



D760 (EGU - 2020 - 22503)

PERFORMANCE ANALYSIS OF TWO-CLASS SVM TO DETECT THIN INTERLAYER DEBONDINGS WITHIN PAVEMENT STRUCTURES

Presenter: Shreedhar Savant Todkar



INTRODUCTION



BY

PROBLEM STATEMENT

- Pavement degradation: surface (cracks) and subsurface defects (delaminations → reflexive cracks)
- Detection using Non-destructive GPR imaging and advanced processing methods

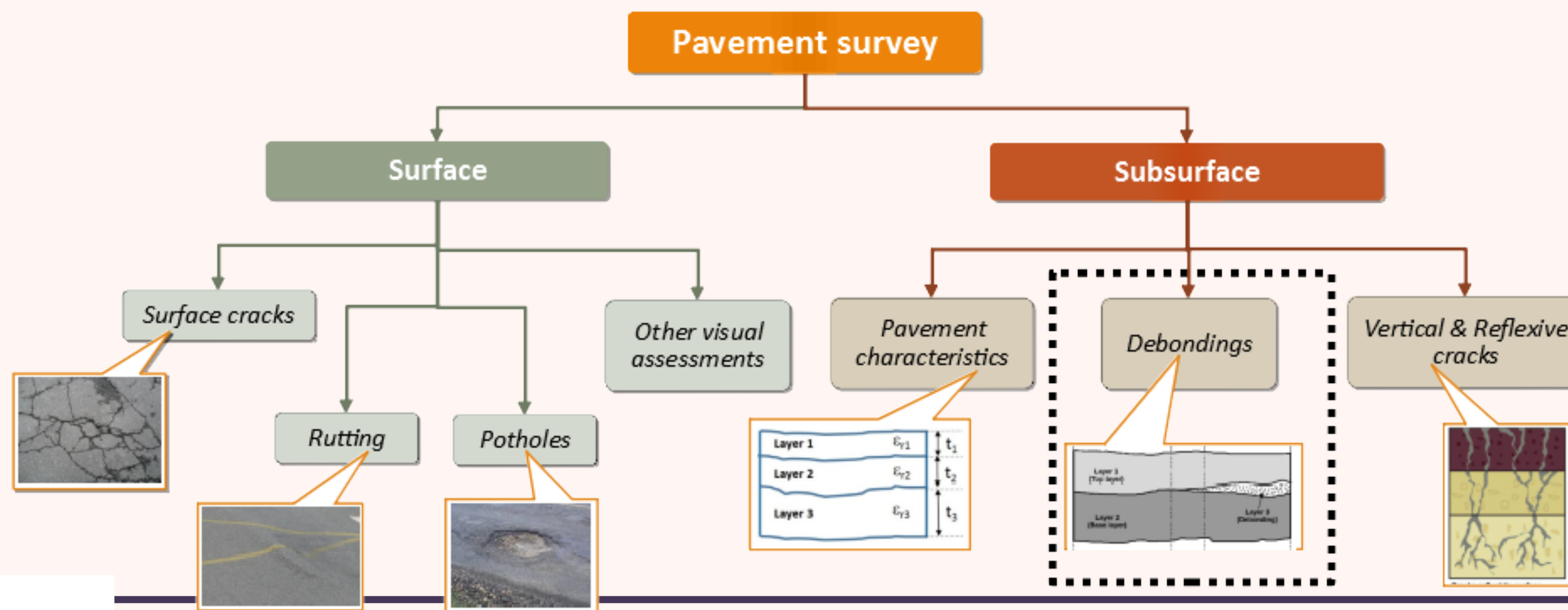


Fig 1. Pavement survey: An overview

DEBONDINGS CHARACTERISATION

- **Debonding: Presence of an additional layer between the top two pavement layers**
- **Constructive interference of overlapping backscattered echoes ($< \lambda_{\text{mat}} / 4$)**

