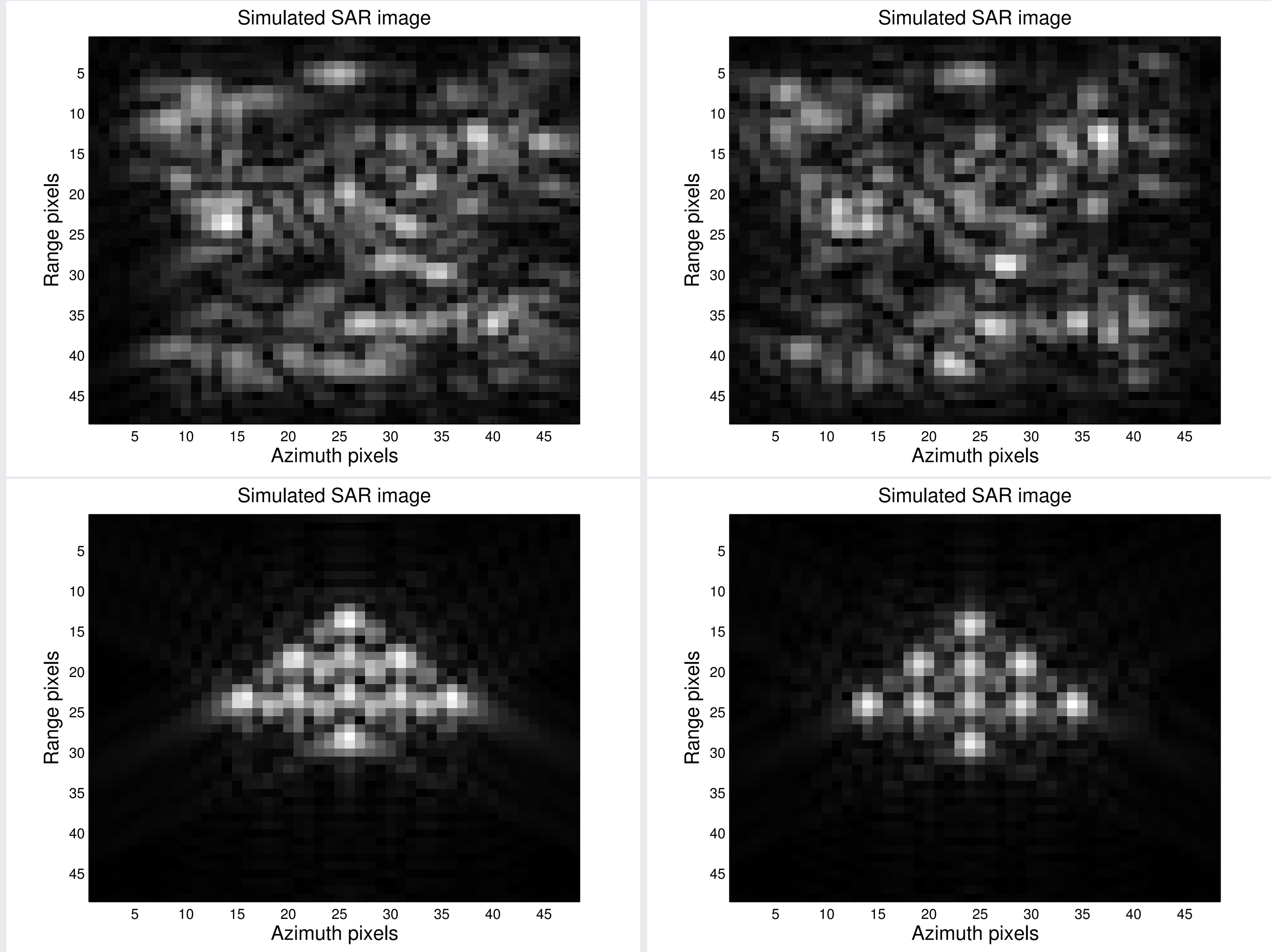
$$R_N = \sqrt{R_m^2 + (X_m - X_t)^2}$$



Results and Conclusions



RMSE for the position and the velocity for the unstructured scene



Only inertial measurements — Inertial + Range Derivative measurements

- Navigation states estimate and image focus are improved
- No GNSS is used
- Method works better with structured scenes
- Method is suitable for real time SAR applications
- Can easily be combined with several sensors, e.g. vision

Future Work

- Finding a better way to estimate the range gradient
- Applying different filters, e.g. Particle Filter
- Use real SAR measurements and images