EGU General Assembly 2020

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

Presenter: Shreedhar Savant Todkar

Université Gustave Eiffel

Cerema

INTRODUCTION

PROBLEM STATEMENT

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

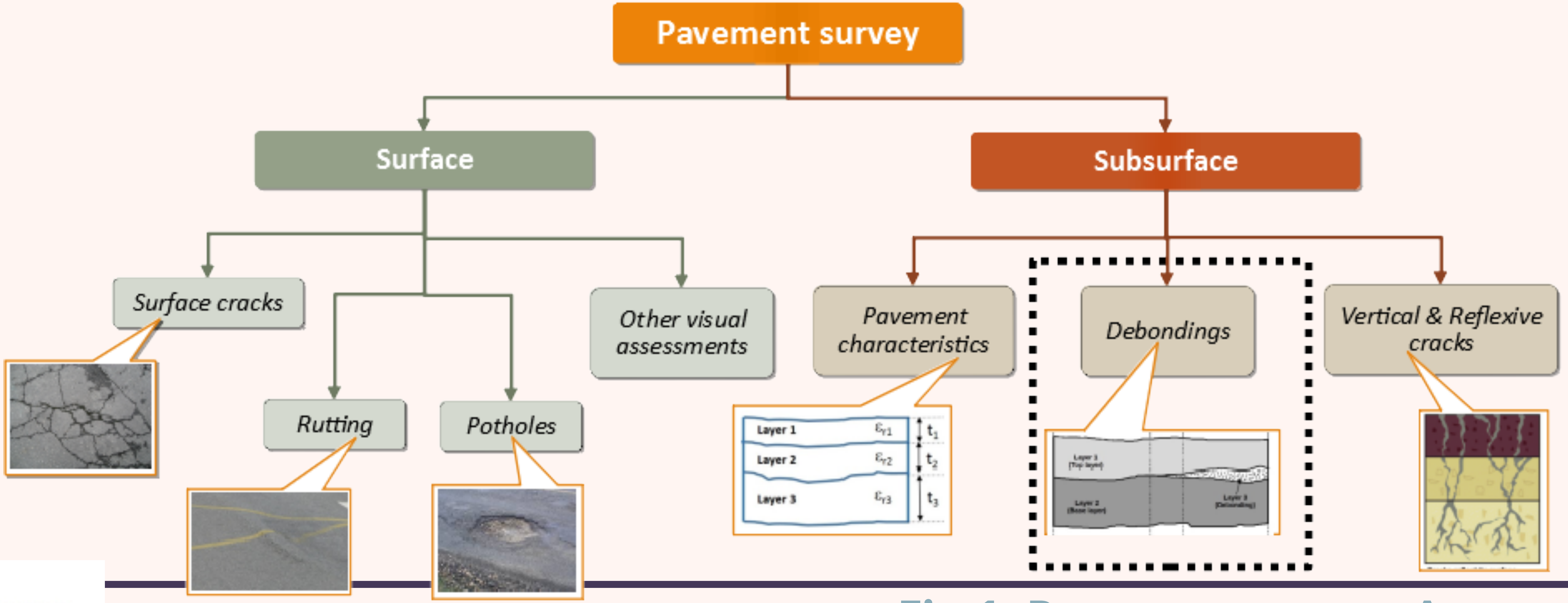


Fig 1. Pavement survey: An overview

