CONFIDENCE METRICS FOR PARTICLE FILTER BASED DATA FUSION

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Introduction

Inverse problems in nondestructive evaluation (NDE) focus on estimating flaw profiles from measurements. A recursive flaw profile estimation technique based on the sequential Monte Carlo (SMC) algorithm was proposed earlier by the authors [1] for solving such problems. This inversion technique computes the posterior PDF of a flaw profile $p(X_k \mid Z_k)$ at discrete locations. The PDFs are represented using samples and associated weights:

$$p(X_k \mid Z_k) \approx \sum_{i-1}^{N} w_k^i \delta(X_k - X_k^i) \qquad (1)$$

In this paper, the SMC algorithm is extended to fuse measurements from multiple sensors to improve solution accuracy. Data fusion is accomplished by setting the weight assigned to sample *i* at index *k* as:

$$w_k^i = \prod_{j=1}^{M} w_k^{i,j} \qquad (2)$$

where $w_k^{i,j}$ is the weight assigned to sample i at spatial index k by using the j^{th} measurement mode. The accuracy of this estimation method is quantified using metrics such as credibility intervals and the CRLB.

Credibility intervals

The credible interval (CI) is a posterior probability interval which is used for interval estimation. $(1-\alpha)$ Credible interval on posterior PDF $p(X_k \mid Z_k)$ is given by:

$$p(LB < X_k < UB) = \int_{LB}^{UB} p(X_k \mid Z_k) dX_k = (1-\alpha) \qquad (3)$$

In this study, the percentile method [2] is used to evaluate the credibility interval of posterior PDFs computed from both single and multiple measurement modes.

Cramér–Rao lower bound (CRLB)

The CRLB provides a lower bound on the variance of estimators of a deterministic parameter [3]. If $\hat{X}_{k|k}$ is an unbiased estimator of the state vector X_k based on measurement sequence and prior density, the covariance matrix of $\hat{X}_{k|k}$, denoted by $P_{k|k}$, has CRLB given by [3]

$$P_{k|k} = E\left\{\left(\hat{X}_{k|k} - X_k\right)\left(\hat{X}_{k|k} - X_k\right)^T\right\} \geq J_k^{-1} \qquad (4)$$

Matrix J_k is the filtering information matrix and its inverse is the CRLB. The information matrix J_k may be computed recursively [3].

Results

The metrics discussed above were used to quantify the accuracy of flaw profile estimation from eddy current NDE measurements. Results from a single probe measurement (magnitude of eddy current coil impedance at 400 kHz) were compared to results after fusion (coil impedance magnitude at 200 kHz, 400 kHz and 800 kHz). Figure 1 shows the comparison in the credibility intervals in both cases for the same flaw. Additional results on CI and CRLB metrics will be presented at the symposium.

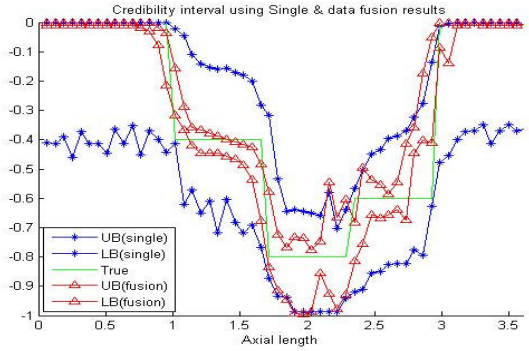

Figure 1. 95% credible intervals

Conclusions

An SMC algorithm for fusing multisensor data to solve inverse problems has been proposed. The results are quantified using the CI and CRLB metrics. Preliminary results indicate improvement in the accuracy of inversion when data fusion is used.

References

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