Engine Fault Detection Using Vibration Signal Reconstruction in the CA Domain

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Organization

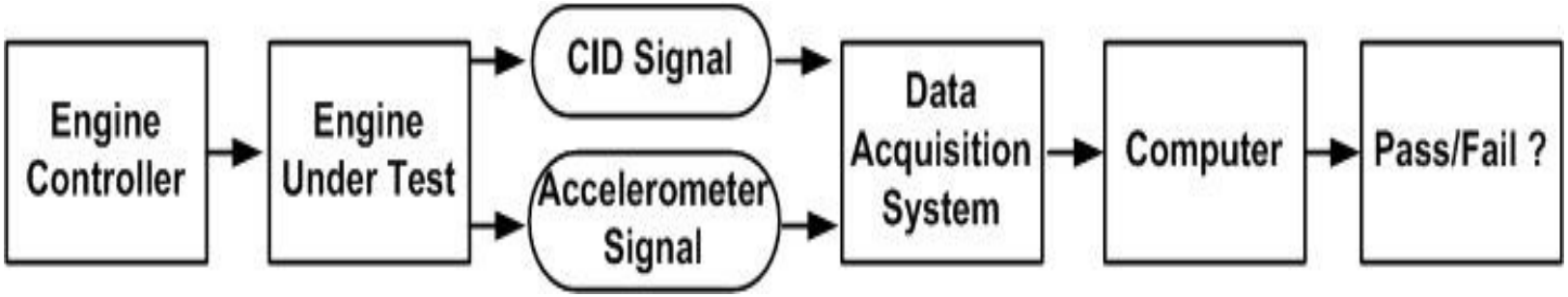
- Engine Fault Detection: Brief Overview
- Test Setup
- Proposed Solution:
  - Sinc-based vibration signal reconstruction in the CA domain
- Main Results
- Concluding Remarks
- Future Work

Overview

- Three types of engine fault detection:
  - In-process test
  - Cold test
  - Hot test
- Measurements used during hot tests:
  - Torque
  - In-cylinder pressure
  - Sound
  - Vibration etc.
- Why vibration measurements are so popular?

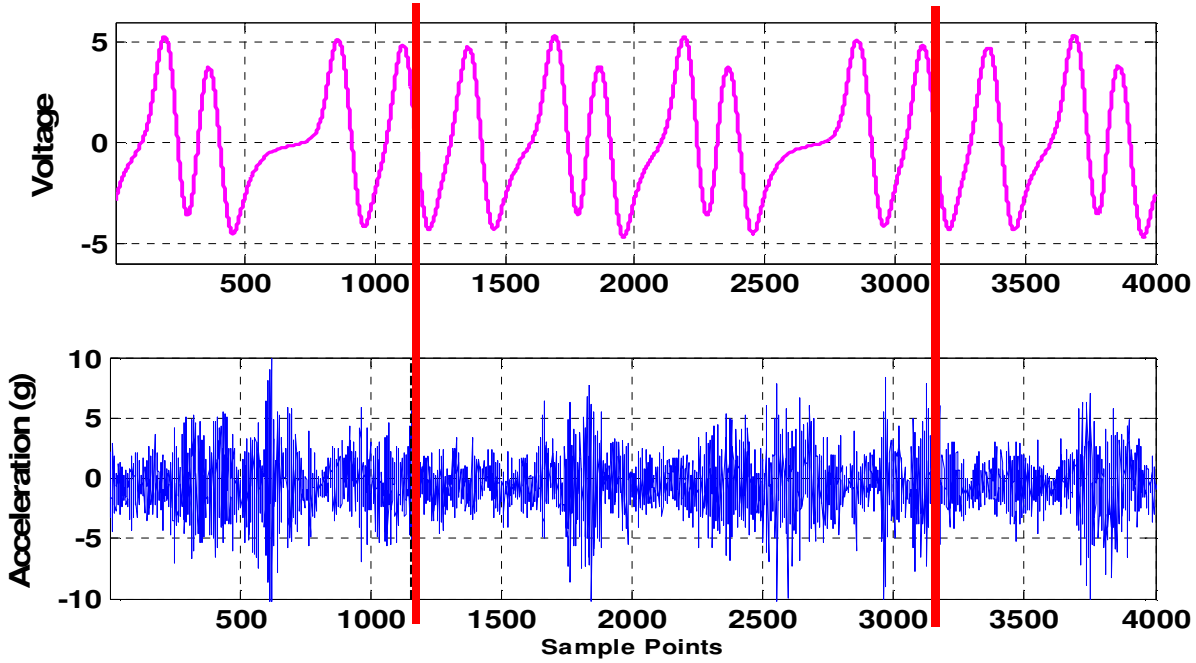
Test Setup

- Objective: To classify engines as pass/fail quantitatively
- Test setup:



CID Signal for Referencing

- CID wheel configuration: [90-120-60-120-60-120-60-180-90]
- Variable reluctance type sensor



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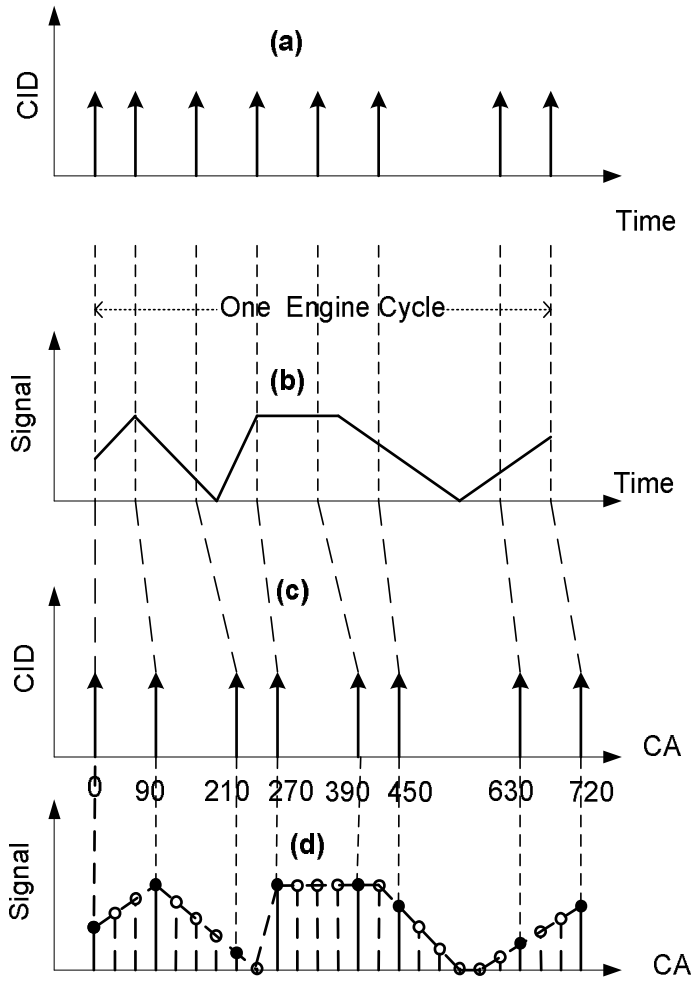
Proposed Solution: 5-Step Procedure

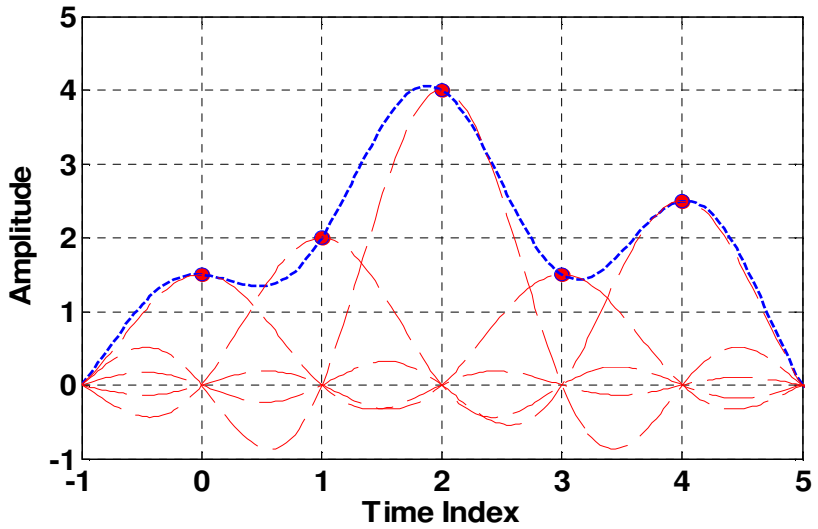


Sinc Interpolation

- Idea: Any band-limited signal x(t) can be reconstructed from its samples at integer spacing as follows:

$$\tilde{x}(t) = \sum_{k=-\infty}^{\infty} x[k]\,\mathrm{sinc}\left(\frac{t - kt_s}{t_s}\right)$$

- Example:



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Sinc Interpolation (Cont'd)

- Virtues
  - More accurate than the linear/cubic spline method
  - Easy to implement

- Limitations
  - Useful for off-line applications only
  - Not suitable for discontinues (broad-band) signals
  - Computationally more expensive