DEBONDINGS CHARACTERISATION

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

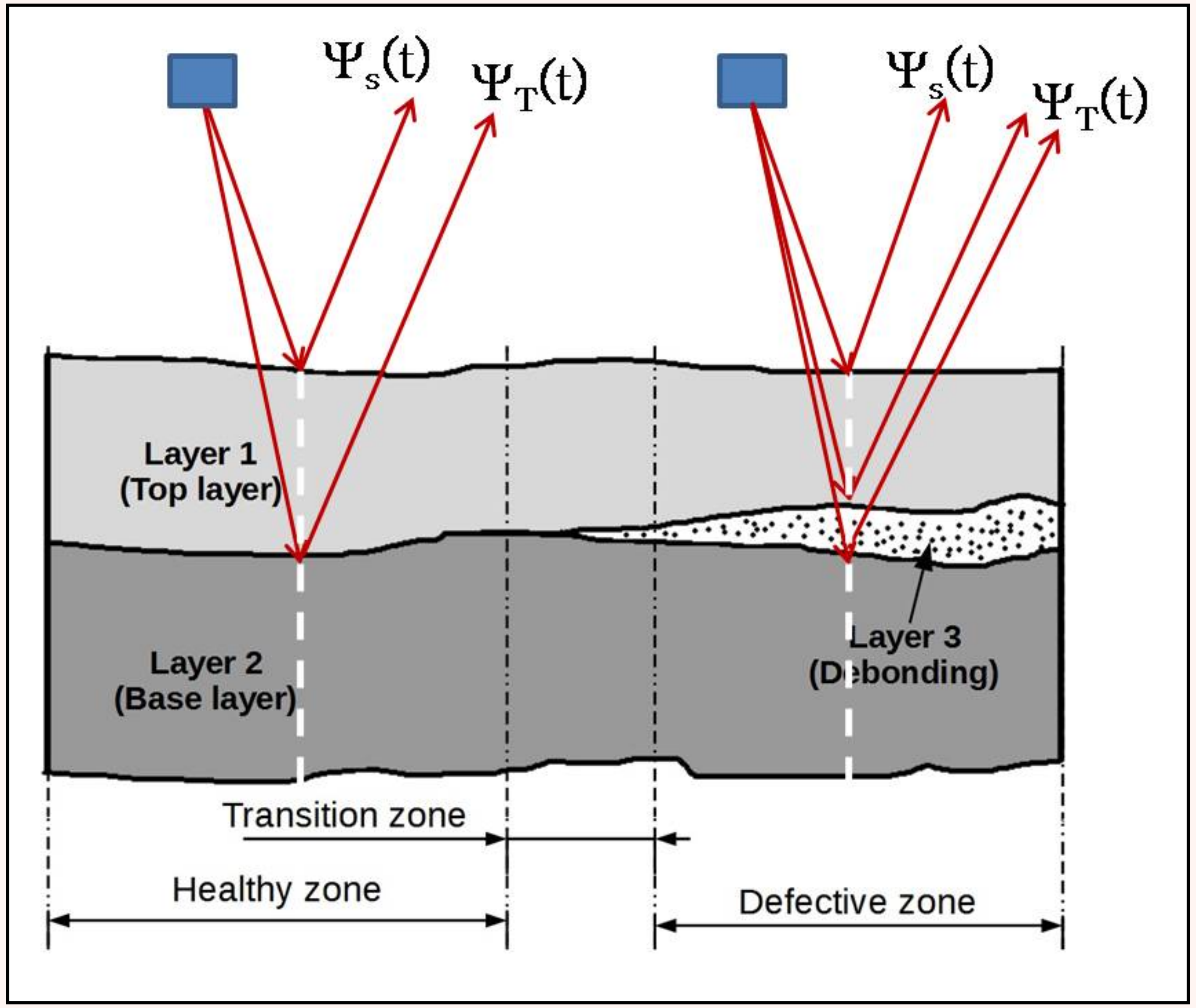


Fig 2. Debonding characterisation

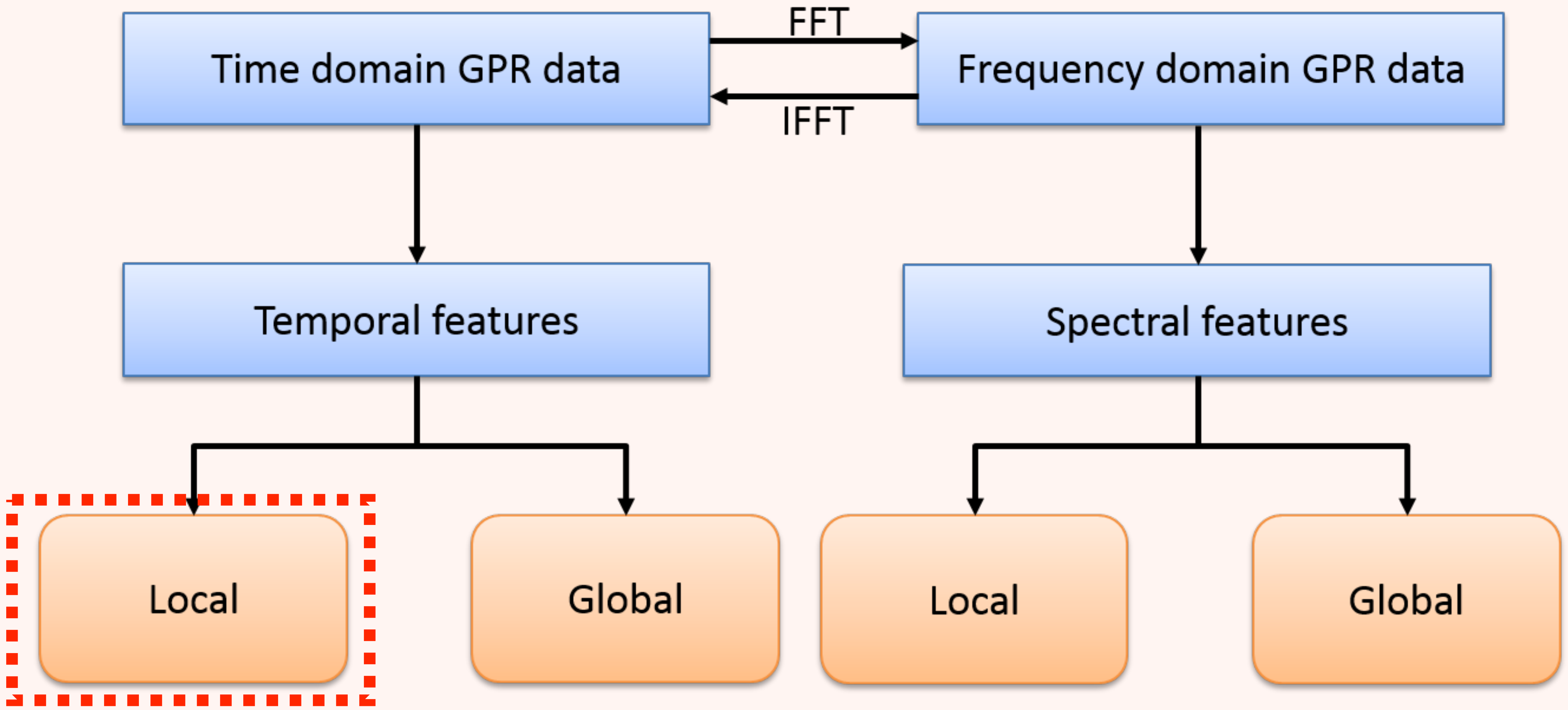
OBJECTIVES

- 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

