Autoregressive Model for Multi-Pass SAR Change Detection Based on Image Stacks

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Outline

- Introduction/Motivation;
- Data description;
- AR model;
- Experimental Results;
- Application;
- Conclusions.

Introduction

SAR change detection is usually used to detect changes in time between to images.

Generally, the changes are natural disasters or deforestation and installations [1, 2, 3].

Currently used algorithms are mainly designed for two SAR images retrieved at different instants.

Introduction

However, the use of the SAR image stack (more than two images observed in different times) emerges as a research topic on SAR change detection.

The stacks are based on the fact that the passes, the heading angles of the platform, and the incident angles, are almost identical [4].

Introduction

Figure 1: Images samples of the stack.

Data description

The data used for this study were delivered by CARABAS II [5], a Swedish ultra-wideband VHF SAR system.

The data included eight images with almost identical flight geometry, but with four different targets deployments in the ground scene [6, 5].

Data description

Each image is represented by a matrix of 3000×2000 pixels, corresponding to an area of 6 km^2.

The ground scene is dominated by forest with pine trees. Fences, power lines and roads were also present in the scene.

Some military vehicles were deployed in the SAR scene and placed in a manner to facilitate their identifications in the tests [5].

Data description

Figure 2: Image of the terrain vehicles used as targets during the experiment, presented in [5].

Data description

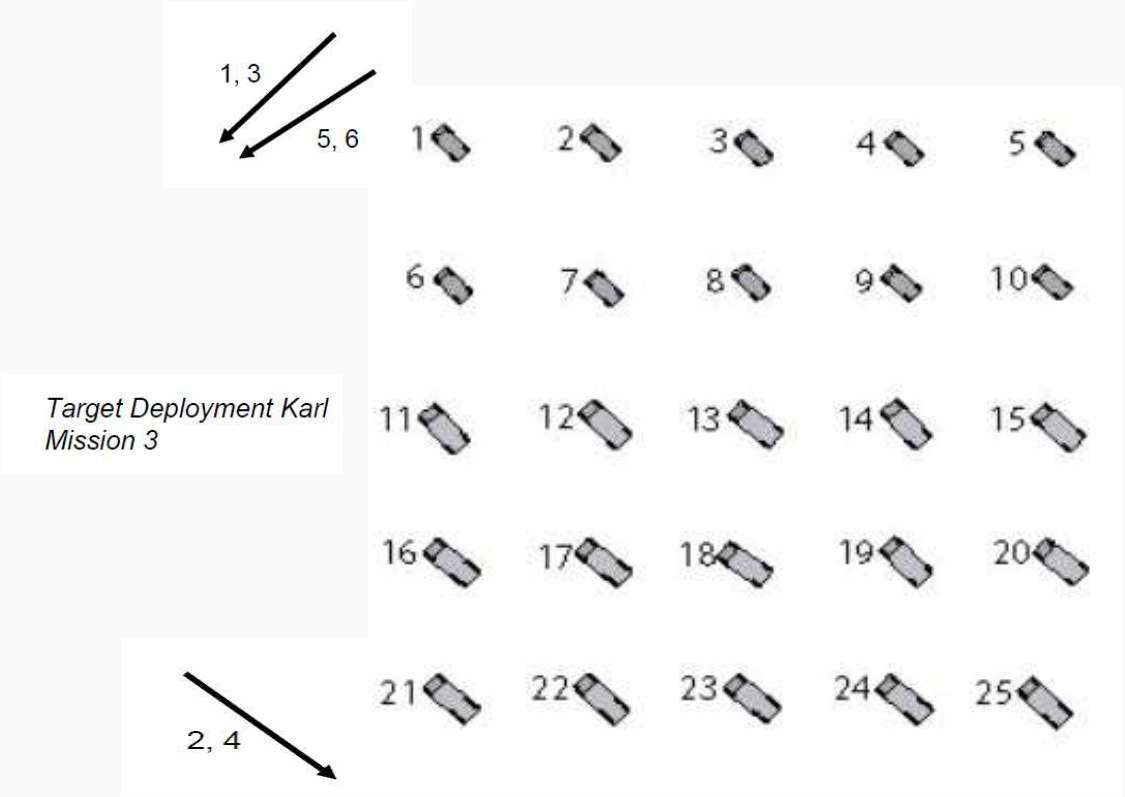

Figure 3: Image of location and orientation of the targets presented in [5].

