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Range tracking for the MRS radar

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1 Introduction

In the MRS radar system at the DDRE there has been a need to perform a rough range tracking of ships or aircrafts. The purpose is to enable automatic setting of the active range gate in which data is recorded. Two steps are involved. First a range of the possibly extended object has to be defined. Secondly the track has to determined.

2 Range

The range to a target is calculated as the amplitude-squared-weighted sum of the ranges within the open range gate. (This results in flat apparatus noise.) The sums needed to calculate the amplitude-squared weighted range are

$$C_0(r,t) = \sum_{r'=r}^{r+s-1} |A(r',t)|^2 \tag{1}$$

$$C_1(r,t) = \sum_{r'=r}^{r+s-1} |A(r',t)|^2 \, r' \, \Delta r \tag{2}$$

where r is the first active bin, s is the number of active bins, and Δr is the size of each active range bin. We allow for an optional subtraction of the local or global background. The local background sums are calculated in the immediate neighbourhood of the active bin as

$$B_0(r,t) = \frac{1}{2}\left(\sum_{r'=r-s}^{r-1} |A(r',t)|^2 + \sum_{r'=r+s}^{r+2s-1} |A(r',t)|^2 \right) \tag{3}$$

$$B_1(r,t) = \frac{1}{2}\left(\sum_{r'=r-s}^{r-1} |A(r',t)|^2 \, r' \, \Delta r + \sum_{r'=r+s}^{r+2s-1} |A(r',t)|^2 \, r' \, \Delta r \right) \tag{4}$$

The resulting local-background-subtracted sums are then

$$S_0(r,t) = C_0(r,t) - B_0(r,t) \tag{5}$$
$$S_1(r,t) = C_1(r,t) - B_1(r,t)\ . \tag{6}$$

The range, $r_{\max}$, which maximizes $S_0(r,t)$ is selected and the range calculated as

$$R(t) = \frac{S_1(r_{\max},t)}{S_0(r_{\max},t)}\ . \tag{7}$$

In the implementation we allow for a threshold to be applied to $S_0(r_{\max},t)$. If rejected, the previous range is reused.

3 Moving average

A simple exponentially damped moving average filter is implemented as a means of smoothing the observed track. The latest estimate of the position is then used as a "prediction" of the next center of the range gate.

Let $R(t)$ be the measured range at time step t. The filter is simply

$$R_S(t) = \alpha R_S(t-1) + (1-\alpha)R(t) \tag{8}$$
$$= (1-\alpha)\sum_{\tau=0}^{\infty}\alpha^{\tau}R(t-\tau) \tag{9}$$

where α is a constant close to 1. The damping factor α is related to the characteristic time τ in the exponential damping and the time resolution Δt by

$$\alpha = \exp\left(-\Delta t/\tau\right). \tag{10}$$

Finally, we allow for a velocity cut on $R_S(t)$.

The "prediction" is taken simply as R_S shifted

$$R_T(t) = R_S(t - t_{\text{pred}}). \tag{11}$$

For prediction times as small as 0.1 s there is no call for more advanced predictors than the exponentially damped tracks. For larger prediction times one could consider e. g. the Kalman filter described in [1].

4 Results

In figures 1-3 examples of detected ranges and exponentially damped tracks are shown for an aircraft moving at 150 m/s and a ship moving at 2.5 m/s. The simple method described in the above clearly solves the "tracking" problem.

