ESTIMATION OF REMAINING USEFUL LIFE OF TURBOFAN ENGINE

PRESENTED BY

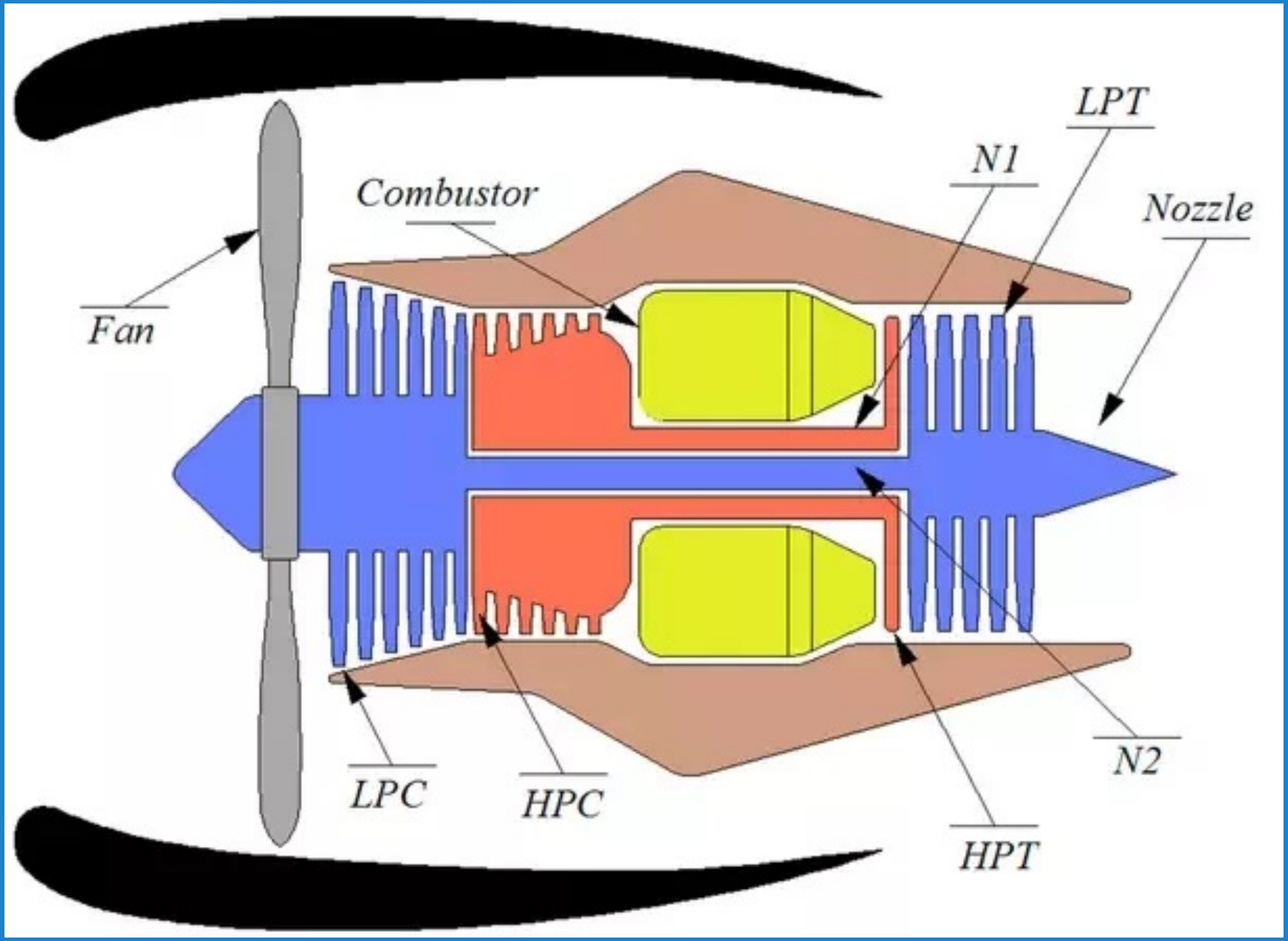
Name : ABHISHEK PATWARI

Roll No. : 16EE10002

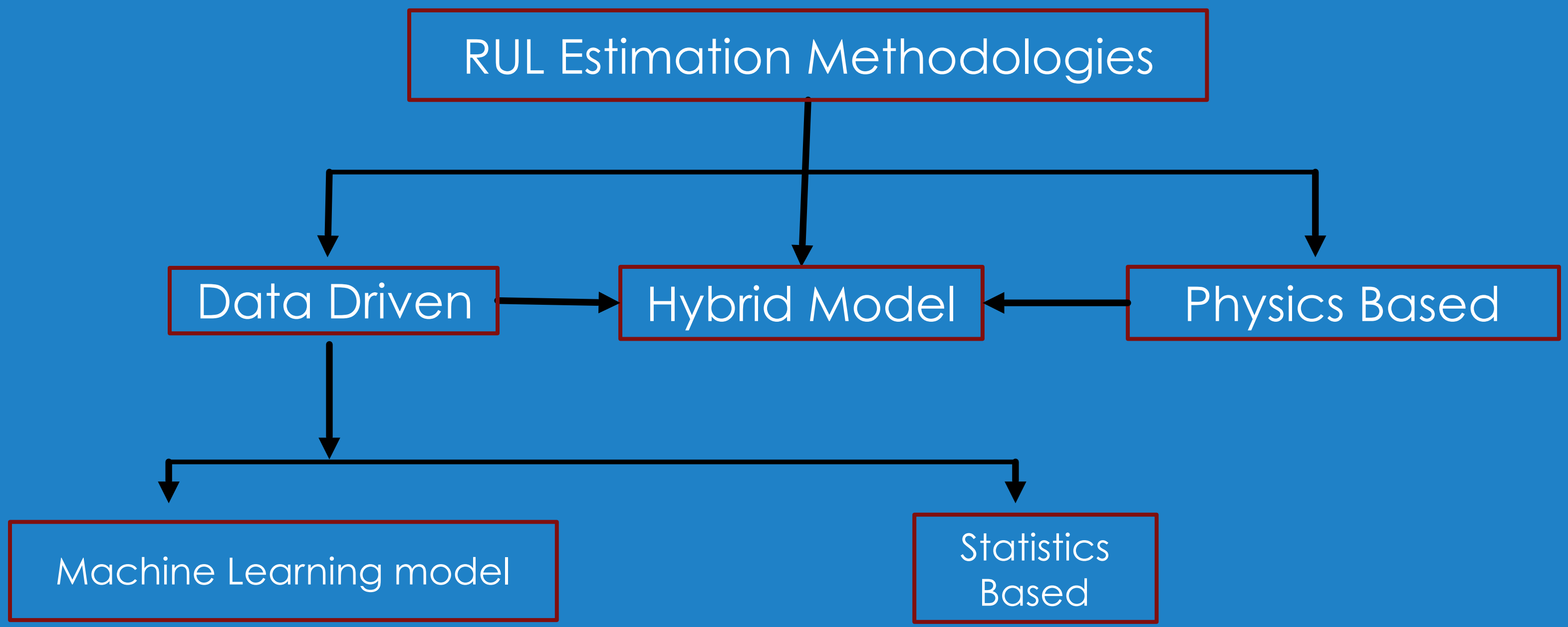
AIM

To estimate the Remaining Useful Life (RUL) of Turbofan Engine used in commercial aircraft using data driven methodology.

SYSTEM DESCRIPTION



METHODOLOGIES OF RUL ESTIMATION



DESCRIPTION OF DATASET

- Data Generated through simulation using thermo-dynamical simulation model(C-MAPSS). C-MAPSS stands for Commercial Modular Aero-Propulsion System Simulation.
- Data obtained from NASA Repository.
- Run to failure data of number of aircraft engines.
- 21 parameters out of 58 outputs utilized to measure system response under different health states and operational conditions.

DESCRIPTION OF DATASET

- Dataset generated includes 5 subset. One subset was used for the PHM Challenge.
- Each subset contains 26 columns, recording the unit number, time, three operational parameters and 21 output parameters.