Data description

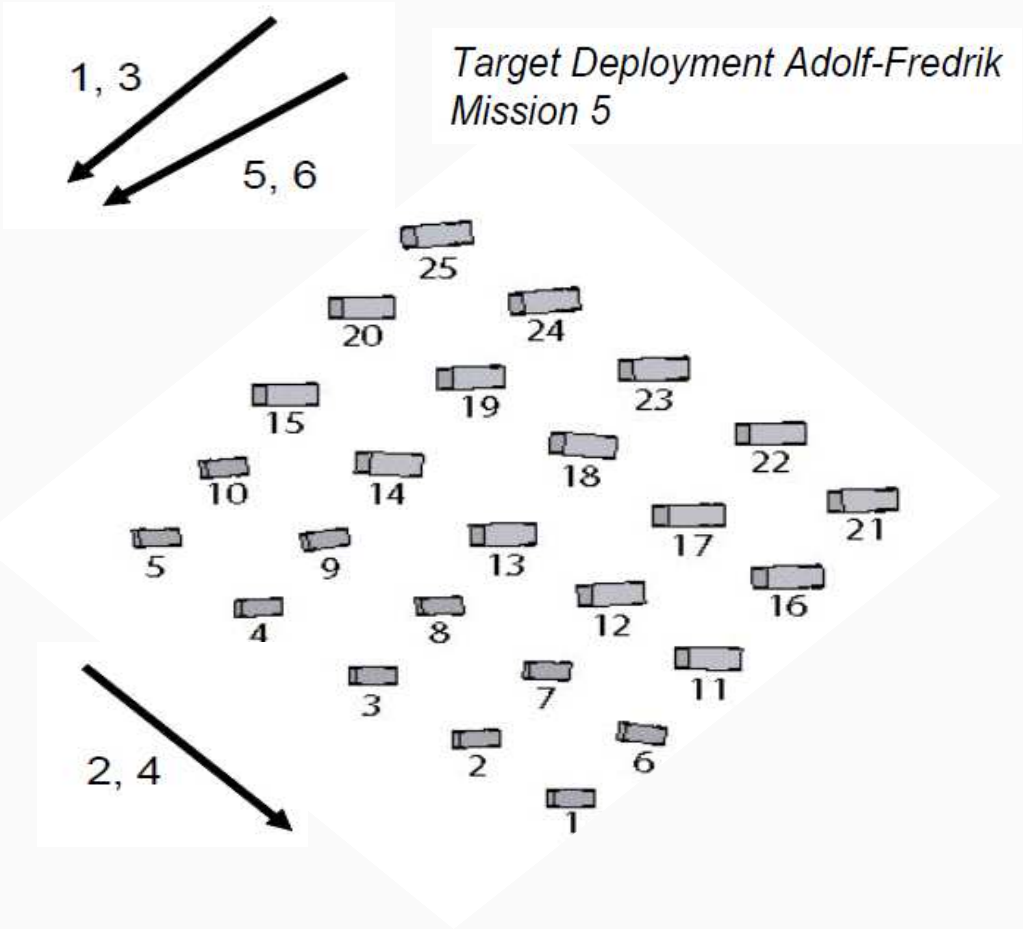

Figure 4: Image of location and orientation of the targets presented in [5].