Performance Metric

- Ensemble-averaged MSE:
  - Step 1: Calculate the ensemble average

$$\bar{x}_i = \frac{1}{N}\sum_{j=1}^{N} x_{i,j}$$

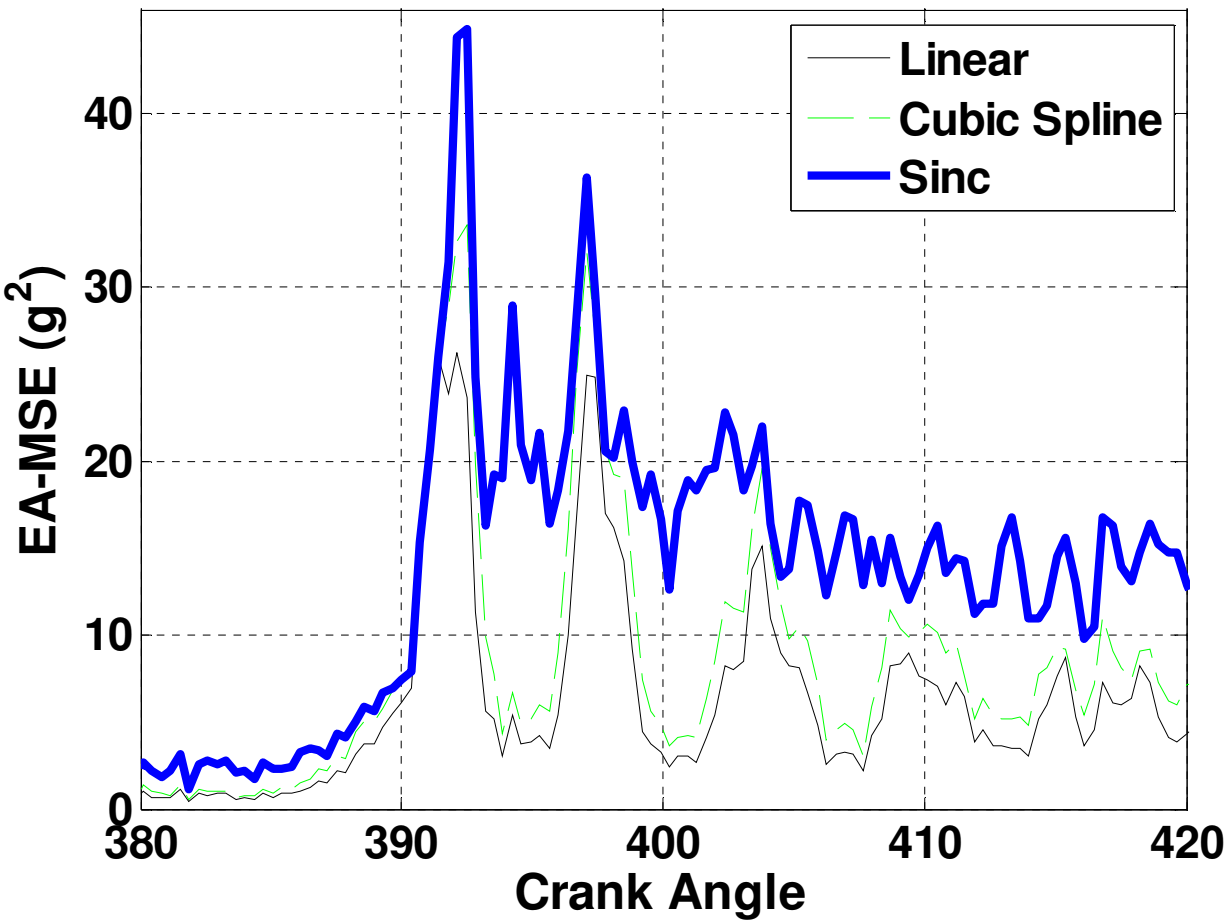
  Step 2: Calculate the instantaneous MSE

$$e_{i,j} = \left(x_{i,j} - \bar{x}_i\right)^2$$

  - Step 3: Calculate the ensemble-averaged MSE

$$e_i = \frac{1}{N}\sum_{j=1}^{N} e_{i,j} = \frac{1}{N}\sum_{j=1}^{N} x_{i,j}^2 - \bar{x}_i^2$$

Results (Cont'd)



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Concluding Remarks

- Sinc interpolation method outperforms the linear and cubic-spline in accurately reconstructing vibration signals in the CA domain
- CA domain analysis can be used to further point to the faulty portion of an engine depending on which accelerometer exhibits abnormal spikes
- Faulty valve events can be located by mapping spikes to the valve timing diagrams

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Future Work

- Use the CA domain analysis for fault detection using
  - in-cylinder pressure and
  - acoustic signals

- Investigate the effects of
  - sampling frequency and
  - the number of teeth used in the reference wheel

  on the final results

Thank you!

Questions ?