Shanghai Jiao Tong University

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OBJECT DETECTION CAPABILITY EVALUATION FOR SAR IMAGE

Authors

Zheyuan Wang, Yuanxiang Li,
Fangjie Yu, Wenxian Yu,
Zhuhui Jiang, Yongke Ding

CONTANTS

ABSTRACT

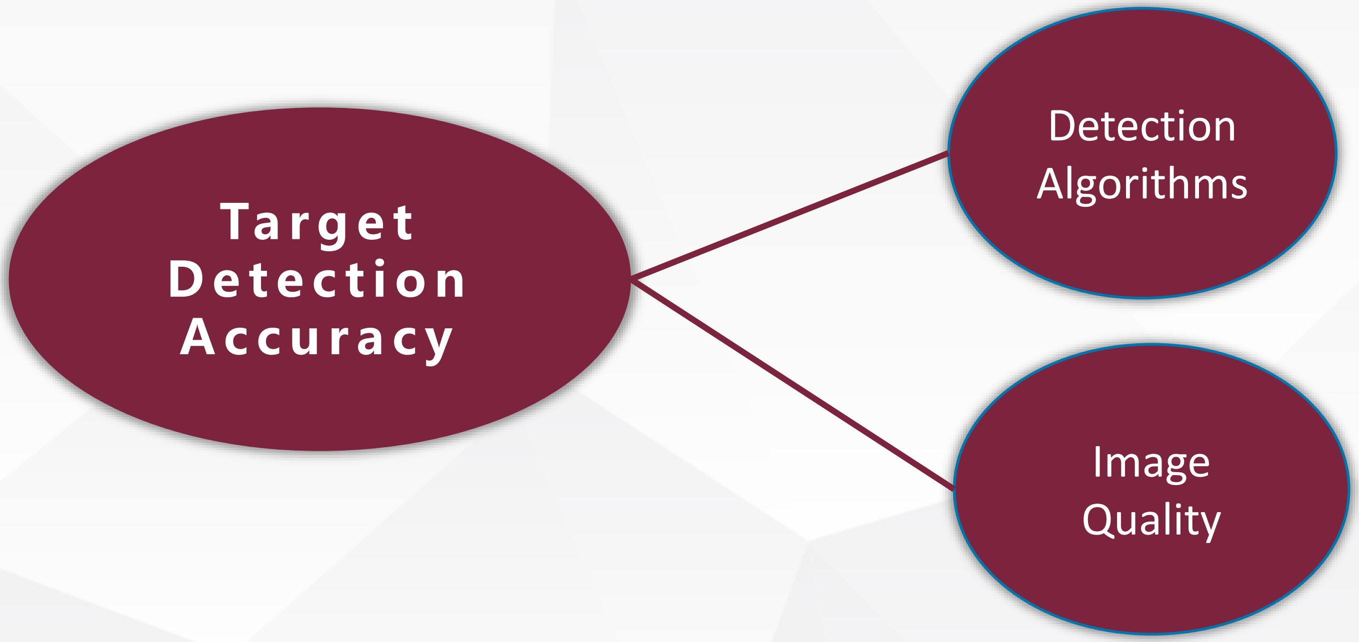
Synthetic Aperture Radar, Image Quality Aircraft Detection, Detection Capability, Evaluation Model

Existing SAR image quality assessment method could not be effectively used for assessing the performance of object detection. Thus, it is difficult to select SAR images and corresponding detection algorithms for SAR object detection.

This paper studies the image quality assessment for image object detection. Based on the concept of "application suitability", basic quality indicators including radiometric resolution, spatial resolution, PSLR and ISLR are integrated into a single indicator called Detection Index, which is able to comprehensively evaluate the degree to which SAR image is suitable for object detection tasks. Experimental results on aircraft detection with single scene show the effectiveness of the proposed model for SAR image capability evaluation in object detection applications.

INTRODUCTION

The decision-making process in SAR applications is directly affected by the accuracy and reliability of SAR image object detection.



As for SAR **image detection methods**, scholars have conducted a lot of research, and developed effective theories and methods. But there is much less research on SAR image detection capability.

The existing **quality assessment method** does not take the detection capability into consideration and is unable to provide the support for the selection and design of the image detection algorithm, affecting the application level of detection tasks

The so-called **target detection ca**pability of SAR image refers to the ability of SAR image itself on how well a certain target in it can be detected clearly.