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)**

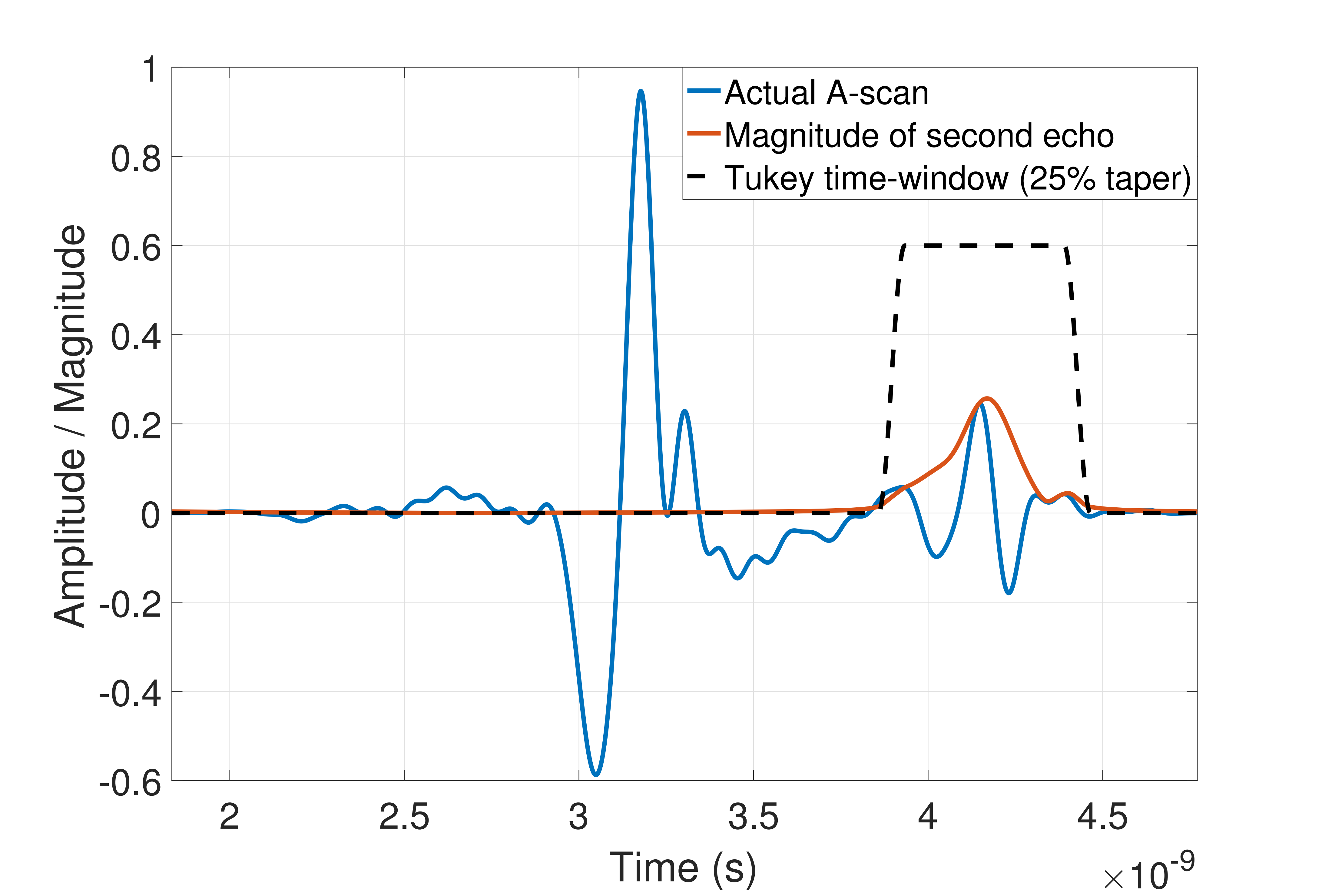


Fig 3. Time-gating of second echo

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)**

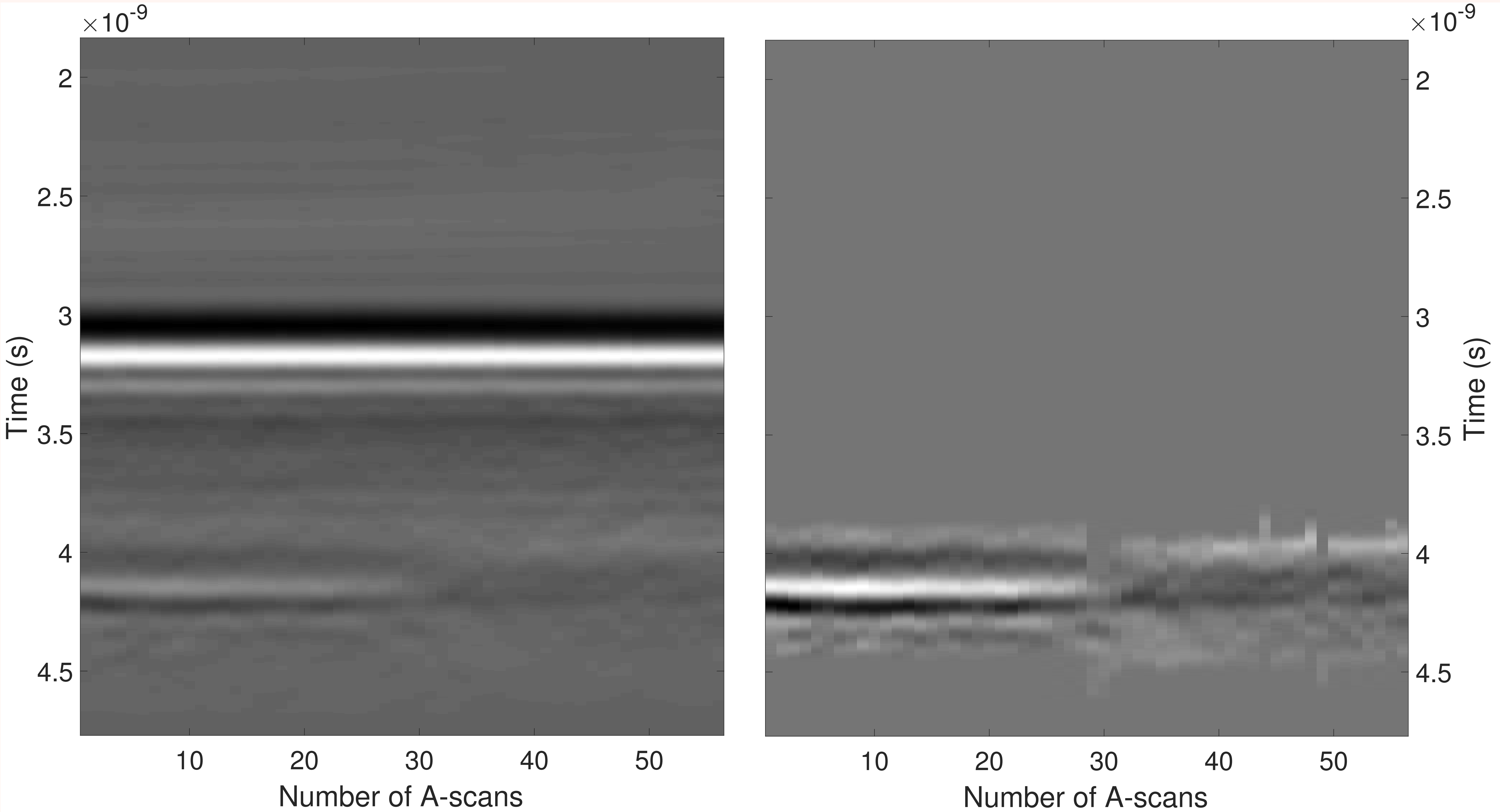


Fig 4. Ungated *vs.* Time-gated GPR B-scan

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:

