AI for Predictive Maintenance

Prognostics and Forecasting

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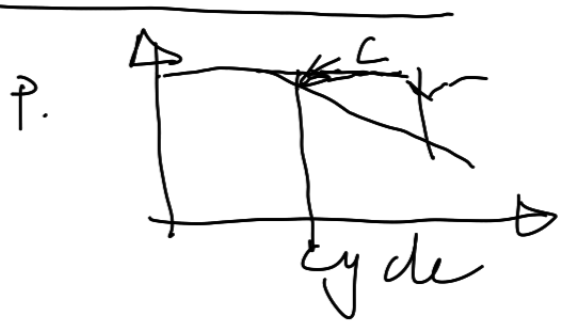
Prognostics

- Prognostics and health management
  - Monitoring health of equipment/software/human being using real-time data
  - Forecast the health of equipment/software/human using the historical data
- Prognostics:
  - Predict actual remaining useful life of equipment while it is in operation
- Condition-based maintenance System:
  - Combination of hardware and software
  - Monitor, detect, isolate and predict performance of equipment and degradation
  - No interruption to the operation
  - Maintenance based on the current condition

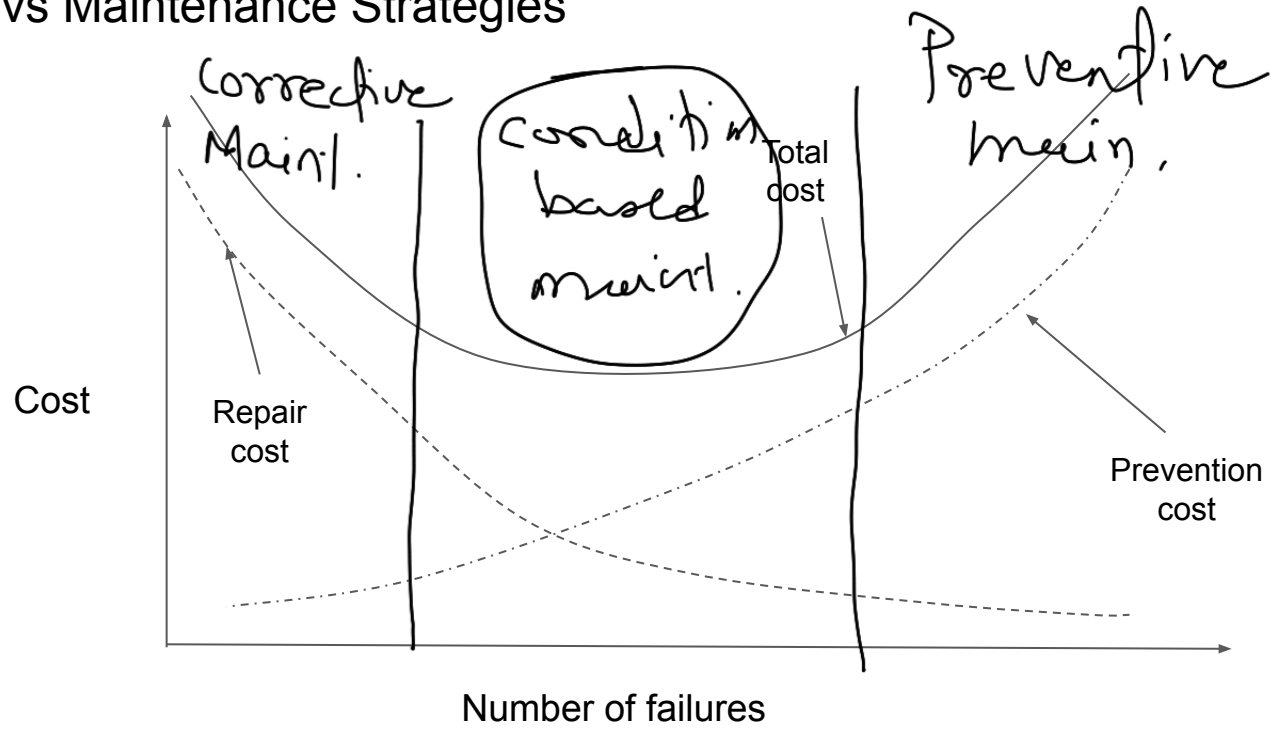
Prognostics

- Maintenance Paradigm
- Corrective Maintenance
- Preventive Maintenance
  - Periodic interval
  - Use reliability engineering to decide proper intervals for maintenance and replacements
  - Pre Scheduled maintenance
- Predictive Maintenance (Condition-based maintenance System)

