Hybrid Physics-Data Driven Model for Prescriptive Control and Design

Satyan Bhongale, *Lead Data Scientist*

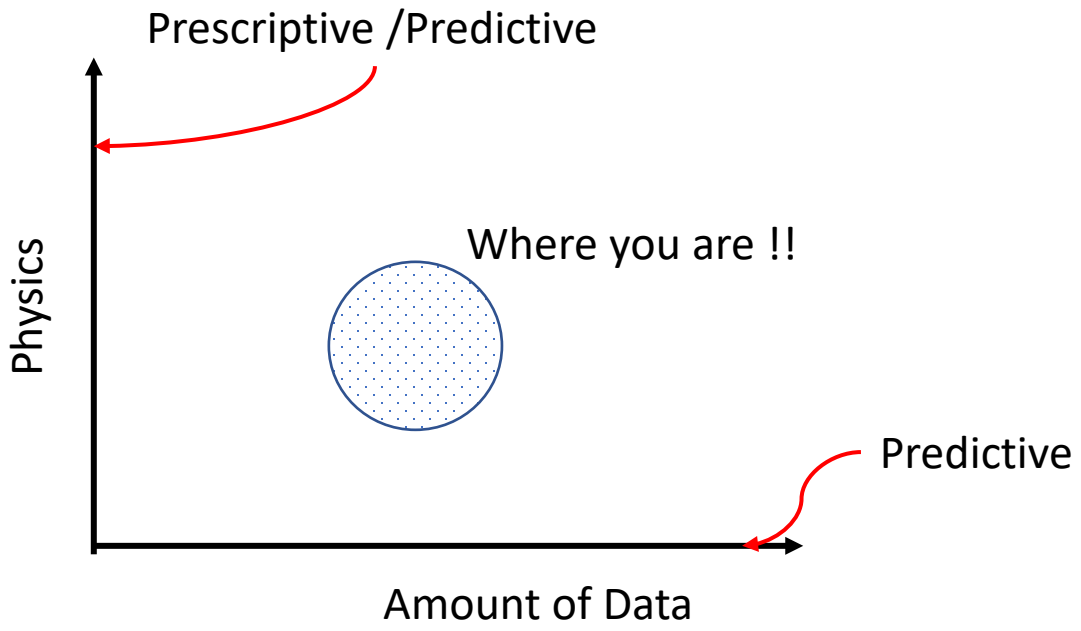
November 9, 2021

Industrial Data Science Challenges

Industries
- Automotive
- Power /Energy
- Mining
- Semiconductor

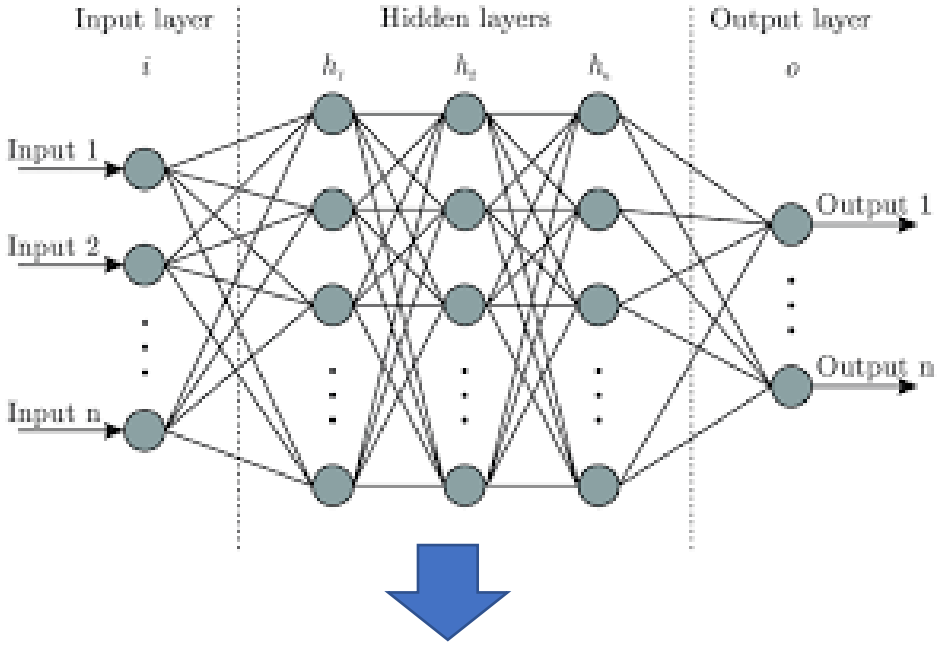
Typical Applications
- Process Optimization
- Predictive Maintenance
- Composite metrology
- Anomaly Detection

Key Challenges
- Lack of Data
- Bad Data Quality
- Lack of Variability
- Multivariant prescriptive control