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

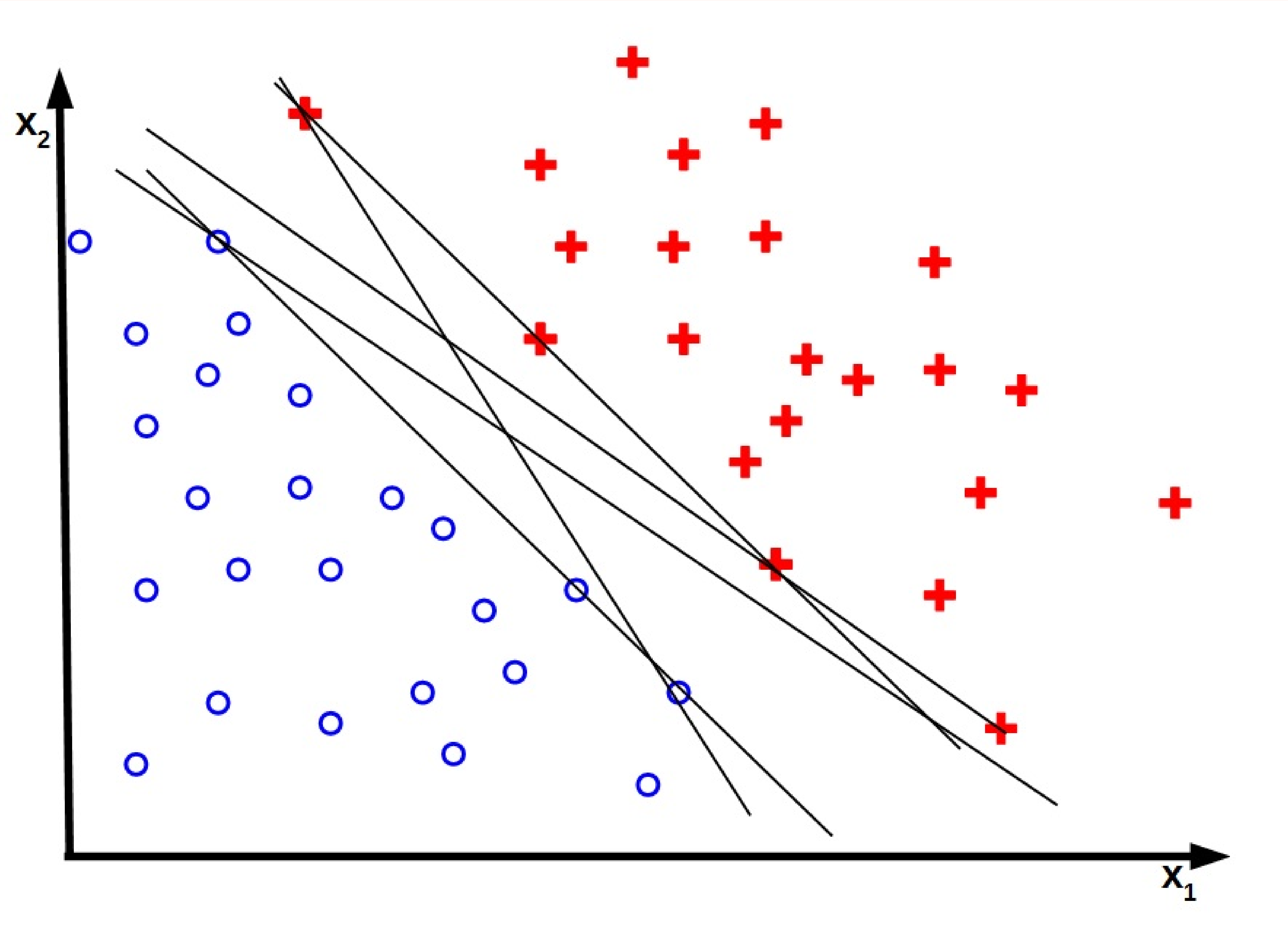


Fig 5(a). Example of possible hyperplanes for SVM classification