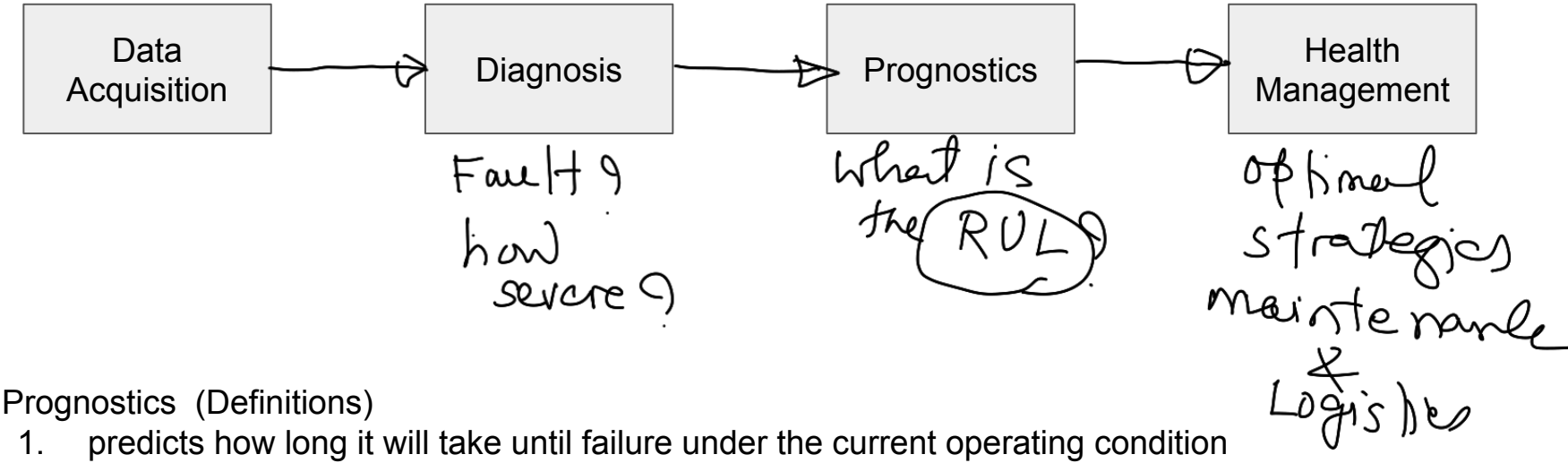


Prognostics

- Cost vs Maintenance Strategies



Prognostics and Health Management



Prognostics (Definitions)

1. predicts how long it will take until failure under the current operating condition
2. An estimation of time to failure and risk for one or more existing and future failure modes

Prognostics and Health Management: an Example

Statistics on helicopter accident rate by the Civil Aviation Authority of United Kingdom before PHM (1980-1990) and after PHM (1991-2000)

	Per 100,000 Flying Hours		Per 100,000 Sectors (Flight Stages)	
	Occupant Fatal Accident Rate	Non-Fatal Reportable Accident Rate	Occupant Fatal Accident Rate	Non-Fatal Reportable Accident Rate
1981-1990 years	5.61	2.24	2.39	0.96
1991-2000 years	1.13	0.82	0.49	0.35

John Burt Associates Limited 2011 and Oil and Gas UK

Prognostics: Algorithms

- Prognostics methods:
  - Physics-based approaches
  - Data-driven approaches
- Objective:
  - To predict future damage/degradation and the remaining useful life (RUL) based on measured data
- Physics-based approaches
- Data-driven approaches

Prognostics: Algorithms

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Hybrid Approach:

Data { degradation data + Usage conditions

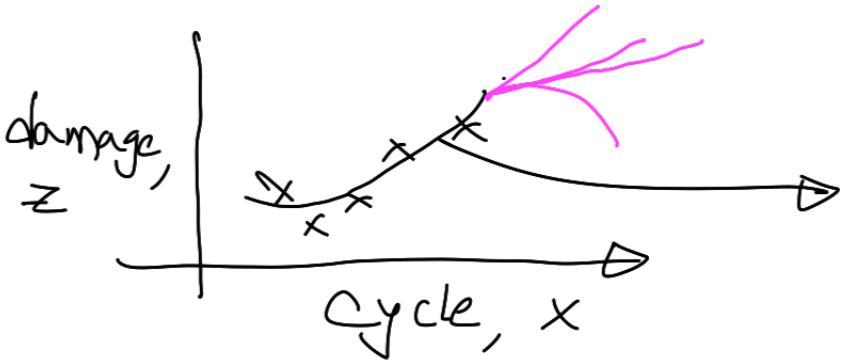
physics-based model → estimate parameters

(ML/DS/DL) → function → Regression / Classification

RUL

Prognostics: Algorithms

- Paris (or Paris-Erdogan) Model for damage vs cycle



$Z = f(X, \underline{\theta})$ → parameter estimable.