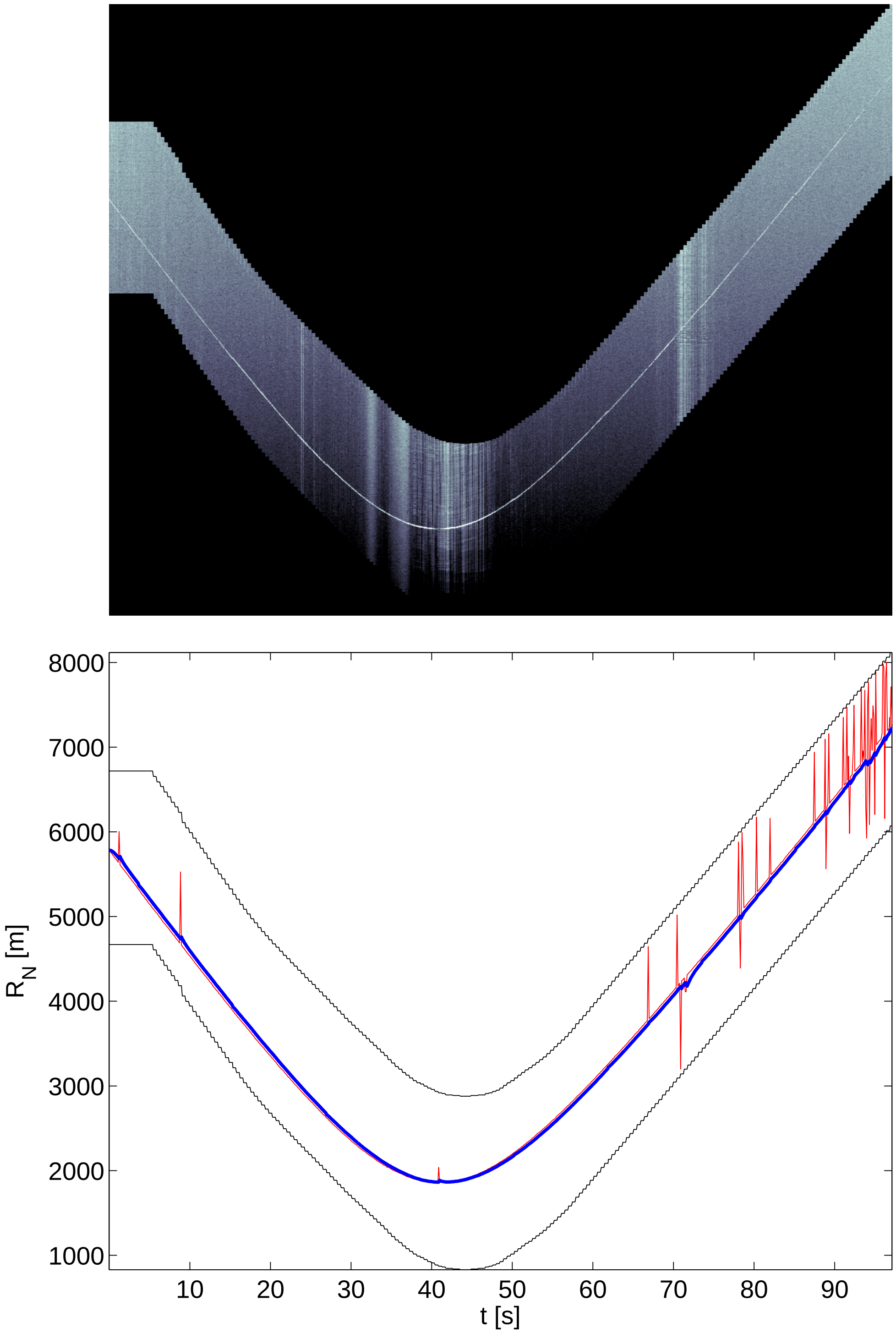

Figure 1: Aircraft. Top: Raw data. Bottom, red: Range detected in a 24 m window without background subtraction. (Cross section threshold $0.1\,\mathrm{m}^2$.) Bottom, blue: Exponentially damped "prediction" with 0.5 s memory, 200 m/s velocity constraint, and shifted 0.1 s.