This paper focuses on analyzing the detectability of SAR image itself, that is, estimating how well the detection results could be achieved before a specific target detection algorithm is run. Solving these problems has obvious scientific significance and application value in the following areas:

1. Help SAR target detection applications better select SAR image
2. Provide the basis for designing target detection algorithms tailored to the specific SAR characteristics.
3. Help evaluate the performance of SAR sensor

METHODOLOGY

Aircraft target detection

Improved two-parameter CFAR detection algorithm

The algorithm sets up two sliding window: target window T and background window B, and the two windows move at the length of the target window to ensure all pixels of the image get detected. Since there may be some target pixels in the background window while sliding the windows, the improved algorithm first removes the target pixels found in the background window, and then uses the remaining portion of the background window to estimate the mean and variance of the clutter.

Figure of Merit (FoM)

$$FoM = \frac{N_{tt}}{N_{fa} + N_{gt}}$$

Where, N_{tt} is the target number being correctly detected, N_{fa} is the number of false targets, N_{gt} is the number of actual targets.

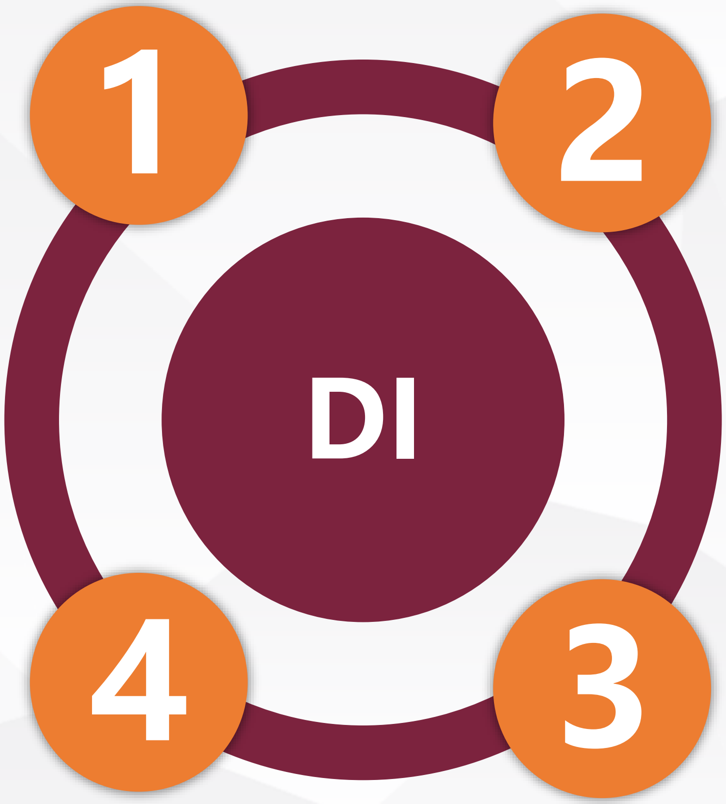
Prediction Model

Using single quality indicator to evaluate the detectability is always incomplete and not accurate

We choose radiometric resolution, spatial resolution, PSLR (peak side-lobe ratio) and ISLR (integral side-lobe ratio) as the basic quality indicators

Then, based on the concept of “application suitability” [8], we establish detection index to evaluate the target detection capability of SAR images and give its calculation method.

Prediction Model – Detection Index



1) For each basic quality indicators, specify the value of *Tol* and *Req* based on the application requirements

2) Calculate the values of basic quality indicators of SAR image, including radiometric resolution , spatial resolution , PSLR and ISLR;

3) Use the following formula to calculate *DI* components;

$$\Lambda_x = 1 - \left[1 + \exp\left(2\frac{Req - x}{Tol - Req} \right) \right]^{-1}$$

4) Calculate *DI* as follows.

$$DI = (\Lambda_\gamma \cdot \Lambda_{\rho_a} \Lambda_{PSLR} \cdot \Lambda_{ISLR})^{1/4}$$

Prediction Model – Parameters selection

To calculate the *DI* components, the corresponding *Tol* and *Req* must be first determined. The parameters are usually selected empirically, and optimized according to the actual evaluation results.

	Req	Tol
Spatial Resolution (m)	2	4
PSLR (dB)	-6	-3
ISLR (dB)	-9	-4
Radiometric Resolution(dB)	2	6

