D760 (EGU - 2020 - 22503)
PERFORMANCE ANALYSIS OF TWO-CLASS SVM TO DETECT THIN INTERLAYER DEBONDINGS WITHIN PAVEMENT STRUCTURES
Presenter: Shreedhar Savant Todkar
INTRODUCTION
Pavement degradation: surface (cracks) and subsurface defects (delaminations → reflexive cracks)

Detection using Non-destructive GPR imaging and advanced processing methods
Debonding: Presence of an additional layer between the top two pavement layers

Constructive interference of overlapping backscattered echoes (< \(\lambda_{\text{mat}}/4\))
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
Use of time domain statistical signal features

Local vs. Global signal features

Feature set consists of:

- *Standard deviation* ($\sigma$), *Amplitude range of second echo* ($A_2$), *Skewness* ($S_k$), *Kurtosis* ($K_u$), *Interquartile range* (IQR) and *Root-mean square* (rms) of the signal
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 (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:

\[
\text{Minimize} \quad \frac{1}{2} \| w \|^2 + C \sum_{i=1}^{N} \xi_i
\]
SUPPORT VECTOR MACHINES

- Learning data is used to create a classification model.
- Test data is used 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

```
Raw GPR data → Data Preprocessing

Learning database

SVM block - 1

SVM classification
Model for debonding detection

Kernel parameters
CV, C and \( \gamma \)

Testing database

SVM classification
Model for debonding detection

Debonding (+1)
Non-Debonding (-1)
```
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
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

![Graph showing SVM performance with different learning data percentages. The graph plots Dice score against learning data percentage with two error rates (Er = 2 and Er = 10) shown.]
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.