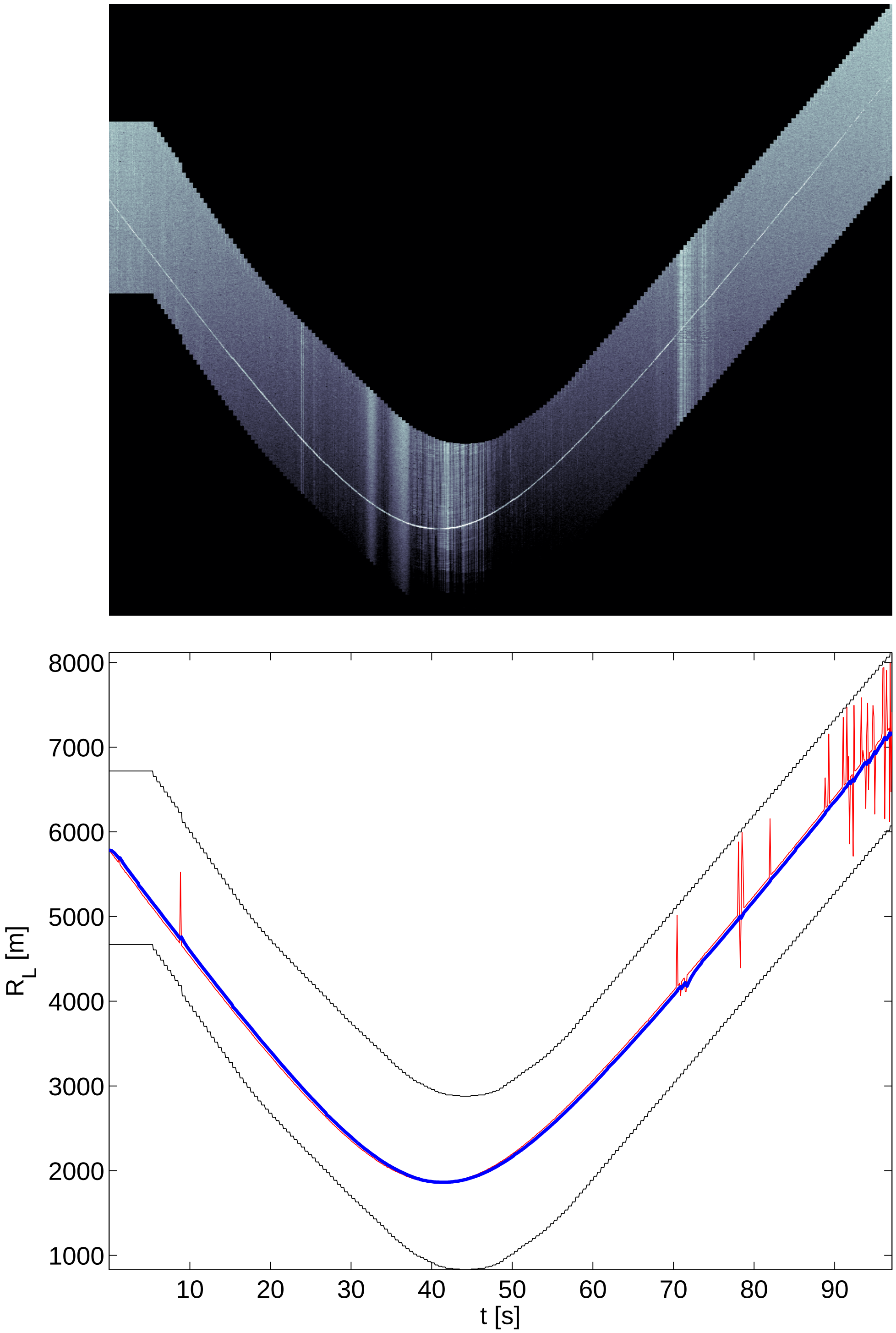

Figure 2: Aircraft. Top: Raw data. Bottom, red: Range detected in a 24 m window with local background subtraction. (Cross section threshold 0.1 m^2.) Bottom, blue: Exponentially damped "prediction" with 0.5 s memory, 200 m/s velocity constraint, and shifted 0.1 s.