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**

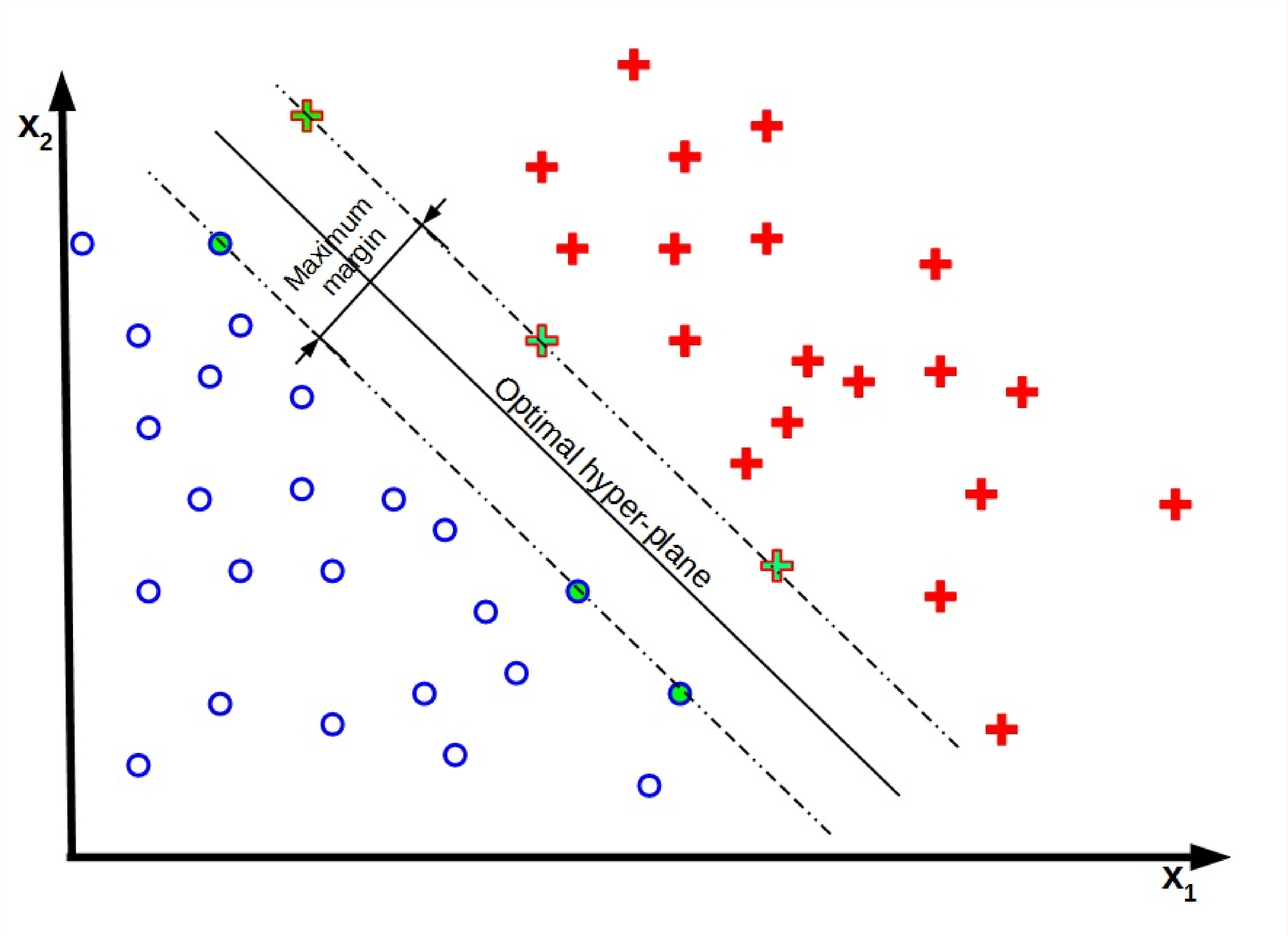
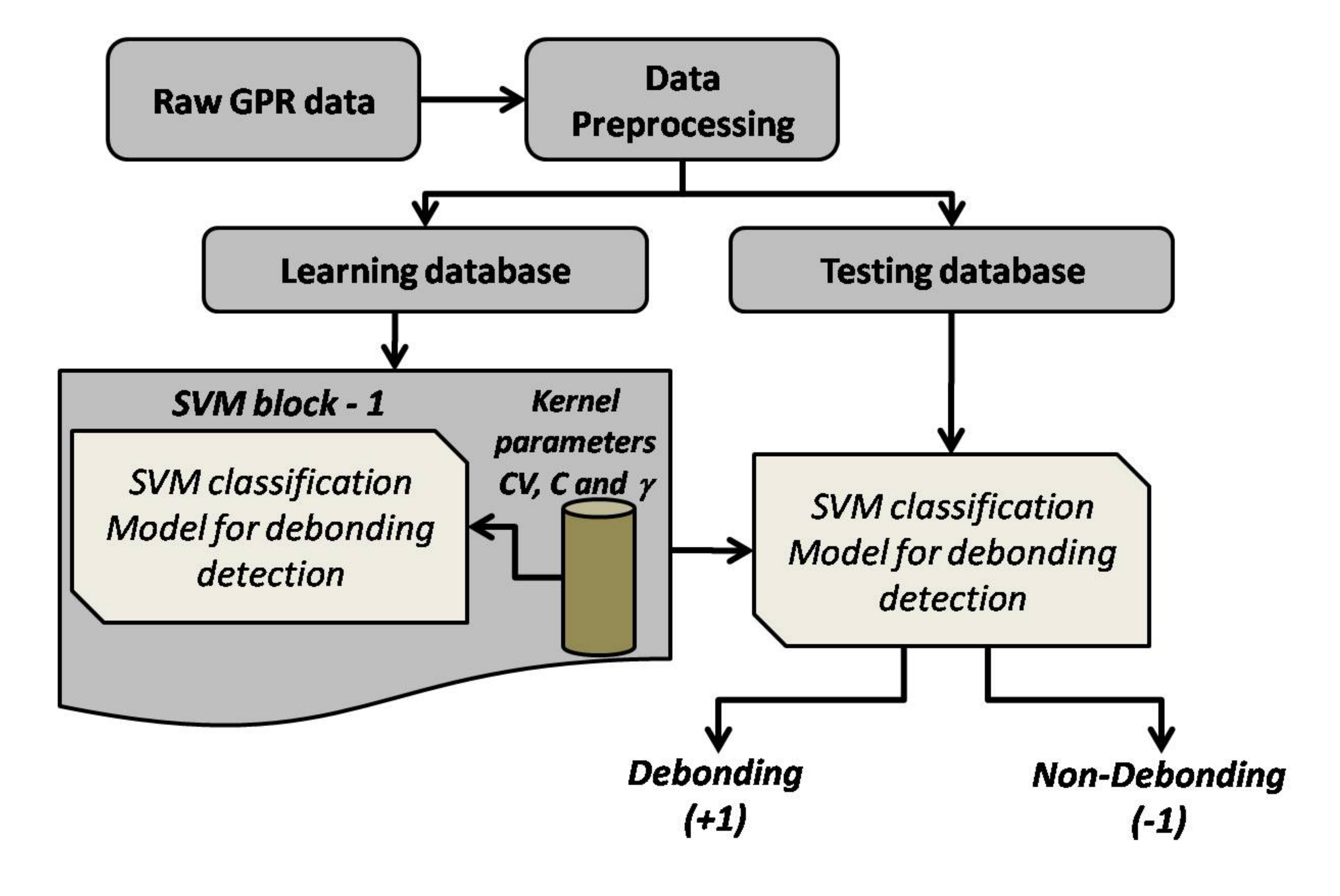