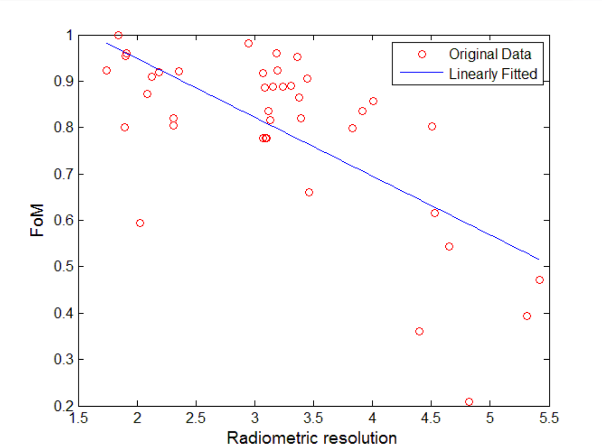
EXPERIMENTAL RESULTS

TerraSAR-X Dataset

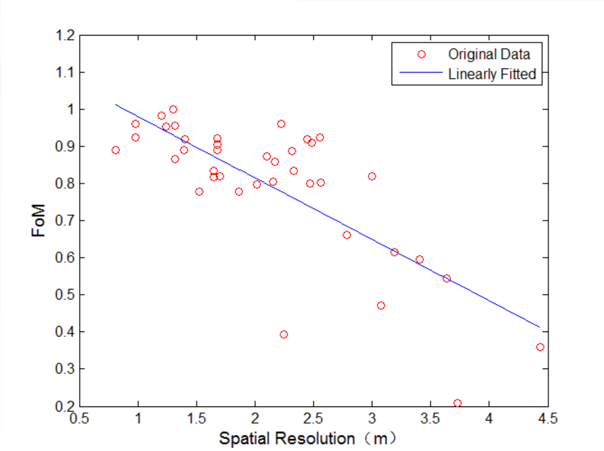
The dataset comes from TerraSAR-X satellite data, with HH polarization. Each scene data was cut into slices with the size of 1500 * 1500 (pixel^2) for aircraft target detection.

Region	GSD (m)	Time	Size
Shanghai Pudong International Airport	1.25* 1.25	2010-11-09	25702* 45421
Shenzhen Bao'an International Airport	1.36* 1.85	2011-01-05	14816* 30659
Hong Kong International Airport	3.01* 3.05	2010-07-24	12904* 26743
Tokyo International AirportHaneda Airport	1.25* 1.25	2011-06-19	25502* 45210
Davis Monthan Air Force Base	0.45* 0.85	2010-12-30	11908* 6112
Davis Monthan Air Force Base	0.45* 0.18	2014-04-01	9016* 18281

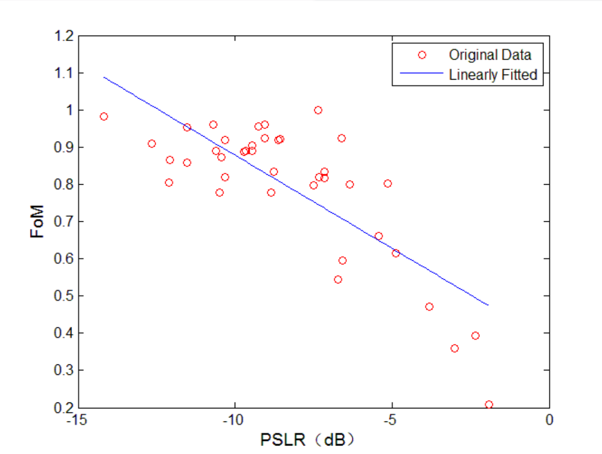
Correlation Analysis – Basic Quality Indicators



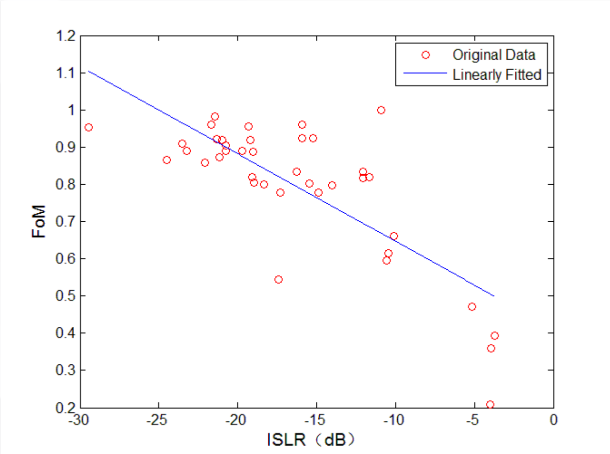
(R = -0.6793)



(R = -0. 7547)



(R = -0.6793)