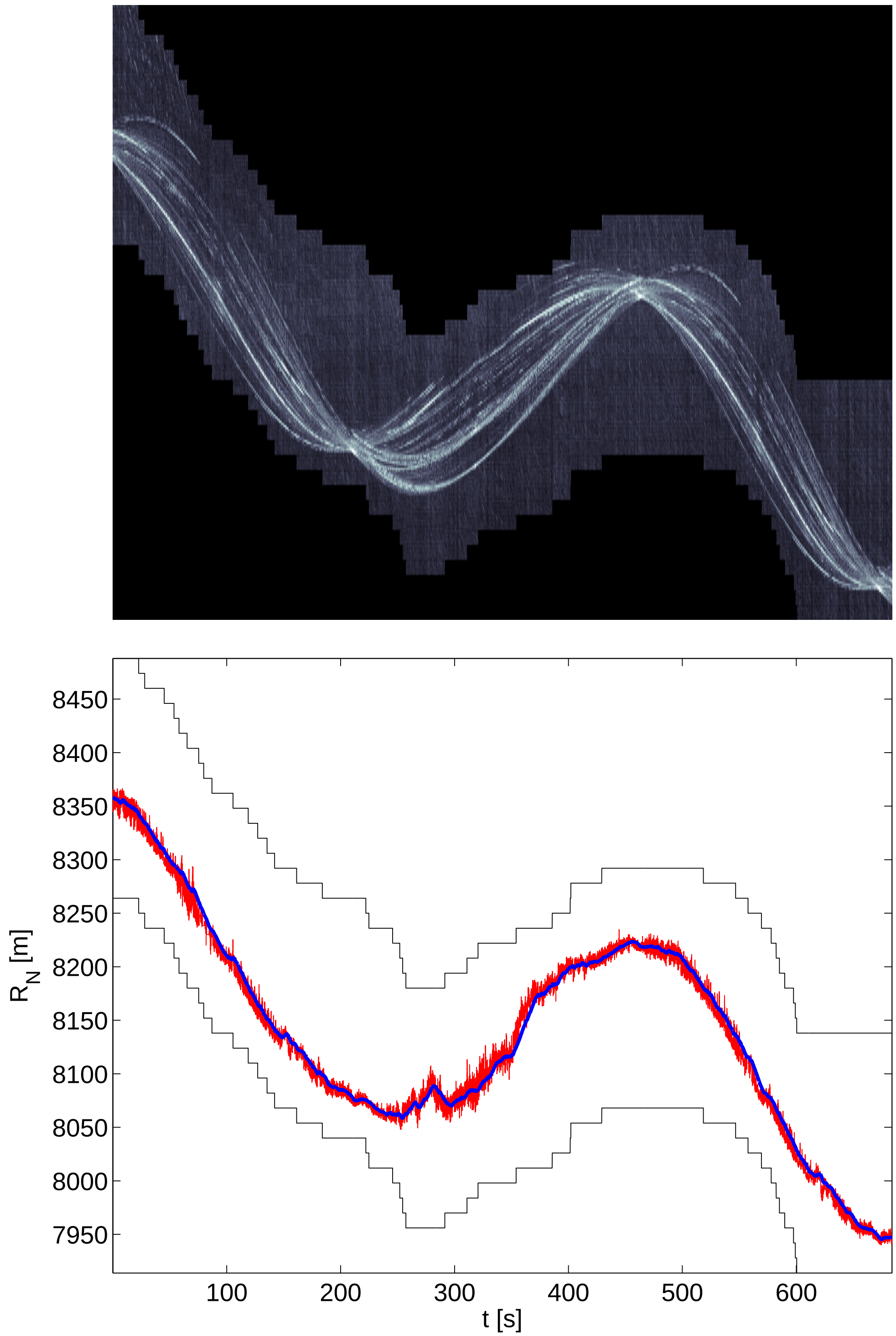

Figure 3: Absalon. Top: Raw data. Bottom, red: Range detected in a 100 m window without background subtraction. (Cross section threshold 300 m^2.) Bottom, blue: Exponentially damped "prediction" with 3 s memory, 3 m/s velocity constraint, and shifted 0.1 s.

References

[1] J. M. Hansen, FOFT Rapport nr. A-04/2005, *Kalmanfilter til anvendelse i FOFT Modulre Radar System*