Data description

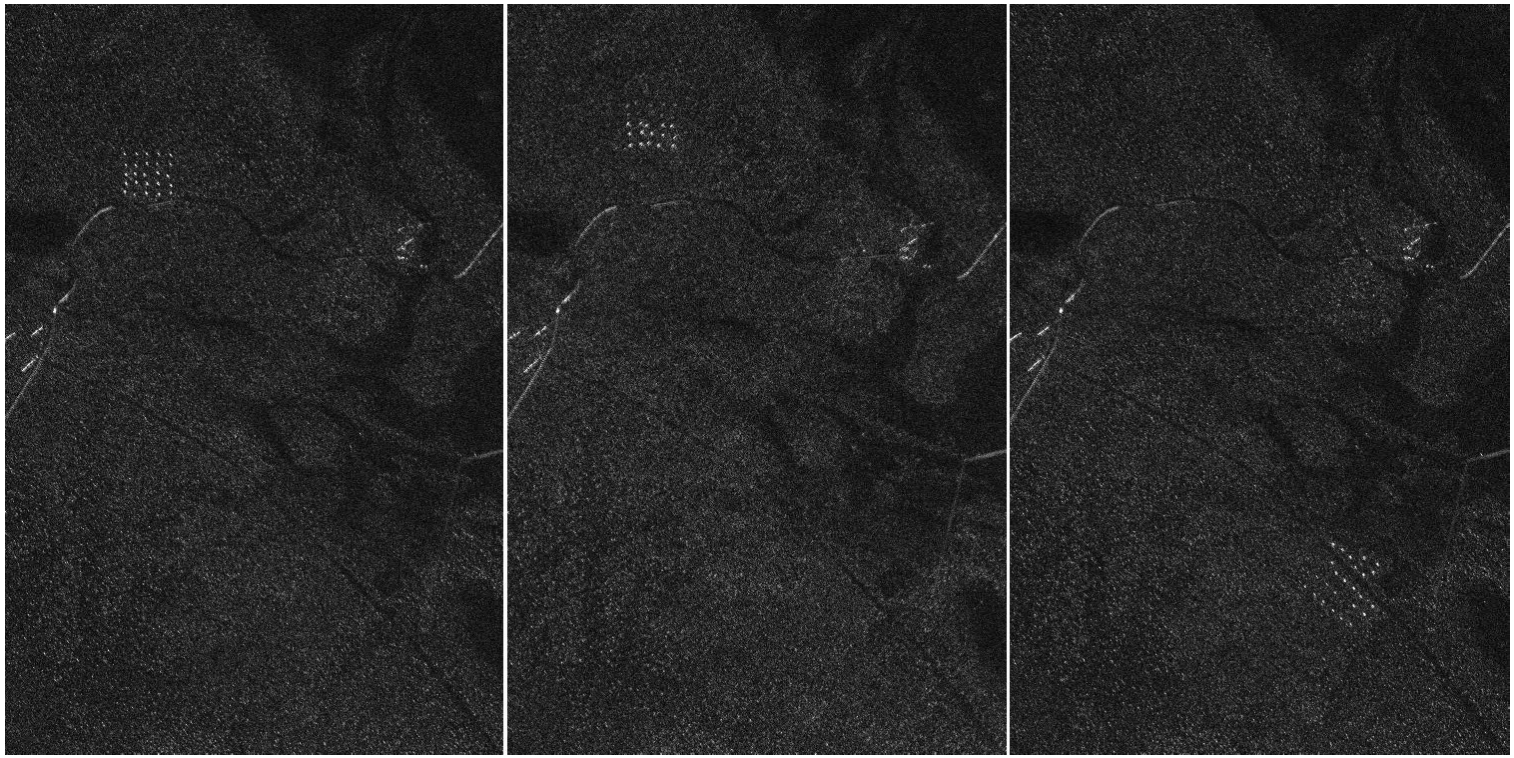

Figure 5: CARABAS-II images.

AR model

A time series is any set of observations, $y[n]$, observed over a specific time, n.

These series are analysed by means of the temporal dependence, being able to make predictions.

AR model

The AR models can be defined as follow:

$$y[n] = -\sum_{k=1}^{p} a[k]y[n-k] + u[n], \tag{1}$$

where $y[n]$ is the amplitude value of each pixel in one image, $a[k]$ are the autoregressive terms, $u[n]$ is white noise, and p is the order of the model [7].

AR model

The predicted image is given by

$$\widehat{y}[N+h] = -\sum_{k=1}^{p} \widehat{a}[k]\widehat{y}[N+h-k], \tag{2}$$

where $\widehat{a}[k]$ are the estimate of $a[k]$.

