# An Adaptive Learning-by-Examples Methodology for Accurate Crack Characterization in NDT-NDE Problems

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**Abstract**

This document presents an adaptive learning-by-examples (*LBE*) inversion strategy for the accurate and real-time characterization of a defect within a planar conductive structure. More precisely, the developed technique exploits a Partial Least Squares (*PLS*) linear feature extraction strategy in order to *compress* the relevant information about the underlying relationship between defect and measurements into a small set of predictive features. Successively, an innovative adaptive sampling strategy is exploited in order to collect a set of *N* input-output (*I/O*) training pairs such that an *even exploration* of the *PLS*-extracted feature space is obtained. Such a training database is then used to train a Support Vector Regressor (*SVR*) for building an accurate and robust estimator of the crack dimensions starting from *ECT* measurements. Some numerical results are shown in order to validate the proposed approach also when a non-negligible amount of noise is superimposed on testing data.

# 1 Crack Dimensions Estimation Inside a Plate Structure

## 1.1 $PLS - OSF - SVR$ (Algorithm #3): Analysis for $J = 5$ - Performances

### 1.1.1 Parameters

- **Measurement set-up for the inversion**
  - considered measurement step: $\Delta_x = \Delta_y = 0.5$ [mm];
  - number of considered measurement points $K = K_x \times K_y = 5 \times 31 = 155$;
  - measured quantity for each $k$-th point: $\{\Re(\Psi_k), \Im(\Psi_k)\}$;
  - total number of measured features: $F = 2 \times K = 310$;

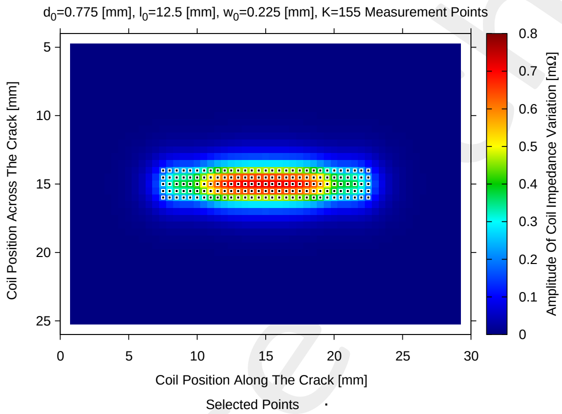



Figure 1: Location of the measurement points selected for the inversion ($K = 155$).

- $PLS - OSF - SVR$ **(algorithm #3)**
  - Initial training set (uniform grid)
    - Number of quantization levels: $Q_{x_0} = Q_{y_0} = Q_{z_0} = 5$;
    - Number of initial training samples: $N_1 = Q_{d_0} \times Q_{l_0} \times Q_{w_0} = 125$;
  - Number of extracted $PLS$ components: $J = 5$;
  - $SNR$ on training measurements: noiseless data;
  - Number of candidate samples: $C = 150$ $(50 \times I)$ (generated via $LHS$ sampling);
  - $SNR$ on training data: Noiseless;
  - Test set generation
    - Sampling: Latin Hypercube Sampling ($LHS$);
    - Number of test samples: $M = 1000$;
    - $SNR$ on test data: Noiseless + $SNR = \{40; 30; 20; 10\}$ [dB].