Fig 5(a). Example of the optimal hyperplane with max margin

THE SVM APPROACH



SOME RESULTS

DATABASES USED

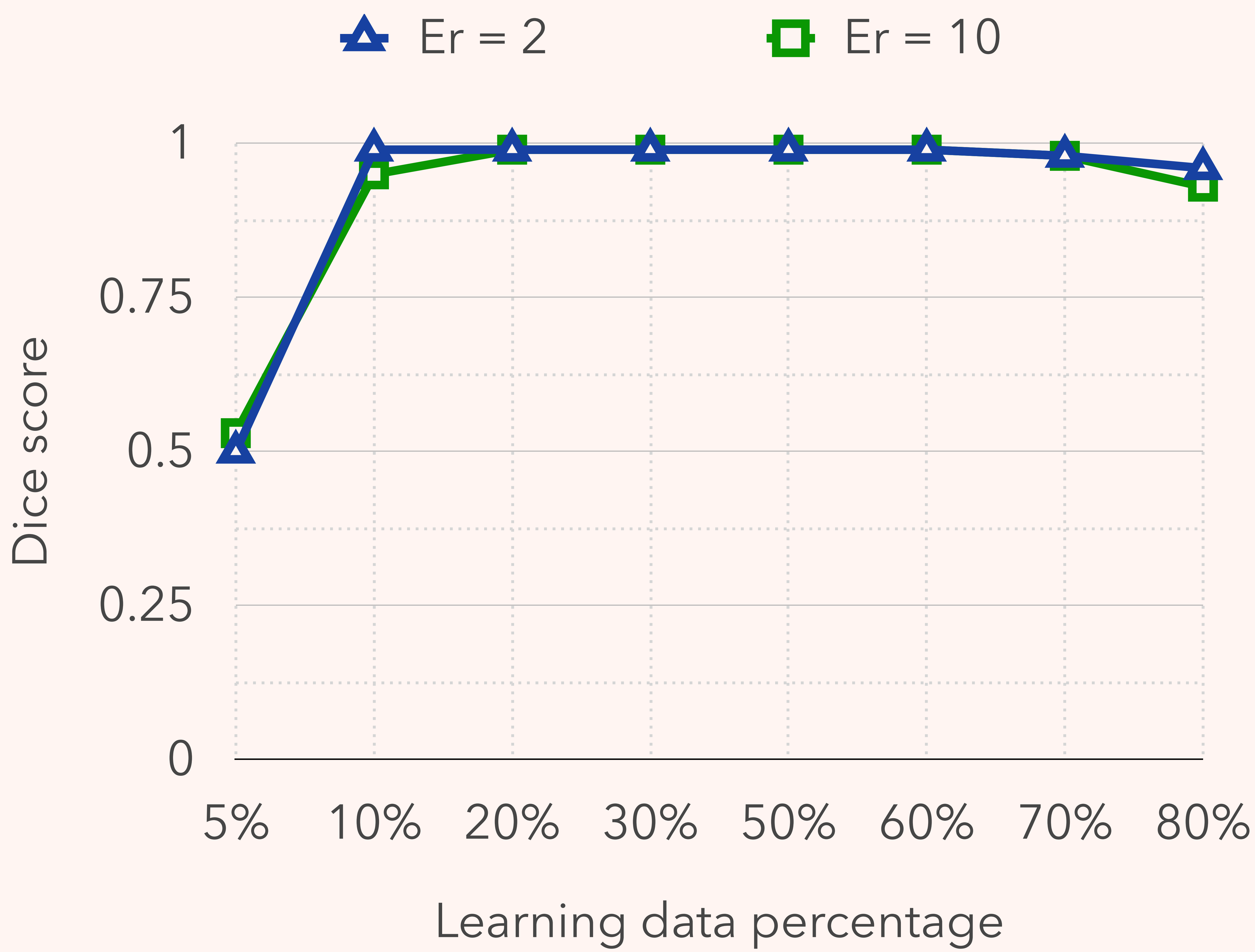
- **Simulated database**
  - ***Three permittivity values: 2 (near air-void defects), 10 (near moisture/wet defects)***
  - ***Each B-scan consists of 150 A-scans with 50 debonding and 100 non-debonding A-scans***
  - ***Gaussian noise of 30 dB added to the B-scans***
- **Experimental database:**