Predictive vs Prescriptive

Neural Nets / Deep Learning



- One way function and non-invertible
- Lack of physical insight (operational difficulties)

$$Output\ 1 = f_{numerical}(Inpout\ 1, Input\ 2, \dots Input\ N\ )$$

Symbolic AI / Regression

Deriving Physical laws from data

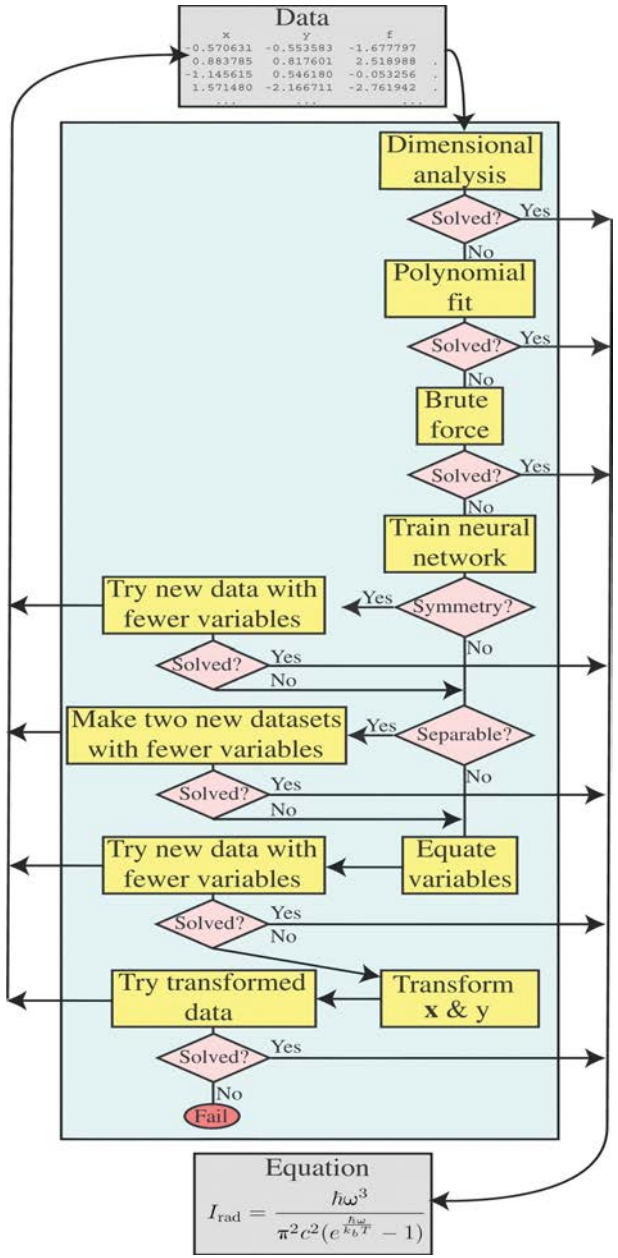
- Data Robot originally Newtonian
- GPLearn (based on genetic algorithm)
- AIFeynman (able to derive over 100 Physics laws from Feynman Lectures

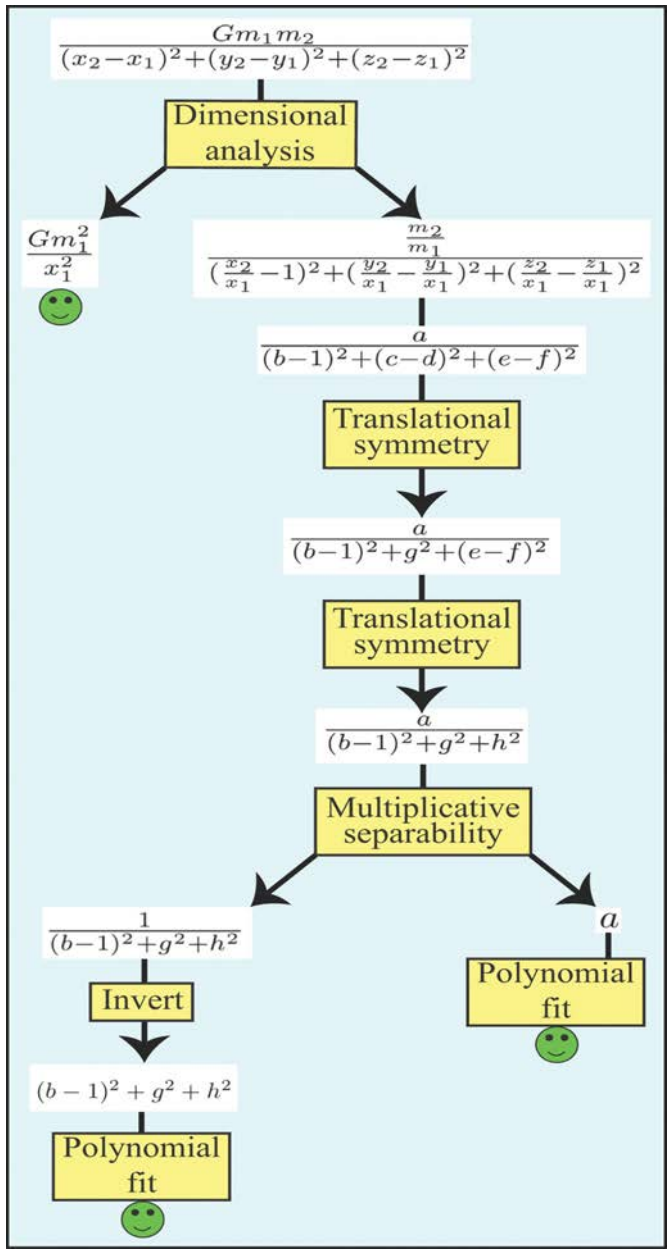
- Most likely invertible (not always)
- Knowledge of gradients and higher derivatives at each point in space