### 1.1.2 Estimation of $d_0$

**$SNR = 30$ [dB] on $ECT$ Measurements**

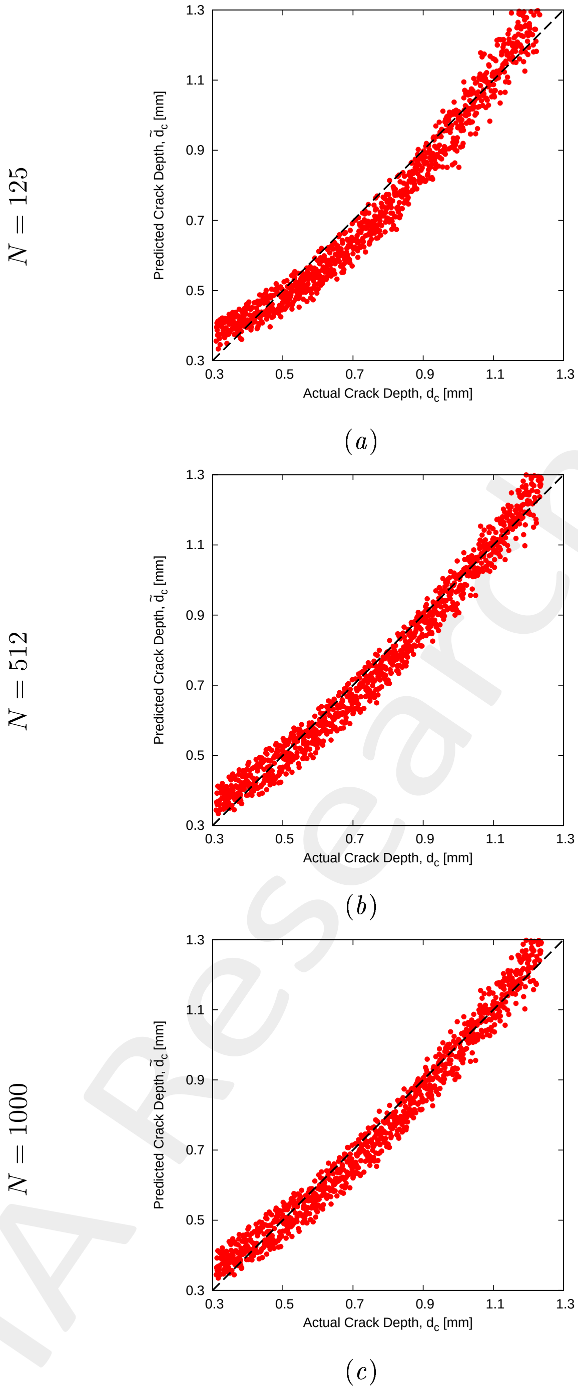



Figure 2: **PLS-OSF-SVR** - Actual vs. predicted depth of the crack for different values of $N$. $SNR = 30$ [dB] on test $ECT$ data.

### 1.1.3 Estimation of $l_0$

**$SNR = 30$ [dB] on $ECT$ Measurements**

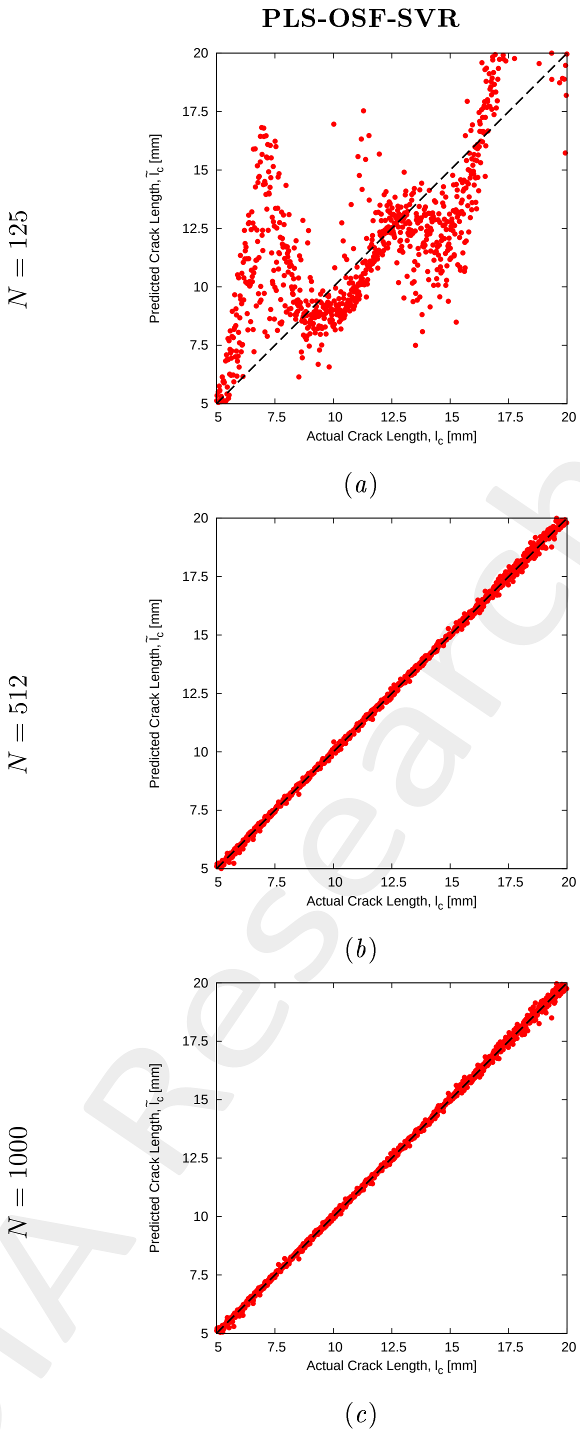



Figure 3: **PLS-OSF-SVR** - Actual vs. predicted length of the crack for different values of $N$. $SNR = 30$ [dB] test $ECT$ data.