Data-driven approach

Linear, nonlinear,

$$\frac{dZ}{dx} = C^1 (\Delta K)^m$$

Estimation

$\Delta\sigma\sqrt{\pi Z}$

→ Usage condition

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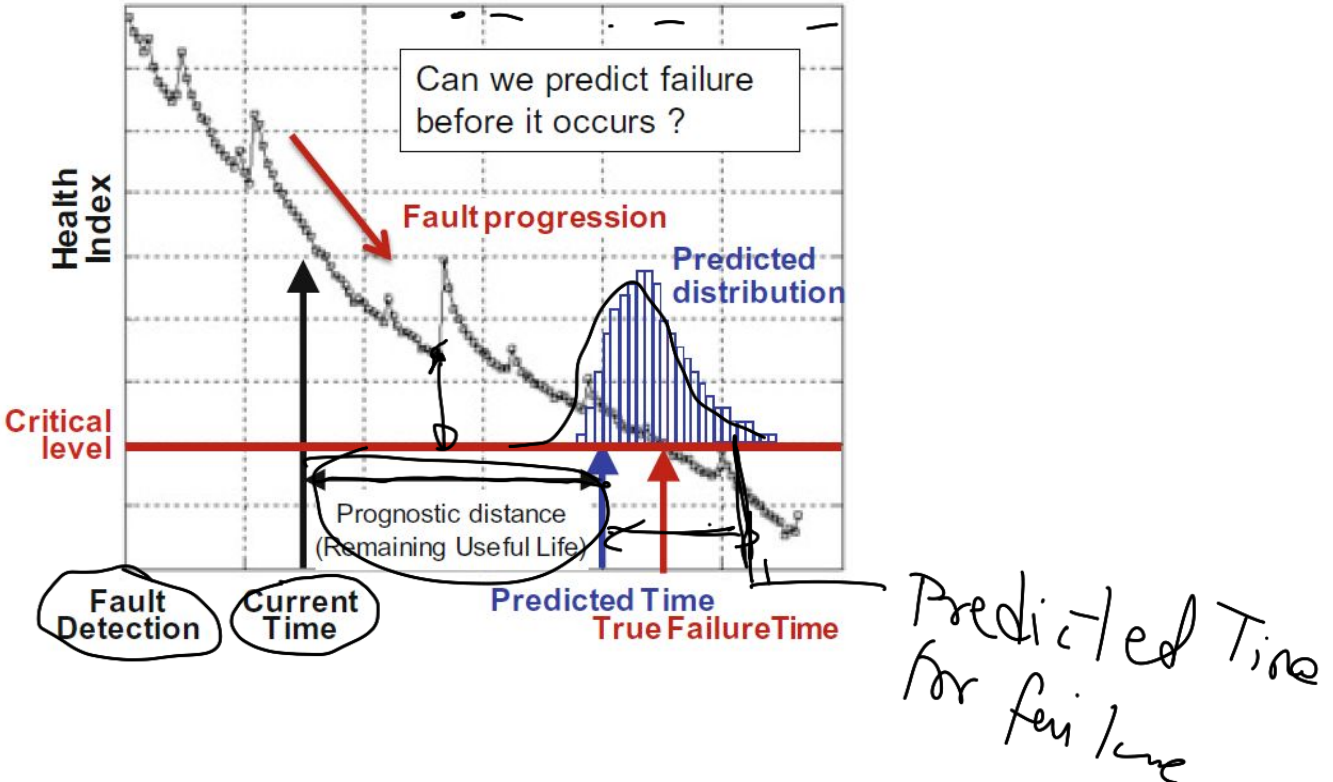
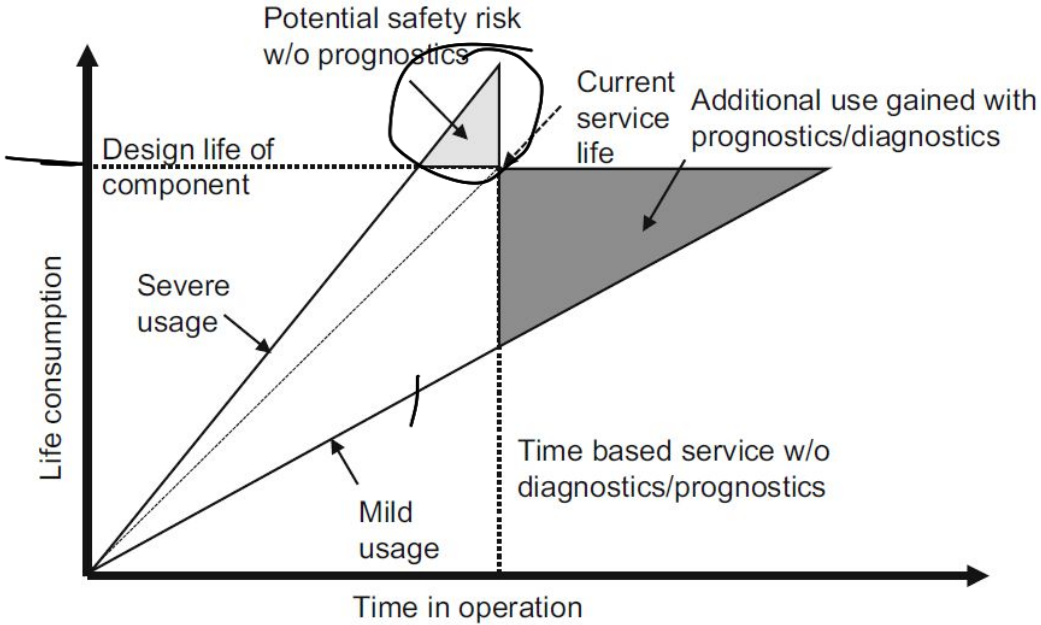
Prognostics: Benefits