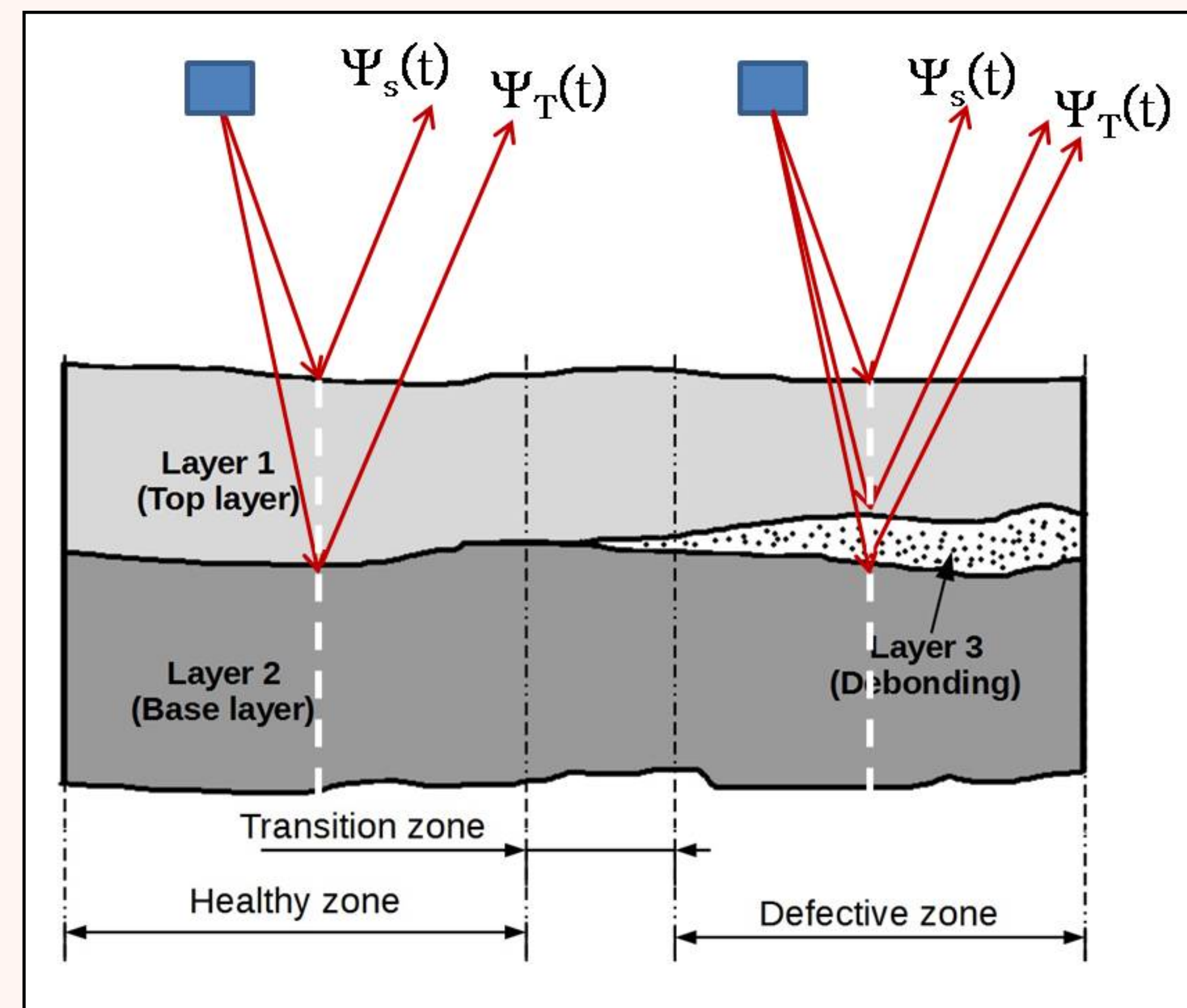


Fig 2. Debonding characterisation

OBJECTIVES

- **Detection of subsurface millimetre-order debondings**
- **Use of Supervised machine learning method on time-domain GPR signatures**
- **Performance analysis of Two-class SVM using simulated data**
- **Result analysis of simulated and field data**

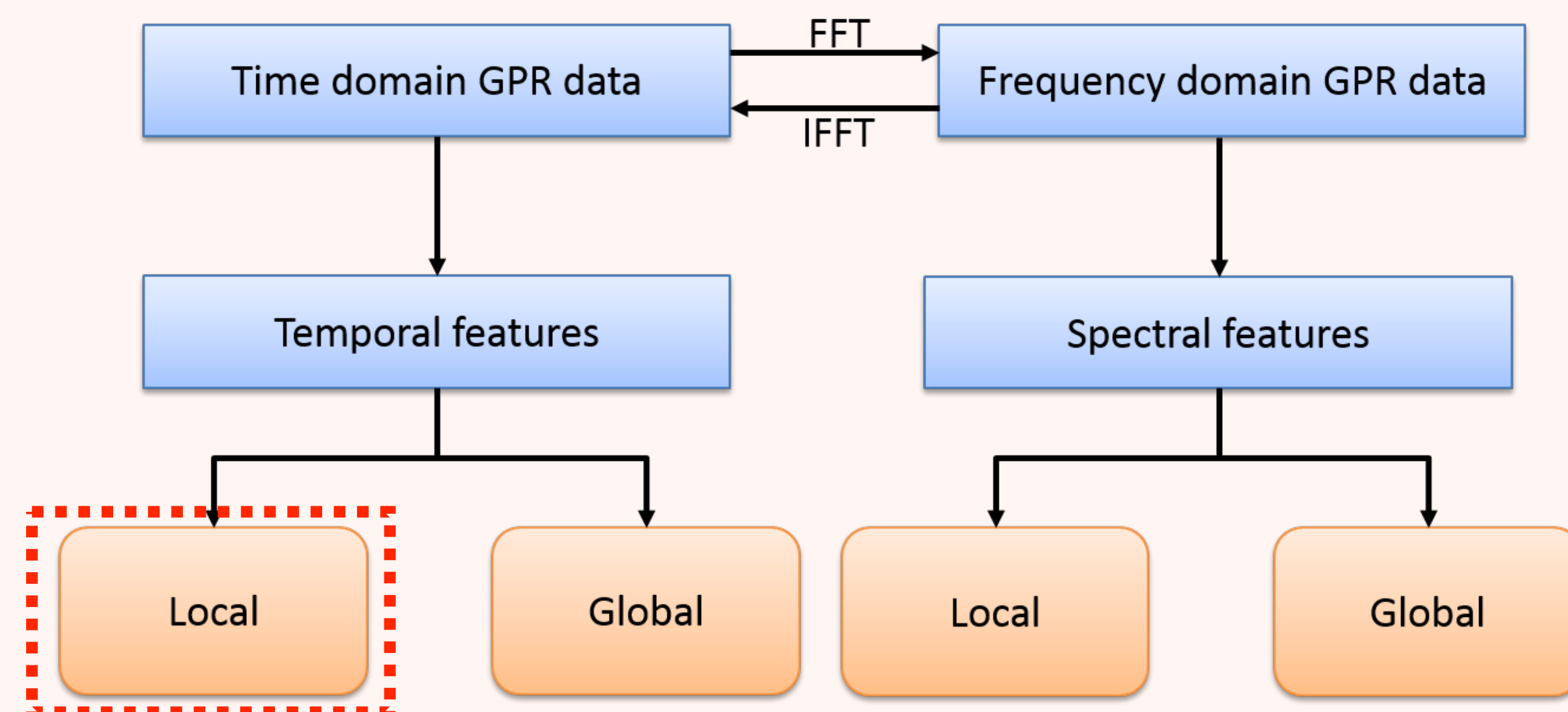
METHODOLOGY



BY

DATA PREPROCESSING

- Use of time domain statistical signal features
- Local vs. Global signal features
- Feature set consists of:
 - *Standard deviation (σ), Amplitude range of second echo (A_2), Skewness (S_k), Kurtosis (K_u), Interquartile range (IQR) and Root-mean square (rms) of the signal*



