Vibration Monitoring
Gearbox identification and fault detection

POLITECNICO DI TORINO · 1859 · 1906

DYNAMICS & IDENTIFICATION DIRG RESEARCH GROUP

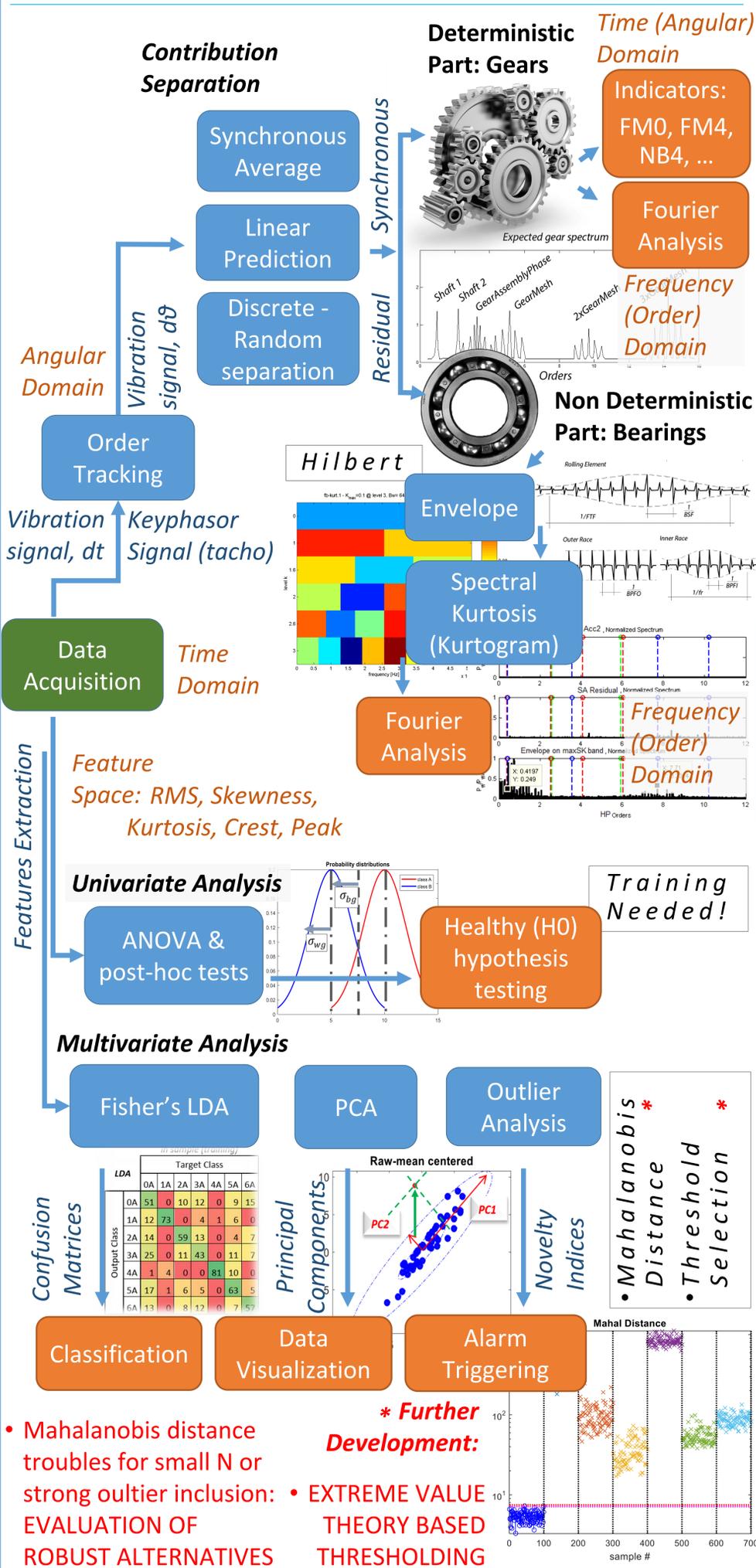*Daga Alessandro Paolo*   XXXI Cycle   alessandro.daga@polito.it

Introduction:

Gearboxes are critical components of power transmission chains and any failure can prove expensive in both repair cost and down-time. Therefore, condition monitoring is nowadays an integral part of most maintenance regimes, able to prevent the breakdown of a damaged component and eventually determine the location and the severity of a fault (diagnostics) and estimate its remaining useful life (prognostics).

Contribution Separation

Deterministic Part: Gears

Time (Angular) Domain

- Synchronous Average
- Linear Prediction
- Discrete - Random separation

Synchronous
Residual

Indicators: FM0, FM4, NB4, …

Fourier Analysis

Expected gear spectrum

Shaft 1 Shaft 2 GearAssemblyPhase GearMesh 2xGearMesh

Orders

Frequency (Order) Domain

Angular Domain

Vibration signal, dϑ

Order Tracking

Vibration signal, dt   *Keyphasor Signal (tacho)*

Data Acquisition

Time Domain

Non Deterministic Part: Bearings

Hilbert

- Envelope
- Spectral Kurtosis (Kurtogram)
- Fourier Analysis

Rolling Element
1/FTF   BSF
Outer Race   Inner Race
BPFO   1/fr   BPFI

Acc2, Normalized Spectrum
SA Residual, Normalized Spectrum
Envelope on maxSK band, Norma...
X: 0.4197 Y: 0.249
HP Orders

Frequency (Order) Domain

Features Extraction

Feature Space: RMS, Skewness, Kurtosis, Crest, Peak

Univariate Analysis

Probability distributions
class A
class B
σ_{bg}
σ_{wg}

- ANOVA & post-hoc tests
- Healthy (H0) hypothesis testing

Training Needed!