AR model

The estimated autoregressive terms $\widehat{a}[k]$ are the solutions of the following equation system

$$\begin{bmatrix} r_{yy}[0] & r_{yy}[1] & \dots & r_{yy}[p-1] \\ r_{yy}[1] & r_{yy}[0] & \dots & r_{yy}[p-2] \\ \vdots & \vdots & \ddots & \vdots \\ r_{yy}[p-1] & r_{yy}[p-2] & \dots & r_{yy}[0] \end{bmatrix} \begin{bmatrix} a[1] \\ a[2] \\ \vdots \\ a[p] \end{bmatrix} = - \begin{bmatrix} r_{yy}[1] \\ r_{yy}[2] \\ \vdots \\ r_{yy}[p] \end{bmatrix},$$

where $r_{yy}[\cdot]$ is the autocorrelation function.

Experimental Results

The resolution of the CARABAS II system is approximately 3×3 m^2.

Since a pixel represents a 1×1 m^2, considering an one-dimensional model, the closest pixels will be more correlated than the others. Thus, we used $p = 1$ in the AR models.

Experimental Results

Based on the fitted model, we obtained the forecast of one step ahead for each pixel.

This forecasting provides a new image representing the ground estimation of the SAR scene.

Experimental Results

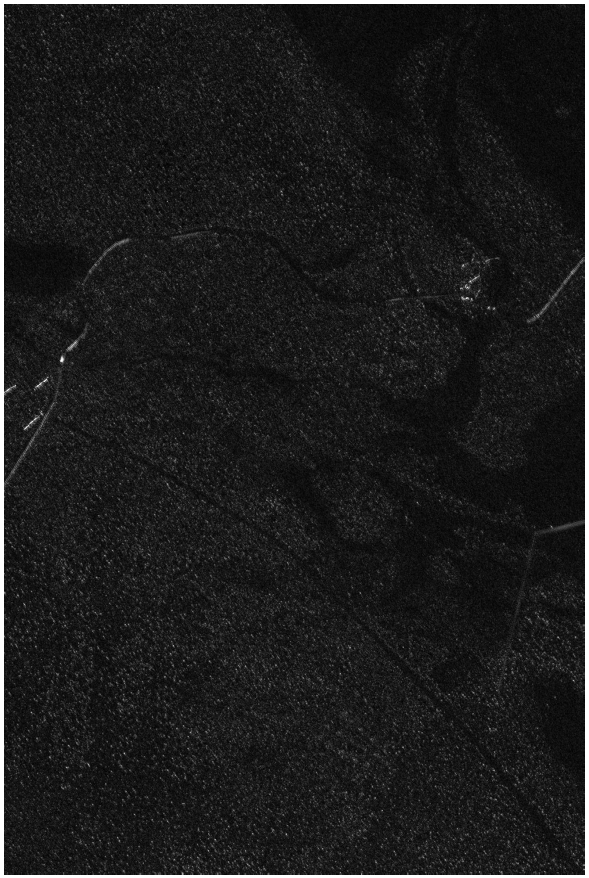

Figure 6: Prediction image for the AR(1) model.