DATA PREPROCESSING

- Use of automatic time-gating window
- Window length (in terms of number of samples) is a function of the sampling frequency (f_s) and the pulse width of the emitted signal (t_w)

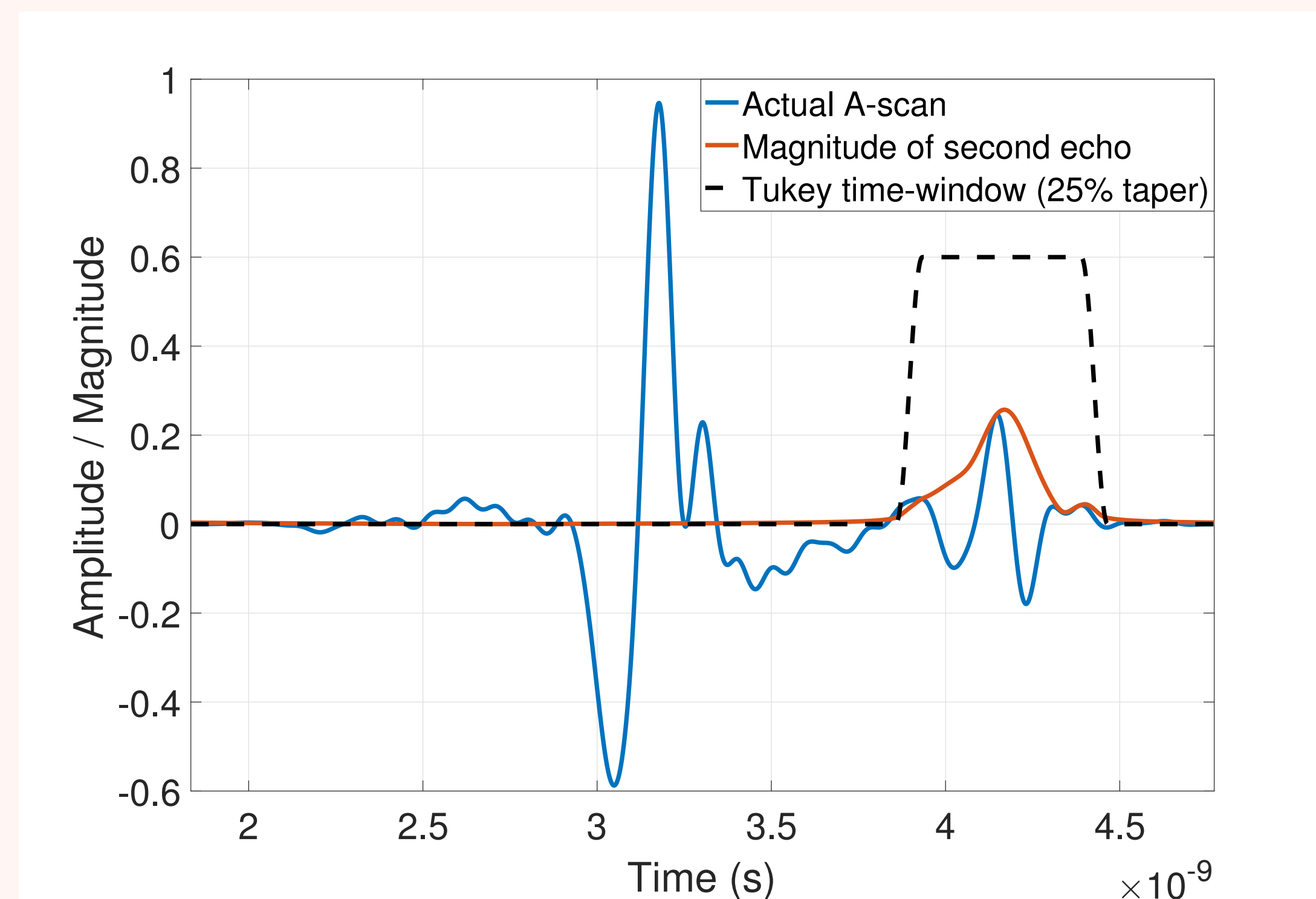


Fig 3. Time-gating of second echo

DATA PREPROCESSING

- Use of automatic time-gating window
- Window length (in terms of number of samples) is a function of the sampling frequency (f_s) and the pulse width of the emitted signal (t_w)