$$Output\ 1 = f_{symbolic}\ (Inpout\ 1, Input\ 2, \dots Input\ N\ )$$

energy

Symbolic AI / Regression





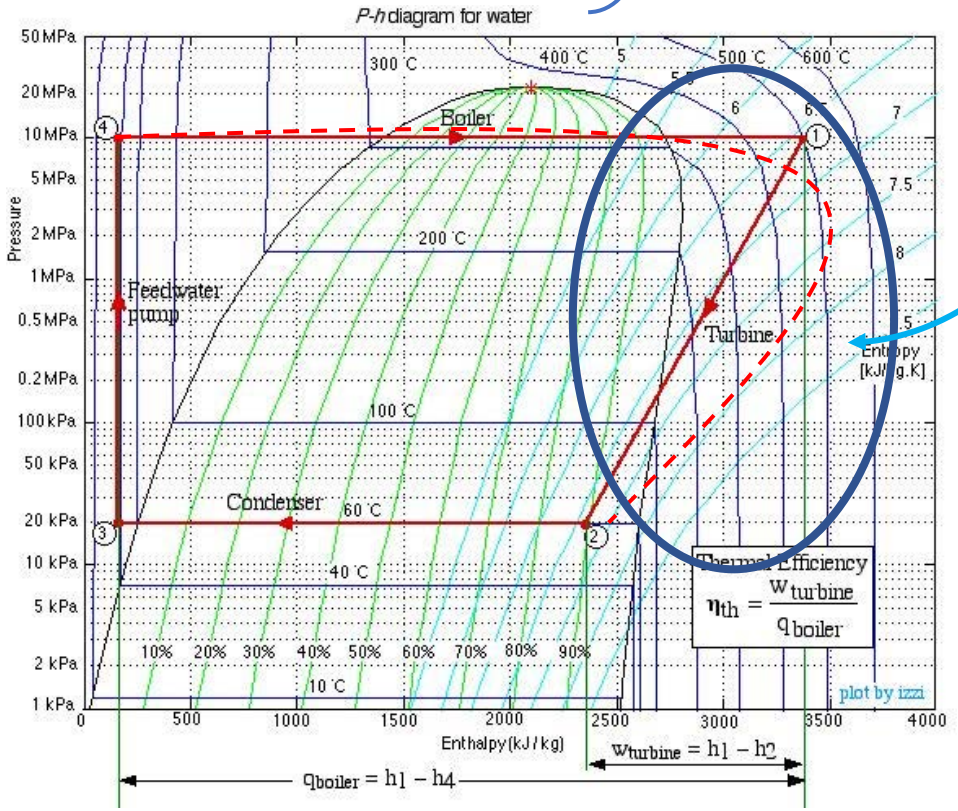
Use case : Condenser – Turbine

$$p_2 = rp_1$$

$$r^{\frac{2}{m}} - r^{1+\frac{1}{m}} = \frac{w^2}{A^2 \rho_1 p_1} \times \frac{m-1}{2\eta m}$$

$$p_2 = NN(p_1, \rho_1, w_1, T_1, .., x_1, x_2, \dots, x_n)$$

$$T \equiv T(h,p) \equiv T = T_0(1 + f(x_1, x_2, .. x_n))$$



Smooth function of variables not captured by the physics equations e.g.

- Vibrations
- Leaks
- Bearing temperature
- Ambient conditions
- Etc.

Symbolic AI

- Prescriptive control
- Extrapolation allowing for design

energy

Summary

- Need to develop Hybrid Physics & Data driven Digital Twins
- Symbolic AI allows for prescriptive control
- Models are extrapolatable beyond their operational regimes