Experimental Results

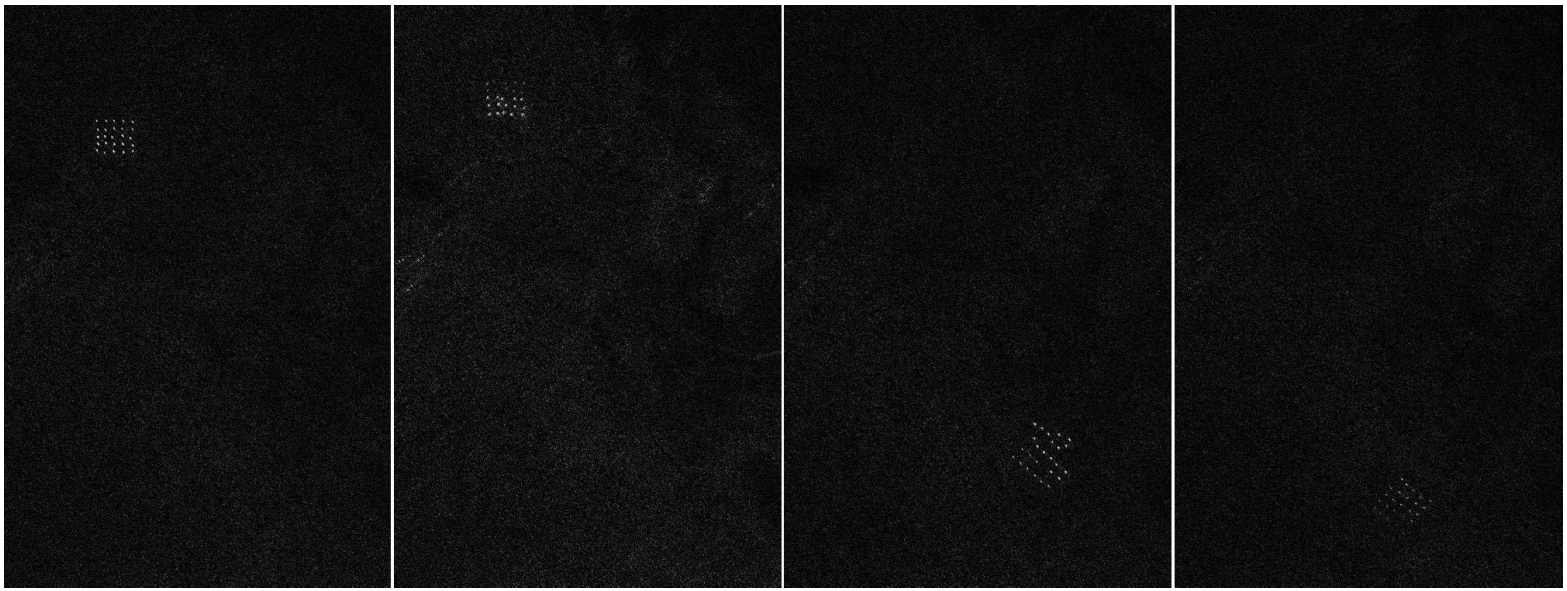

Figure 7: Difference images between interest images and prediction image.