  -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

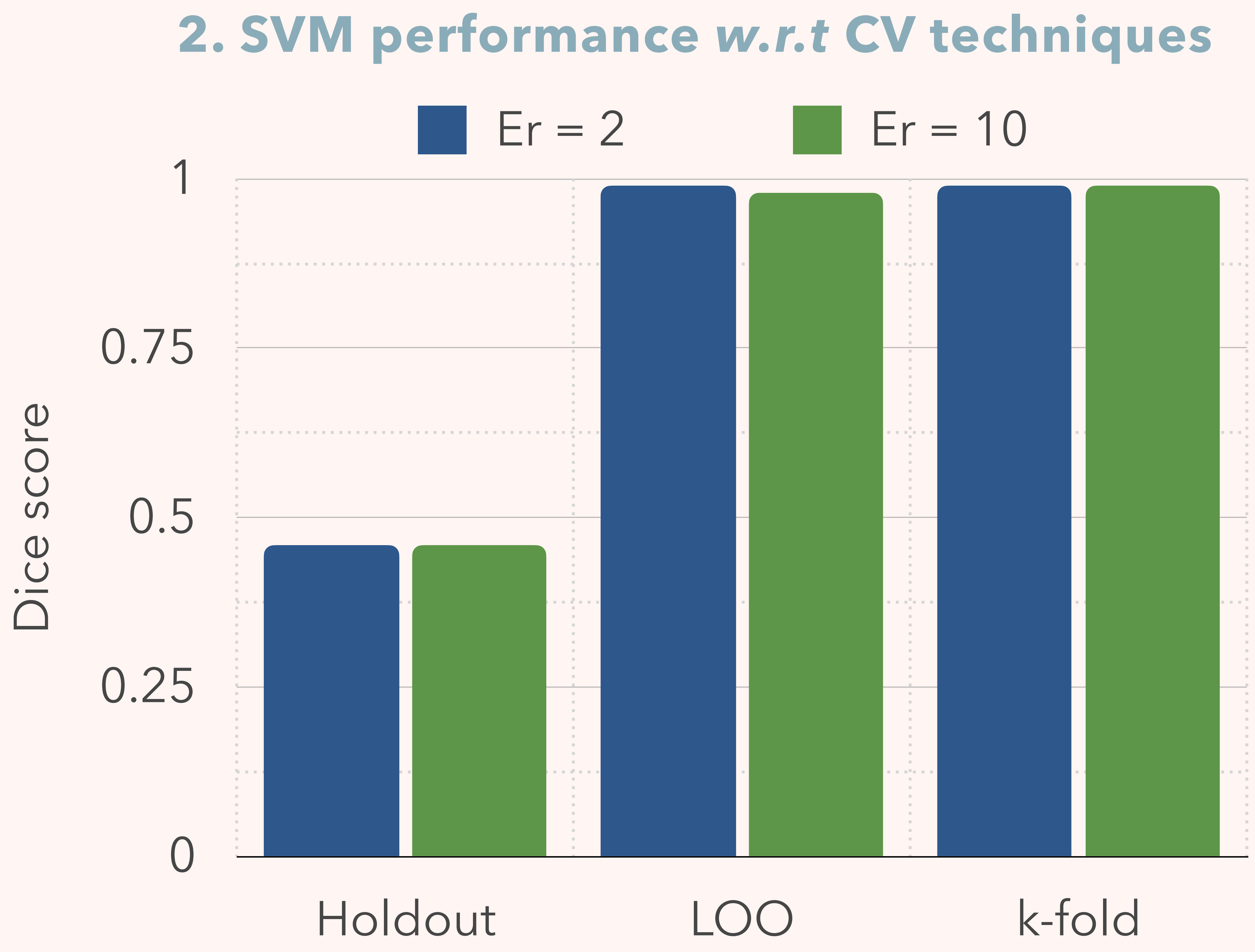
- The study of relationship uncertainties between the input and its outputs
- To observe the robustness and adaptability of a method *w.r.t* various input data configurations
- Sensitivity analysis studied:
  - ***Data-based SA**: Effect of learning data size and input feature set*
  - ***Method-based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