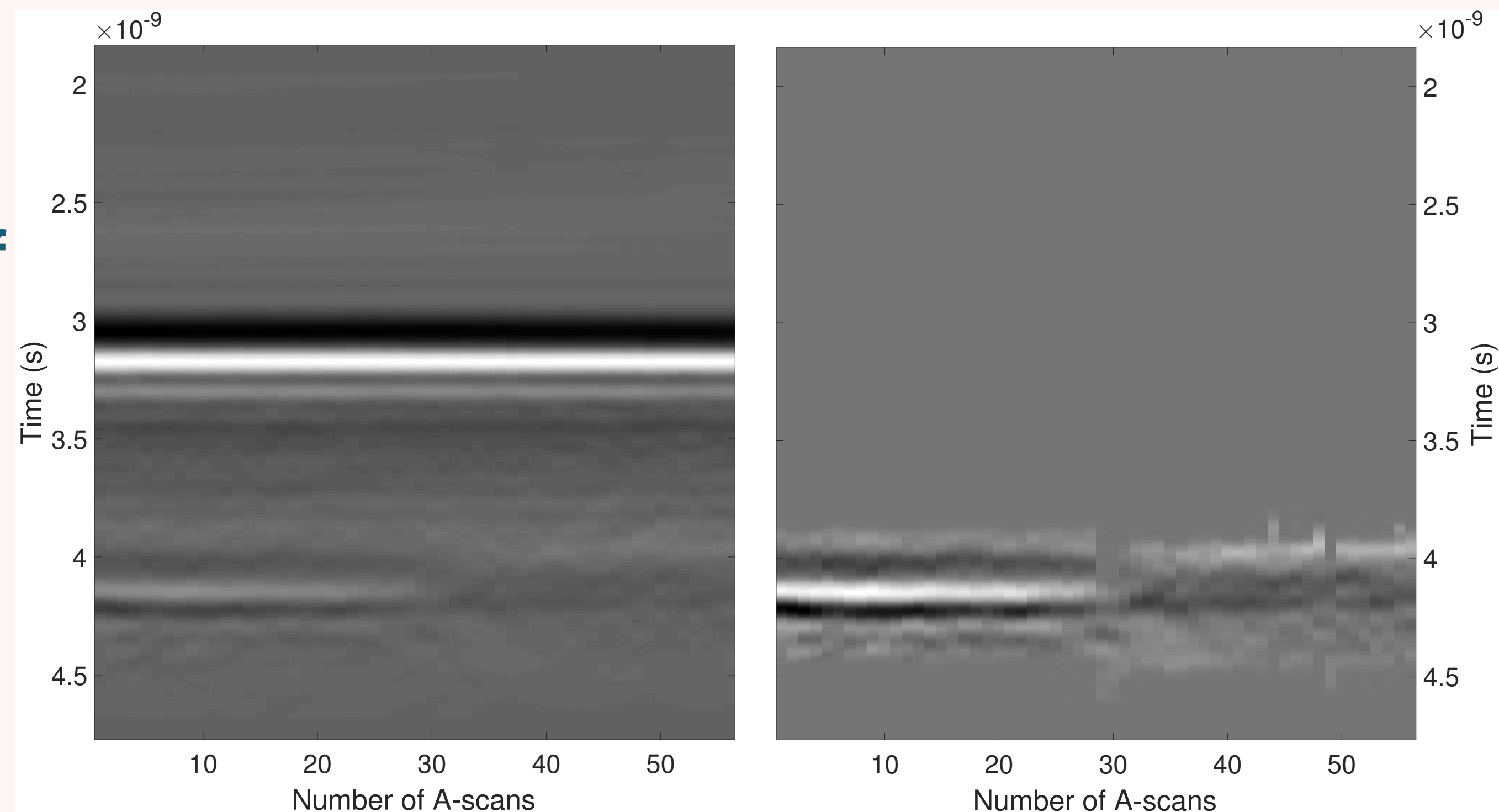


Fig 4. Ungated vs. Time-gated GPR B-scan

SUPPORT VECTOR MACHINES

- Support Vector Machines (SVM) for two-classes
- Supervised machine learning method; relies on the use of N-1 dimensional hyperplane to separate the data mapped on a N dimensional hyperspace

- Minimisation function:

$$\text{Minimize } \frac{1}{2} ||\mathbf{w}'||^2 + C \sum_{i=1}^N \xi_i$$

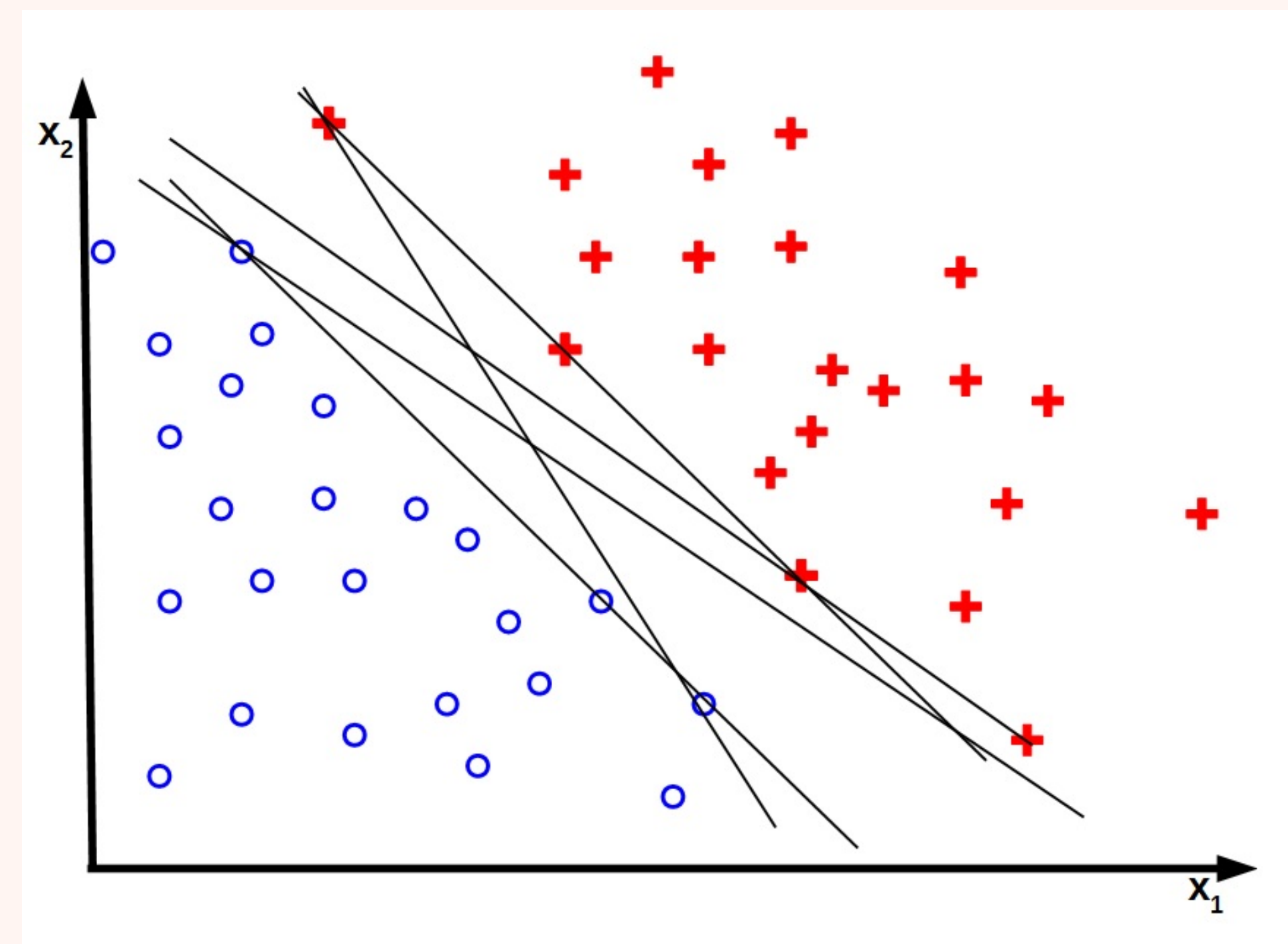


Fig 5(a). Example of possible hyperplanes for SVM classification

SUPPORT VECTOR MACHINES

- Learning data is use to create a classification model