Experimental Results

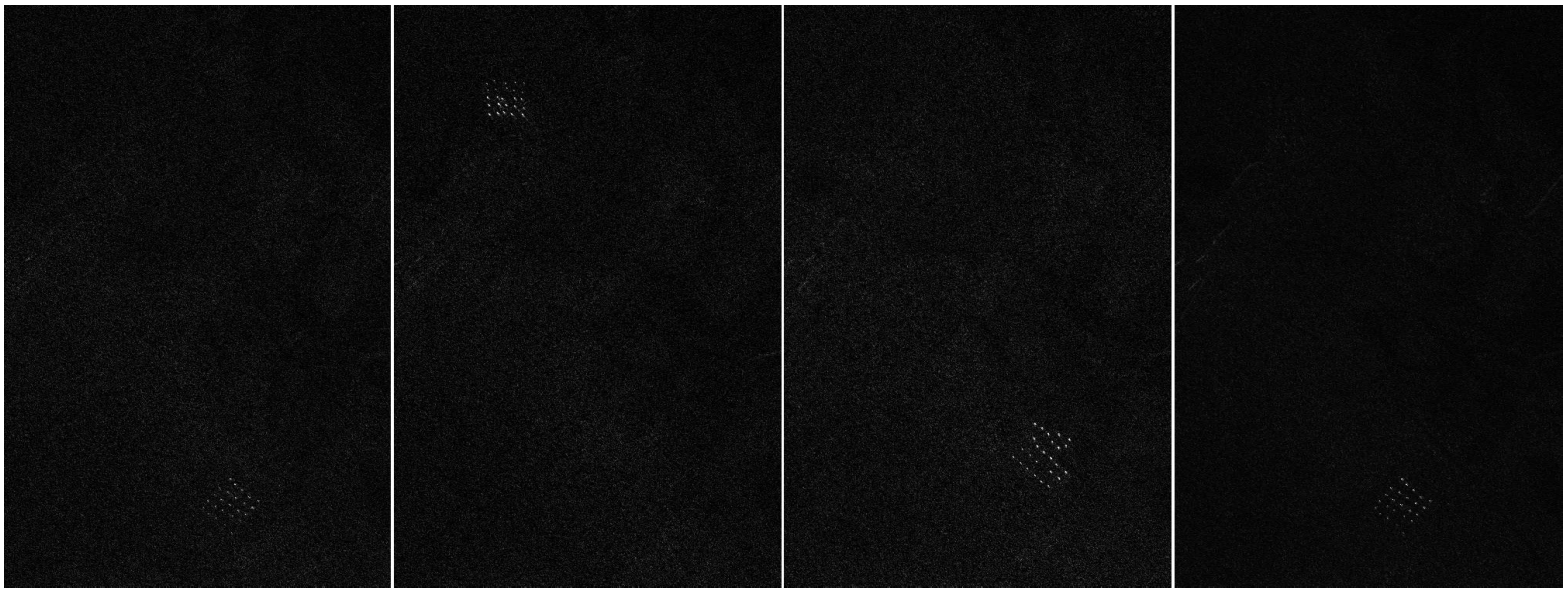

Figure 8: Difference images between interest images and prediction image.

Application

We considered change detections methods in the difference images.

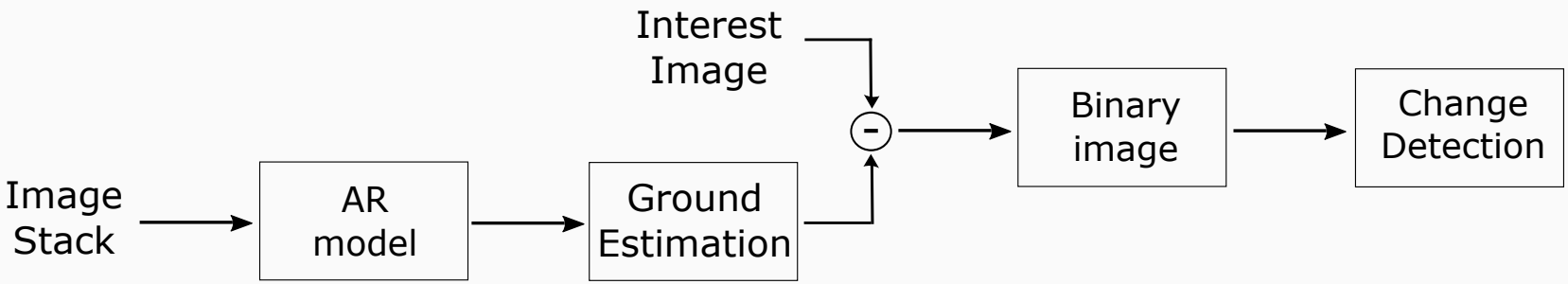

Figure 9: Processing scheme for change detection.

Application

Table 1: Change detection results obtained

Case of Interest		Number of	Detected	P_d	Area	Number of	FAR
Mission	Pass	known targets	Targets		[Km^2]	false alarms	
1	5	25	25	1.00	6	0	0.00
2	5	25	16	0.64	6	9	1.50
3	5	25	25	1.00	6	1	0.17
4	5	25	22	0.88	6	2	0.33
1	6	25	25	1.00	6	1	0.17
2	6	25	25	1.00	6	2	0.33
3	6	25	25	1.00	6	3	0.50
4	6	25	25	1.00	6	15	2.50
Total		200	188	0.94	48	33	0.69

Application

	Number of detected targets[1]	Number of false alarms
Our proposal	188	33
Reference paper	188	52

[1] Number of known targets = 200.