- Cost: Reducing operating costs, Increased revenues
- System Design: Optimizing system design in future, Improved reliability predictions
- Production and Operation: Better process control, Safety, Improved operational reliability
- Logistic Support and maintenance: Optimized supply chain, reduced maintenance-induced faults

Prognostics: Fault to Failure



Prognostics: for improved online reliability

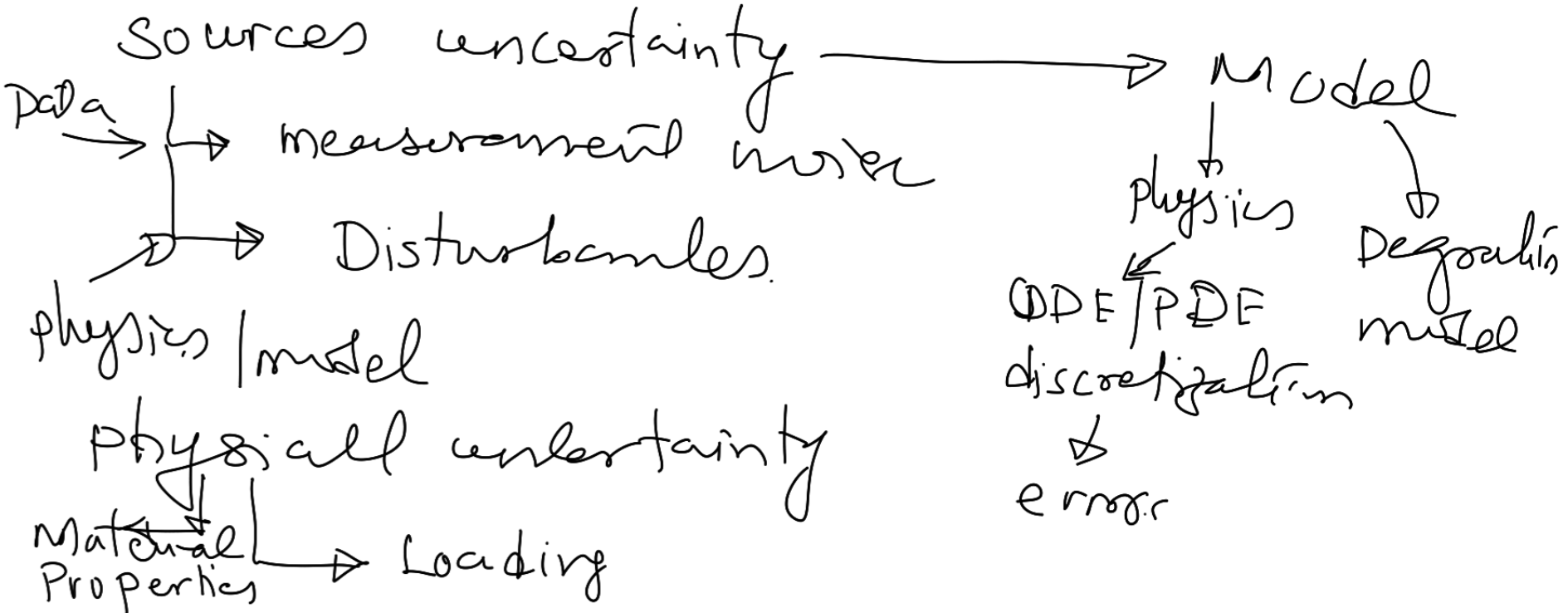


Prognostics: Challenges

- Optimal sensor selection and location:
- Feature Extraction
- Conditions for prognostics approaches
  - ↳ physics vs data driven

Prognostics: Challenges

- Uncertainties and accessing its accuracy



Prognostics: Challenges

- Uncertainties and accessing its accuracy

* False alarm rate, missed estimation rate, correct rejection rate & statical metrics

* RUL : Remaining useful life