- Each subset is further divided into a training set and a testing set.
- The dataset used for challenge depicts high pressure compressor degradation.

C-MAPSS INPUT MODULES

S.NO	NAME	S.NO	NAME
1	Fuel Flow	8	HPC Flow Modifier
2	Fan Efficiency Modifier	9	HPC Pressure Ratio Modifier
3	Fan Flow Modifier	10	HPC Efficiency Modifier
4	Fan Pressure Ratio Modifier	11	HPT Flow Modifier
5	LPC Efficiency Modifier	12	HPT Efficiency Modifier
6	LPC Flow Modifier	13	LPT Flow Modifier
7	LPC Pressure Ratio Modifier	14	LPT Efficiency Modifier

C-MAPSS OUTPUT TO MEASURE SYSTEM RESPONSE

S.NO	TYPE OF SENSOR	DESCRIPTION	UNITS
1	T2	Total temperature at fan inlet	^{o}R
2	T24	Total temperature at LPC outlet	^{o}R
3	T30	Total temperature at HPC outlet	^{o}R
4	T50	Total temperature at LPT outlet	^{o}R
5	P2	Pressure at fan inlet	psia
6	P15	Total pressure in bypass-duct	psia
7	P30	Total pressure at HPC outlet	psia
8	Nf	Physical fan speed	rpm
9	Nc	Physical core speed	rpm
10	EPR	Engine pressure ratio (P50/P2)	----
11	Psf30	Static pressure at HPC outlet	psia