- Test data is uses the model to classify unknown data
- Use of Linear or Non-linear kernels to find the best data separation

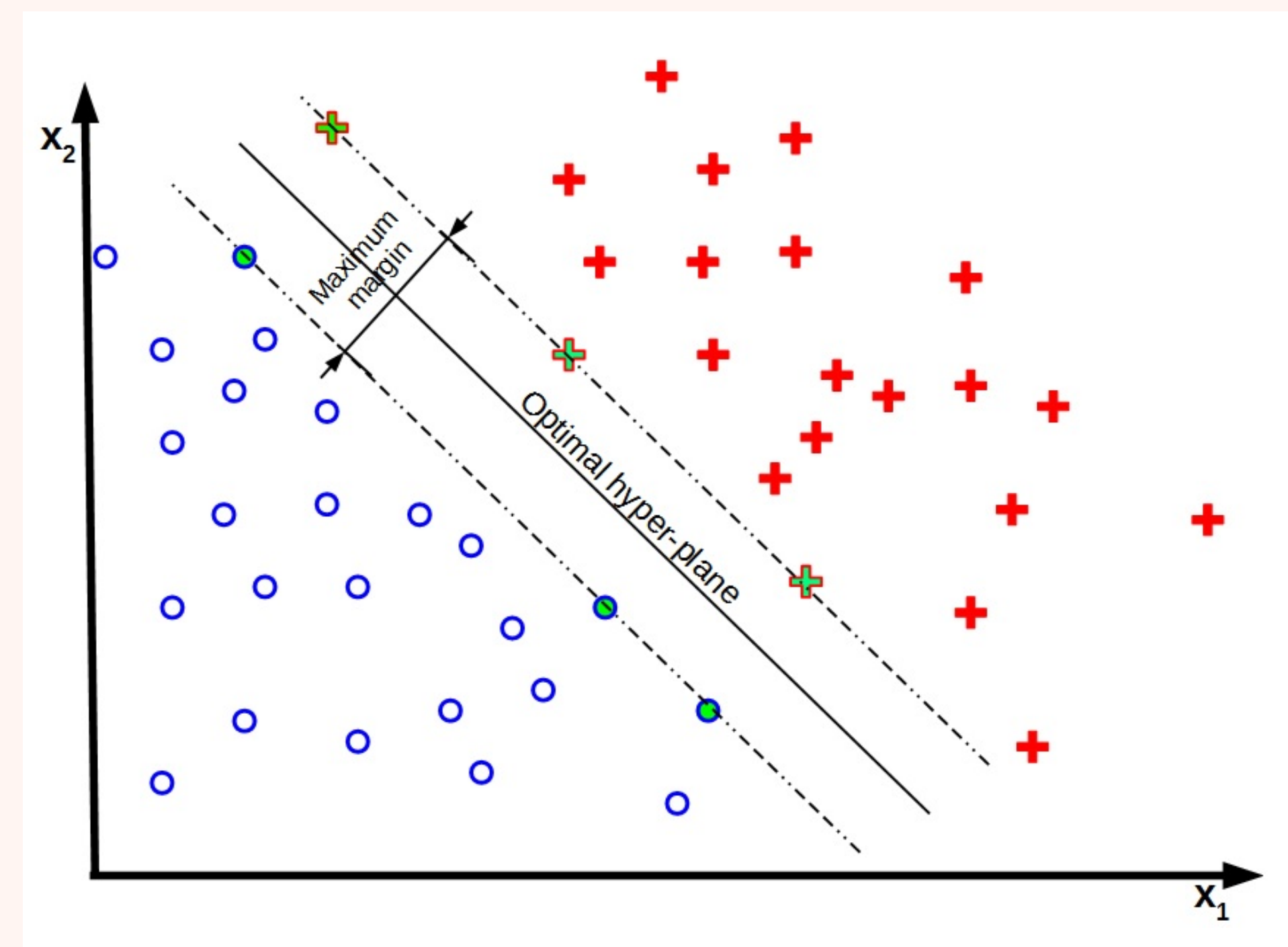
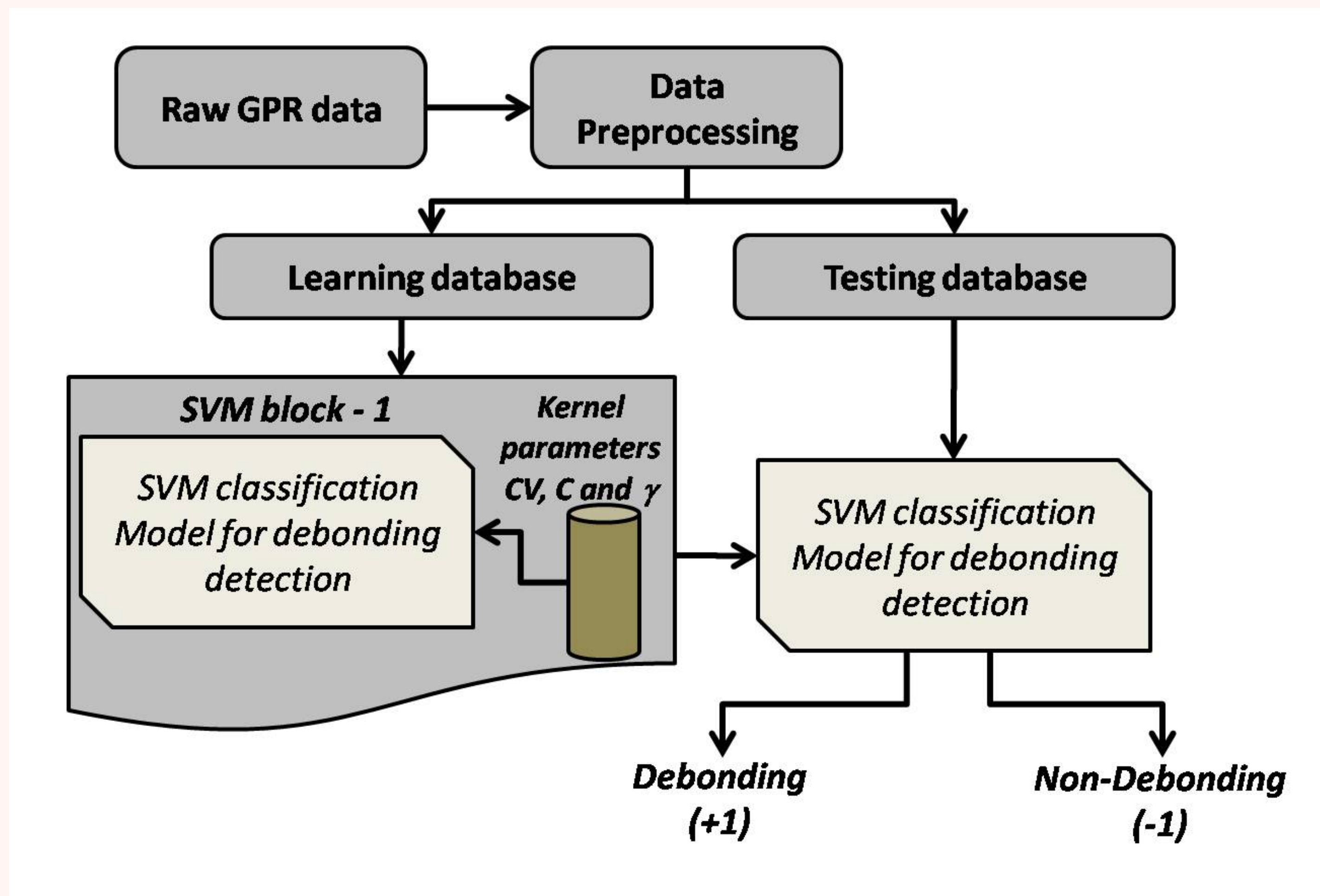