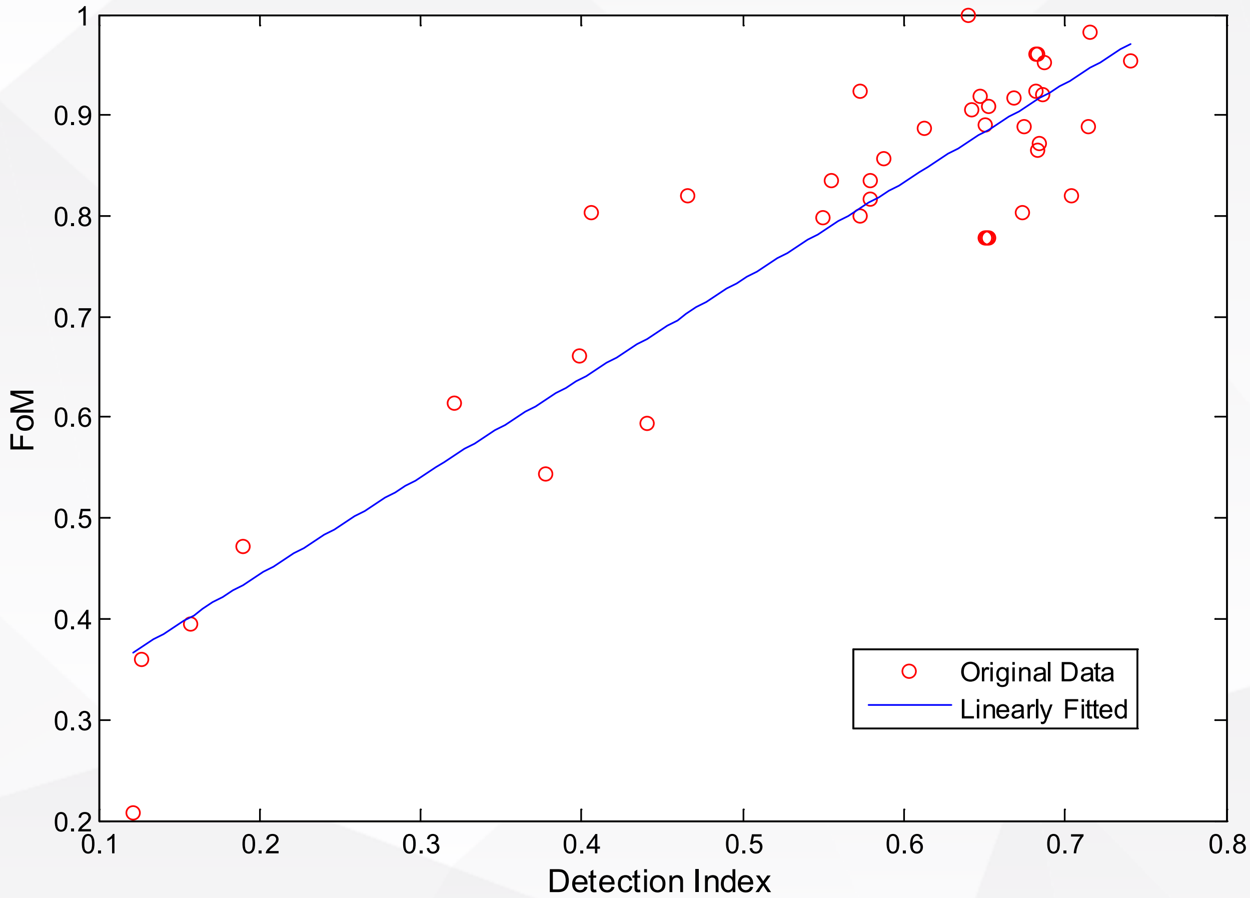


(R = -0. 7799)

To start with, we need to analyze the relationship between FoM values and the values of SAR image quality indicators, on the basis of which predication model of detection capability is established.

The four types of quality indicators are closely related with the target detection capability of SAR images with negative correlation coefficient ranging between -0.8 and -0.6.

Correlation Analysis – Detection Index



The results between *DI* and the optimal value of *FoM* for each image are fitted linearly, which derives the following formula

$$y_{FoM} = 0.9759 x_{DI} + 0.2488$$

The fitted Mean Squared Error is 0.0048, with the correlation coefficient being 0.9325.

Advantages of *DI* over single basic quality indicators are obvious. Because the calculation of *DI* takes the main quality factors into consideration, it better reflects the actual FoM with good correlation.

Verification of SAR Images

Image No.	*DI*	*FoM (Predicted)*	*FoM (Actual)*
1	0.6312	0.8648	0.8889
2	0.5501	0.7856	0.7982
3	0.3781	0.6178	0.5441
4	0.7013	0.9332	0.8889
5	0.3988	0.6380	0.6613
6	0.6874	0.9196	0.9524

The predicted FoM values are closely distributed around the actual values that are obtained after the running of detection algorithms. The difference between the predicted values and the actual ones is fairly small, about 0.01~0.045, except for No.3 with a difference of 0.0737.

The evaluation model is capable of effectively estimating how well the detection results could be achieved before running a specific algorithm in practical tasks.

CONCLUSION

This paper analyzes the various quality factors of SAR image that affect target detection results, and discusses their correlation with FoM. Based on the concept of "Application Suitability", a prediction model for SAR image detection capability is established, where a comprehensive indicator called Detection Index is calculated to forecast how well the results could be under CFAR detection algorithm. The model parameters are given for estimating detection capability for aircraft target and the effectiveness has been proved with TerraSAR-X data.

THANKS