### 1.1.4 Estimation of $w_0$

**$SNR = 30$ [dB] on $ECT$ Measurements**

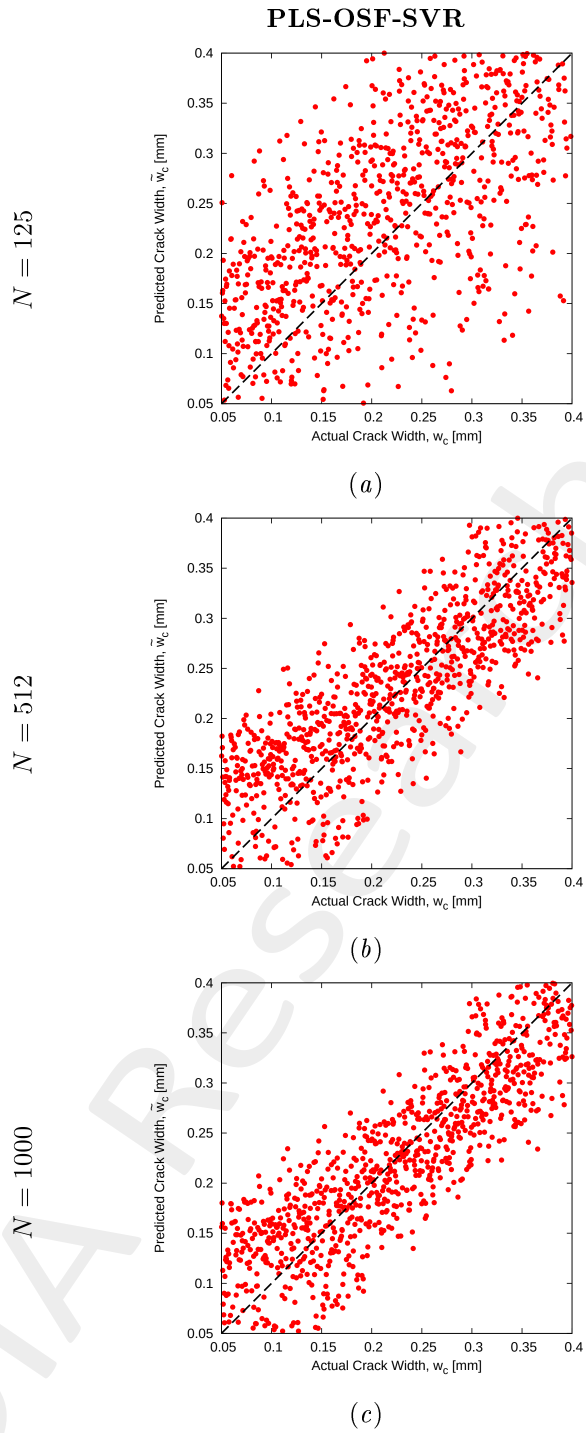
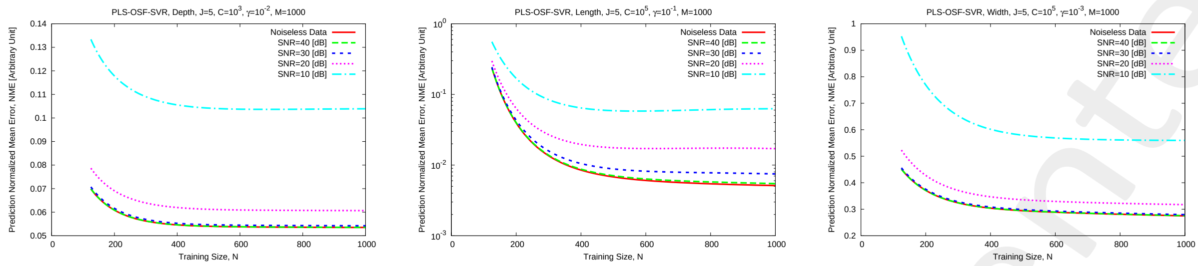



Figure 4: **PLS-OSF-SVR** - Actual vs. predicted width of the crack for different values of $N$. $SNR = 30$ [dB] on test $ECT$ data.

### 1.1.5 Prediction Errors

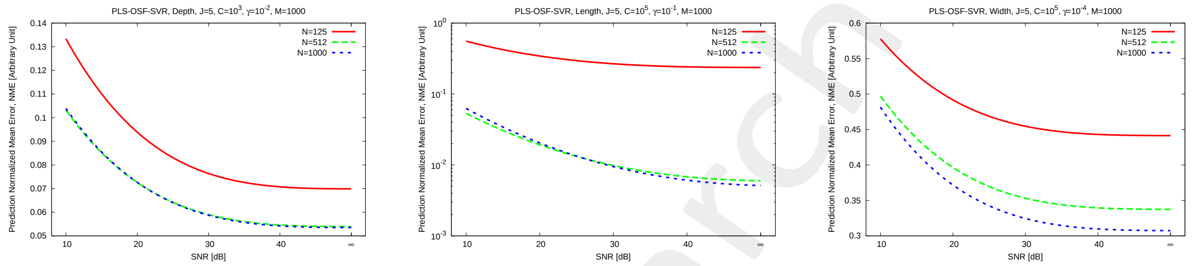
**Depth** $(d_0)$ | **Length** $(l_0)$ | **Width** $(w_0)$




$(a)$ $(b)$ $(c)$

Figure 5: **PLS-OSF-SVR** - Normalized Mean Error $(NME)$ vs. training size $(N)$

**Depth** $(d_0)$ | **Length** $(l_0)$ | **Width** $(w_0)$




$(a)$ $(b)$ $(c)$

Figure 6: **PLS-OSF-SVR** - Normalized Mean Error $(NME)$ vs. $SNR$ on the test $ECT$ measurements.

**More information on the topics of this document can be found in the following list of references.**

# References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