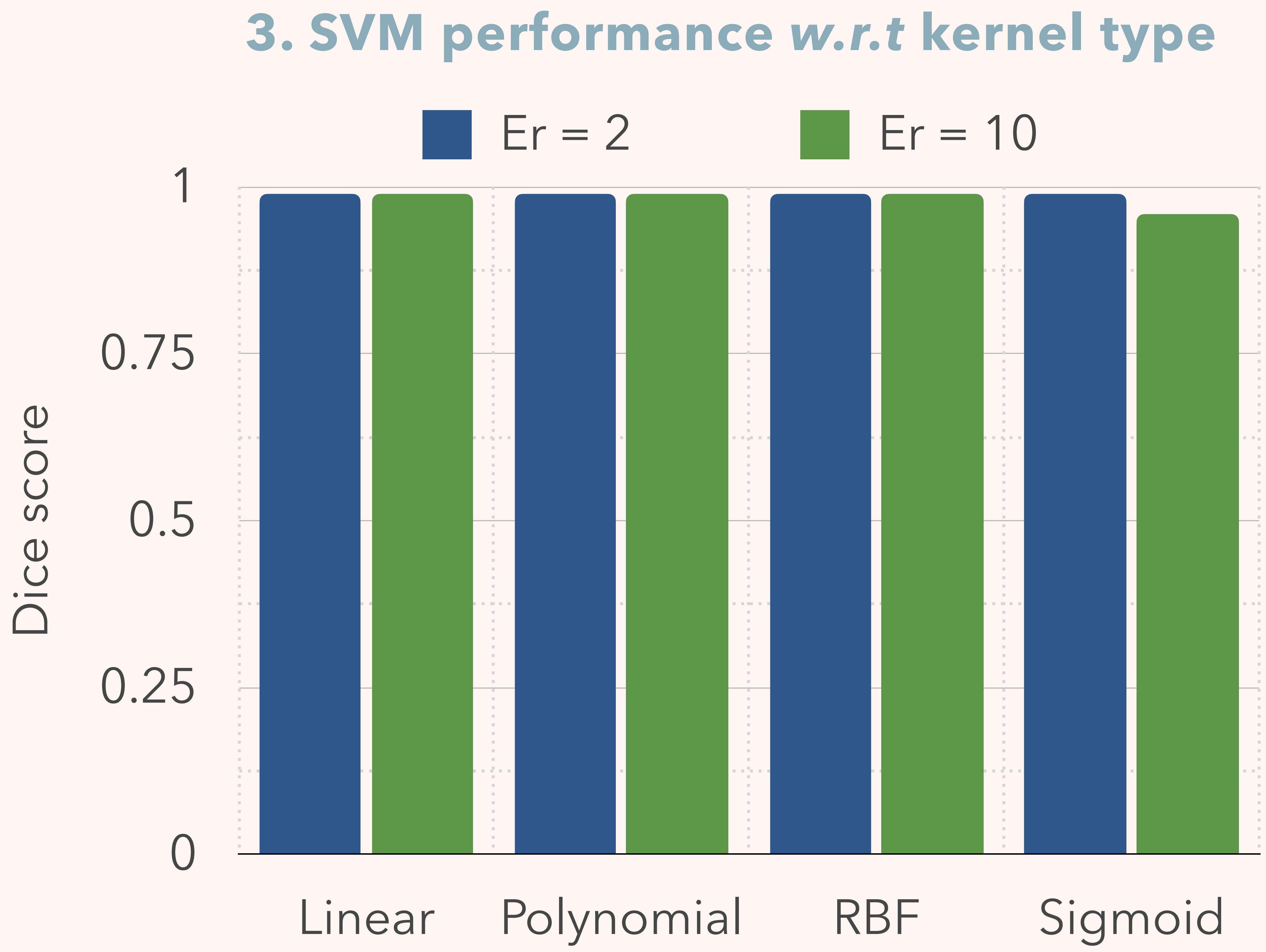
SENSITIVITY ANALYSIS

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



SENSITIVITY ANALYSIS





CONCLUSIONS & PERSPECTIVES

CONCLUSIONS

- Performance testing with simulated and field data
- Sensitivity analysis of the SVM method w.r.t signal features
  - *<u>Feature sets</u>: Performance of Local features > Global features*
  - *<u>CV techniques</u>: k-fold (k=5) presented the best performances*
  - *<u>Learning data</u>: 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.