Application

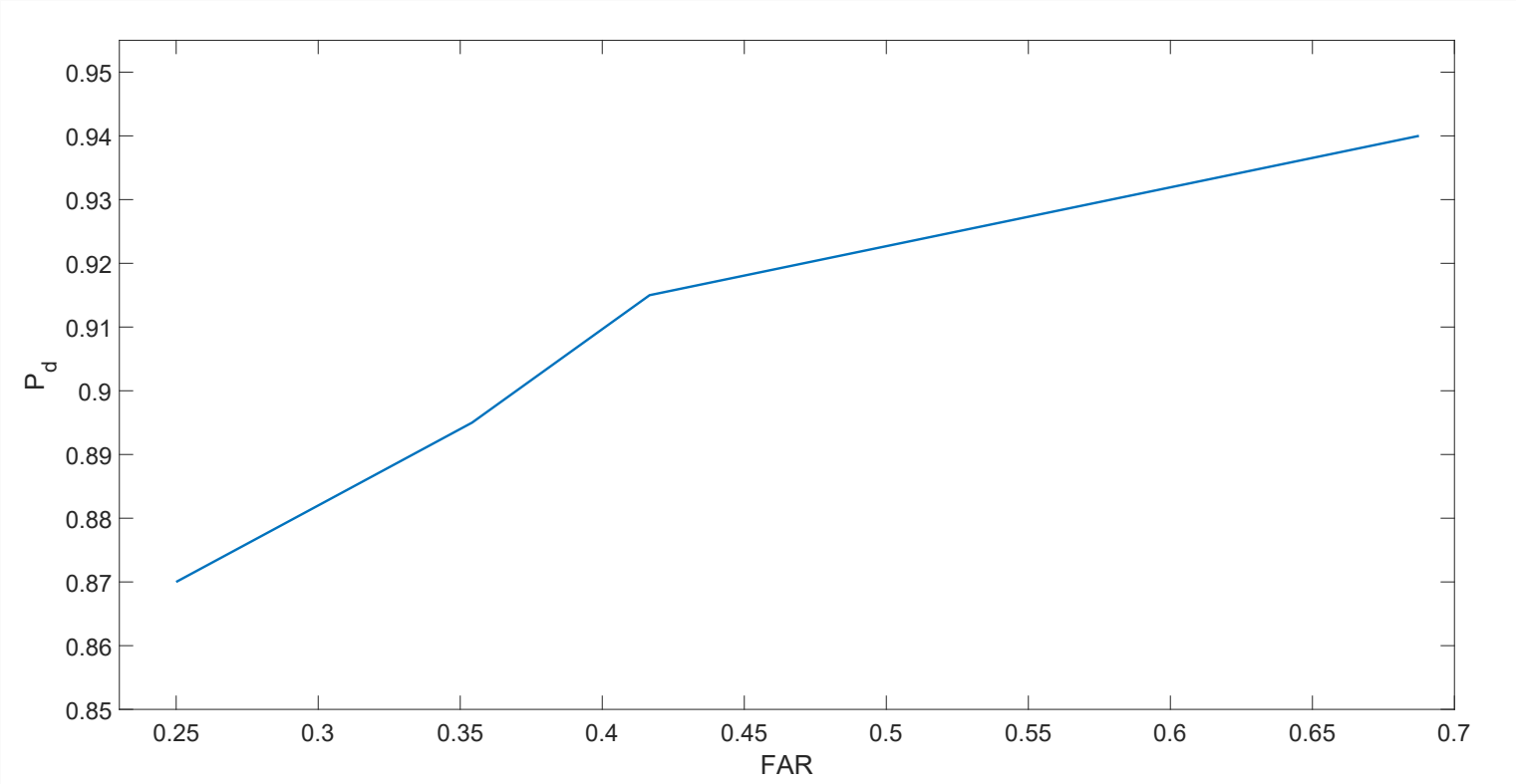

Figure 10: ROC curve obtained with the proposed method.

Conclusions

In this paper we proposed the use of an AR(1) model for a stack of eight SAR images to retrieve a ground scene estimation.

By using this technique, it was possible to obtain a reliable representation of the ground scene.

In CDA, we obtained competitive results of P_d and FAR when compared with the literature.

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References iii

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Thank you!