Fig 5(a). Example of the optimal hyperplane with max margin

THE SVM APPROACH



SOME RESULTS

DATABASES USED

➤ Simulated database

- *Three permittivity values: 2 (near air-void defects), 10 (near moisture/wet defects)*
- *Each B-scan consists of 150 A-scans with 50 debonding and 100 non-debonding A-scans*
- *Gaussian noise of 30 dB added to the B-scans*

➤ Experimental database:

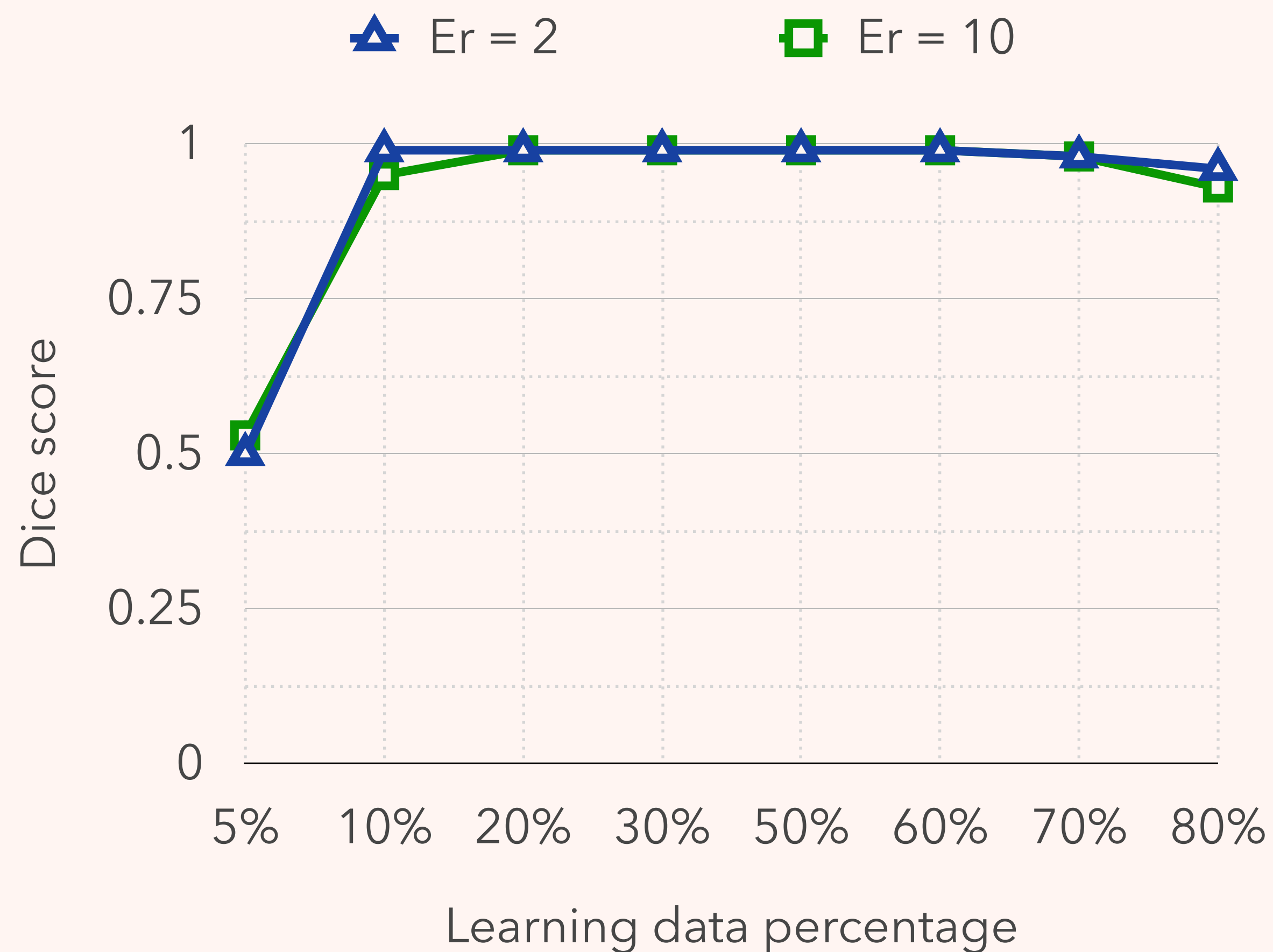
- *Collected at IFSTTAR's fatigue carousel over various loading stages using UWB SF-GPR*
- *Three defect types: Geotextile, Sand and Tack-free based*

SENSITIVITY ANALYSIS

- **The study of relationship uncertainties between the input and its outputs**
- **To observe the robustness and adaptability of a method *w.r.t* various input data configurations**
- **Sensitivity analysis studied:**
 - ***Data-based SA: Effect of learning data size and input feature set***
 - ***Method-based SA: Effect of CV and kernel techniques***
 - ***Pavement-based SA: Effect of debonding thicknesses and composition***