Multivariate Analysis

- Fisher's LDA
- PCA
- Outlier Analysis

• Mahalanobis Distance
• Threshold Selection

Confusion Matrices

LDA	Target Class						
	0A	1A	2A	3A	4A	5A	6A
0A	51	0	10	12	0	9	15
1A	1	73	0	4	1	6	0
2A	14	0	59	13	0	4	7
3A	25	0	11	43	0	1	7
4A	0	1	0	0	81	10	0
5A	17	1	6	1	0	63	5
6A	0	0	5	0	0	0	69

Output Class

Principal Components

Raw-mean centered
PC2   PC1

Novelty Indices

Mahal Distance
sample #

- Classification
- Data Visualization
- Alarm Triggering

- Mahalanobis distance troubles for small N or strong oultier inclusion: **EVALUATION OF ROBUST ALTERNATIVES**

* Further Development: • EXTREME VALUE THEORY BASED THRESHOLDING

Vibration Monitoring: Learn **Health Information** through acquisitions from

ACCELEROMETERS
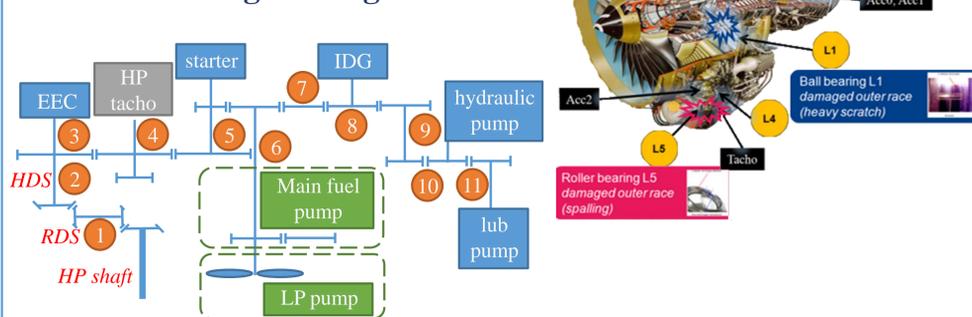*Acoustic Emission*
Laser positioning
Microphones
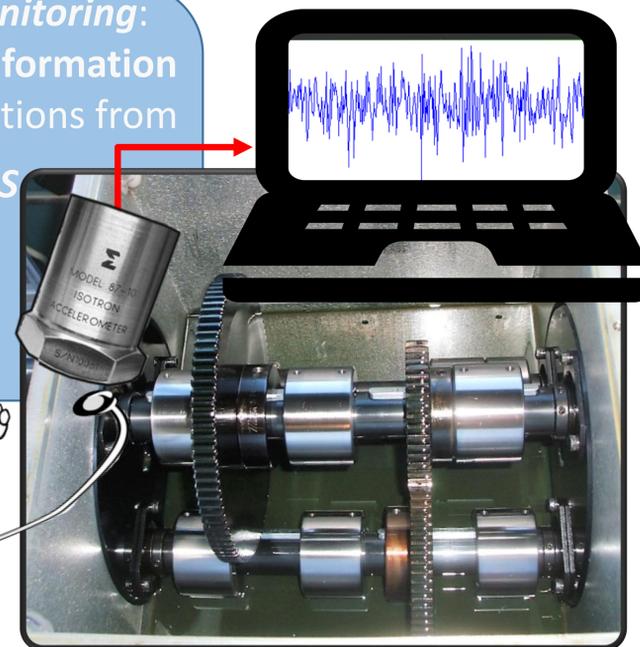
The subject investigated:

Performing **diagnosis** about damages in rotating machinery is becoming every day more important and significant. Two different approaches are possible to extract information about the health:

- **High level techniques**, able to recognize
  - Damage **Location**
  - Damage **Type**
  - Damage **Severity**
- **Low level algorithms**, simply disclosing a fault presence
  - **Pattern Recognition** based on **features → data based,** using **statistical models**
  - **Training** needed (labelled acquisitions)
  - **Alarms** are triggered in case of novelty → non healthy

Exemplary applications:

Surveillance 8 SAFRAN contest:
Civil aircraft engine Diagnostics

EEC HP tacho starter IDG
7
3 4 5 6 8 9 hydraulic pump
HDS 2 Main fuel pump
RDS 1 10 11 lub pump
HP shaft LP pump

Acc0, Acc1
Ball bearing L1 damaged outer race (heavy scratch) L1
Acc2 L5 L4
Roller bearing L5 damaged outer race (spalling) Tacho

- **OT+SA in cascade** for each shaft
- **Fast Kurtogram** of the non deterministic part for optimal band selection
- **Envelope Analysis** to enhance the bearing spectrum

[1] *Bearing damage detection techniques and their enhancement: comparison over real data*
- Surveillance 8 conference, Roanne, 20-21 October 2015

[2] *ANOVA and other statistical tools for bearing damage detection*
- Surveillance 9 conference, Fez, 22-23 May 2017

[3] *Feedback on the Surveillance 8 challenge: vibration-based diagnosis of a SAFRAN aircraft engine*
- Mechanical Systems and Signal Processing, Volume 97, December 2017, Pages 112-144

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