C-MAPSS OUTPUTS TO MEASURE SYSTEM RESPONSE

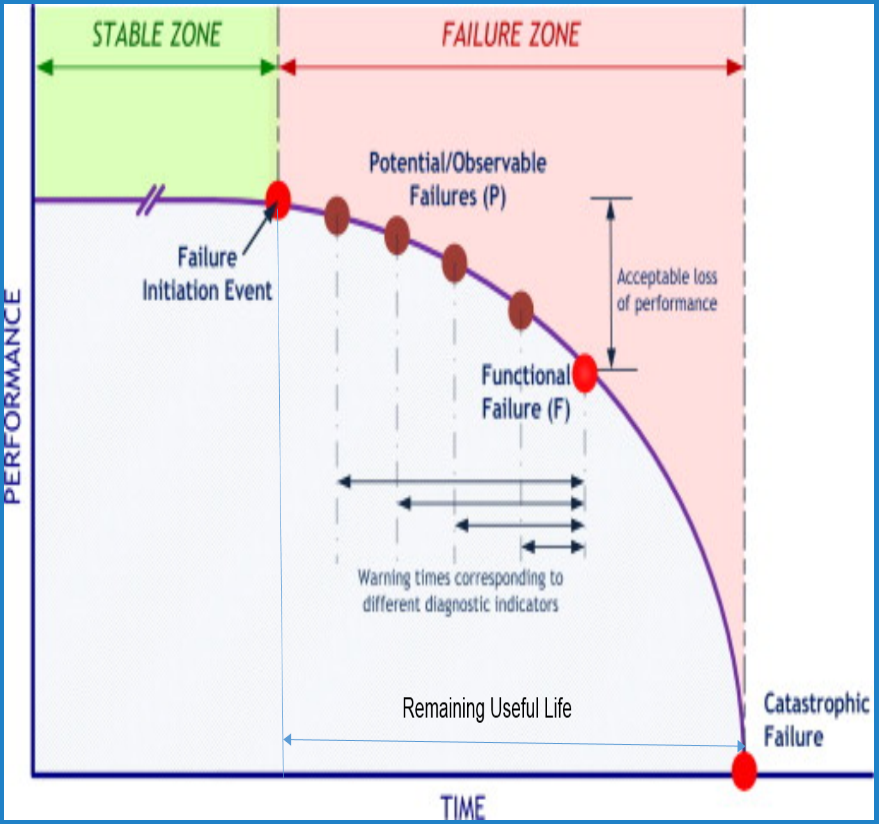
S.NO	TYPE OF SENSOR	DESCRIPTION	UNITS
12	Phi	Ratio of fuel flow to Ps30	pps/psi
13	Nrf	Corrected fan speed	rpm
14	Nrc	Corrected core speed	rpm
15	BPR	Bypass Ratio	----
16	farB	Burner fuel-air ratio	----
17	htBleed	Bleed Enthalpy	----
18	Nf_dmd	Demanded fan speed	rpm
19	PCNR_dmd	Demanded corrected fan speed	rpm
20	W31	HPT Coolant bleed	lbm/s
21	W32	LPT Coolant bleed	lbm/s

DESCRIPTION OF SENSORS

- **Engine Pressure Ratio** It is the ratio of the total pressure at the exit of the propelling nozzle divided by the total pressure at the entry to the compressor.
- **Corrected Speed** It is the **speed of the fan** at ambient conditions.
- **Bypass Ratio** It is the ratio between the mass flow rate of the bypass stream to the mass flow rate entering the core.
- **Fuel Air ratio** It is the ratio of fuel to air which is required for combustion.
- **Bleed Enthalpy** It is amount of heat in the air that will be flowing through the bypass path.
- **LPT/HPT Coolant Bleed**It is the amount of air that will flow above the LPT/HPT section per second.

- Useful life is an estimated time that an asset is expected to continue to serve its intended function.

- Remaining Useful Life is time taken by the unit to reach a failure condition from a current healthy condition.



- RUL can be expressed in years, cycles, miles etc.

SIMILARITY BASED APPROACH

- Step1 : Partitioning of training data into operating regimes.
- Step2 : Linear regression based Health Index having range between 0 to 1 was formed for each operating regime.
- Step 3 : Degradation model based on exponential distribution was built by fitting a curve of the HIs vs time cycle.

SIMILARITY BASED APPROACH

- Step 4 : Parameters of model was calculated for each unit in training set.

- Step 5 : The essential element of the similarity method was to seek the most similar degradation model. The similarity between testing unit and degradation model for each unit was defined by Euclidean distance. Euclidean distance was calculated between testing unit and the training unit data points.

- Step 6 : RUL was the minimum of summation of Euclidean distance calculated in the last step.

SIMILARITY BASED APPROACH

- Limitations
  - Selection of sensors was done only on the basis of consistency in the trend.
  - Technique implemented for similarity measurement was Euclidean distance. Other similarity measures may give better result.
  - Linear regression based modelling was used for health index formation.
  - Other than exponential distribution, no distribution was tested for deriving a degradation model.


Thank You