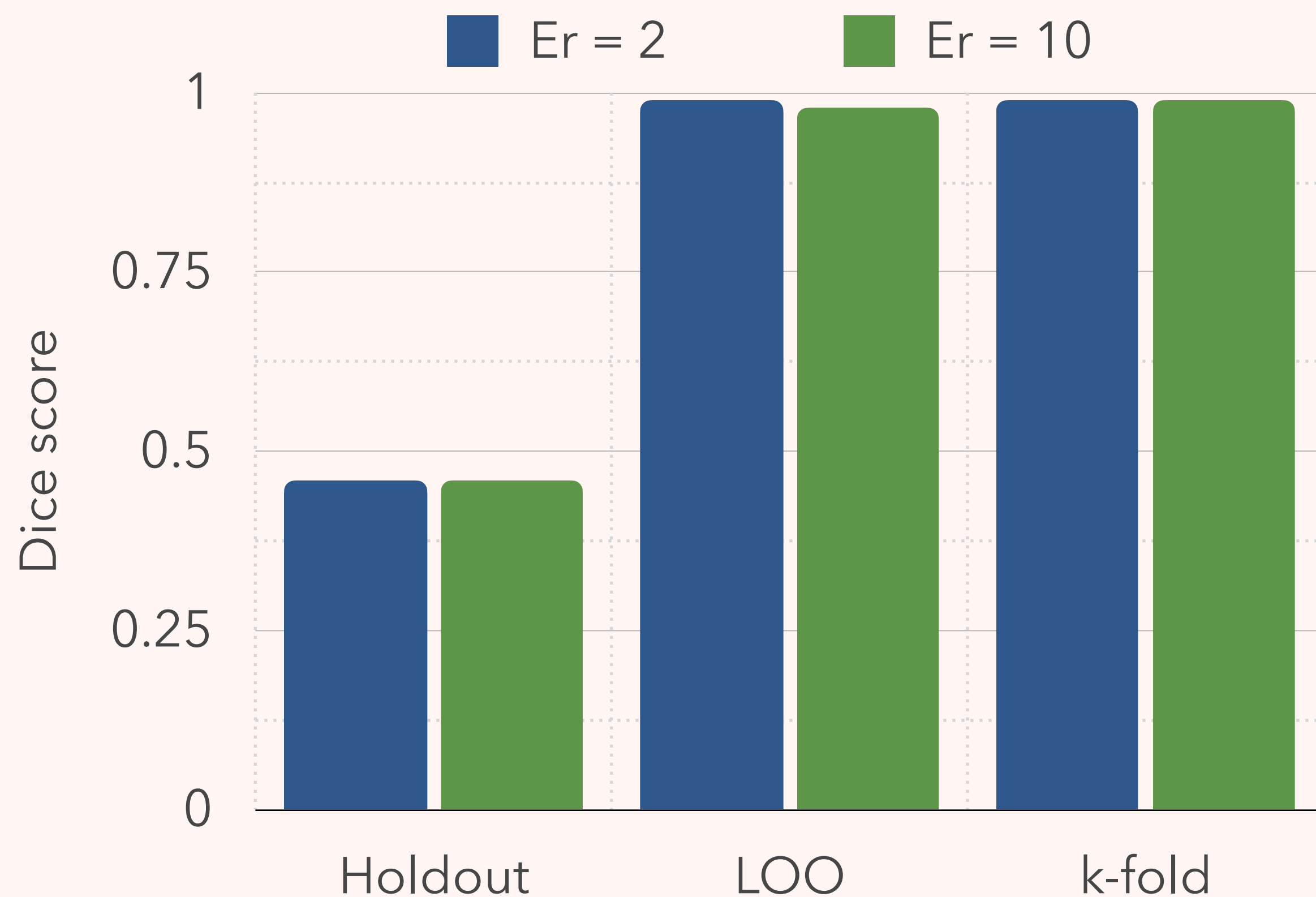
SENSITIVITY ANALYSIS

1. SVM performance w.r.t learning data size

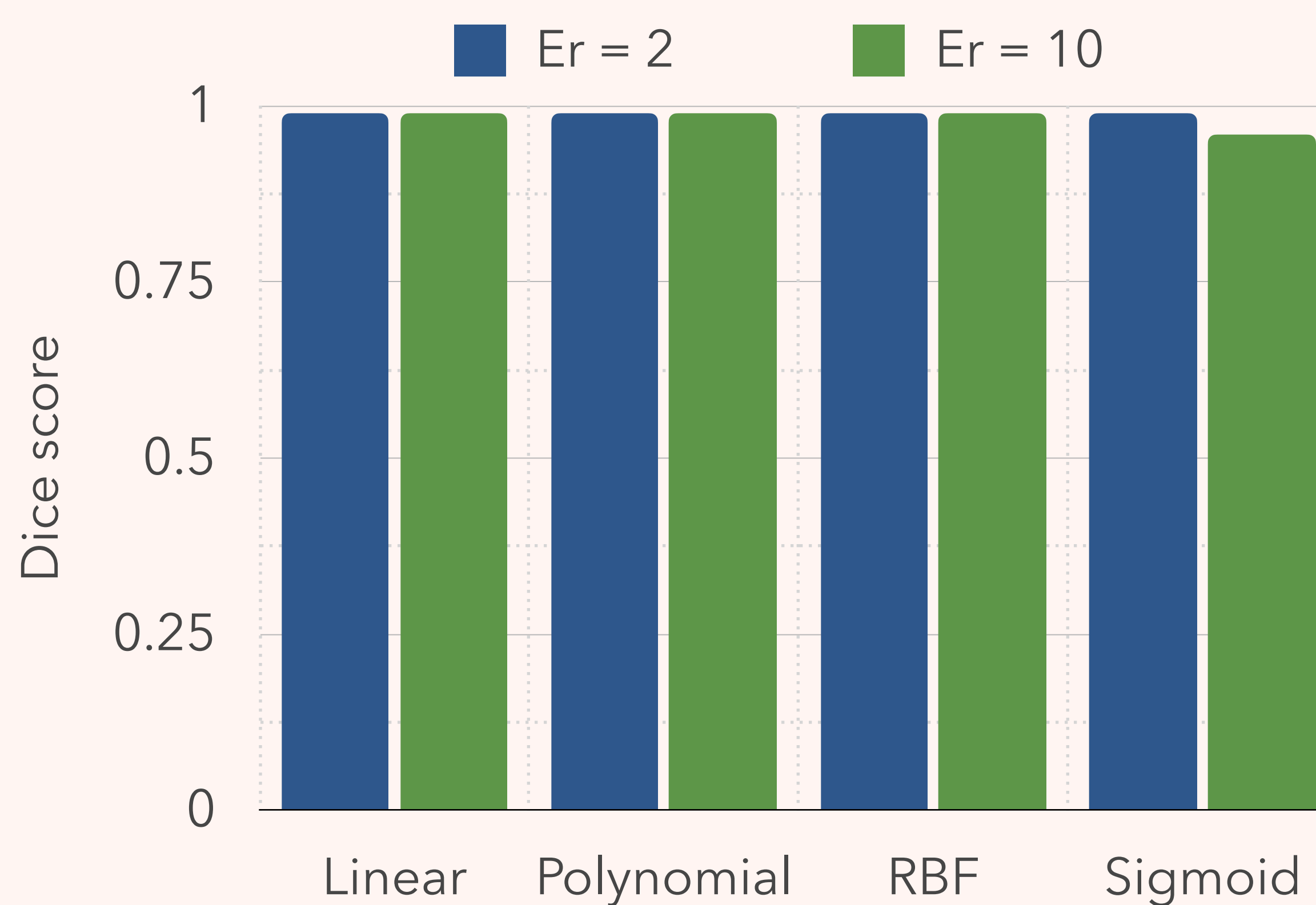


SENSITIVITY ANALYSIS

2. SVM performance w.r.t CV techniques



3. SVM performance w.r.t kernel type



CONCLUSIONS & PERSPECTIVES



CONCLUSIONS

- Performance testing with simulated and field data
- Sensitivity analysis of the SVM method w.r.t signal features
 - Feature sets: Performance of Local features > Global features
 - CV techniques: k-fold (k=5) presented the best performances
 - Learning data: Optimal learn-to-test ratio is between 1:1 to 3:1
- Individual signal features do not provide conclusive results on the performance

PERSPECTIVES

➤ Improving performance by

- *Implementation of additional time domain features*
- *Adapting the conventional Amplitude Ratio test (ART) with SVM*

➤ Estimation of debonding layer characteristics

**THANK YOU FOR YOUR
ATTENTION.**



BY