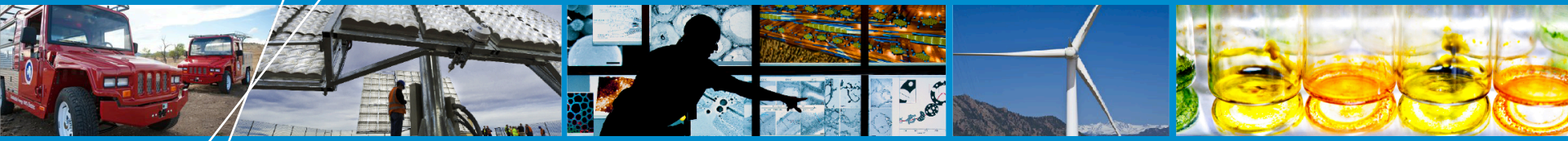
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Machine Learning



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Power Curve Working Group
New Orleans, LA

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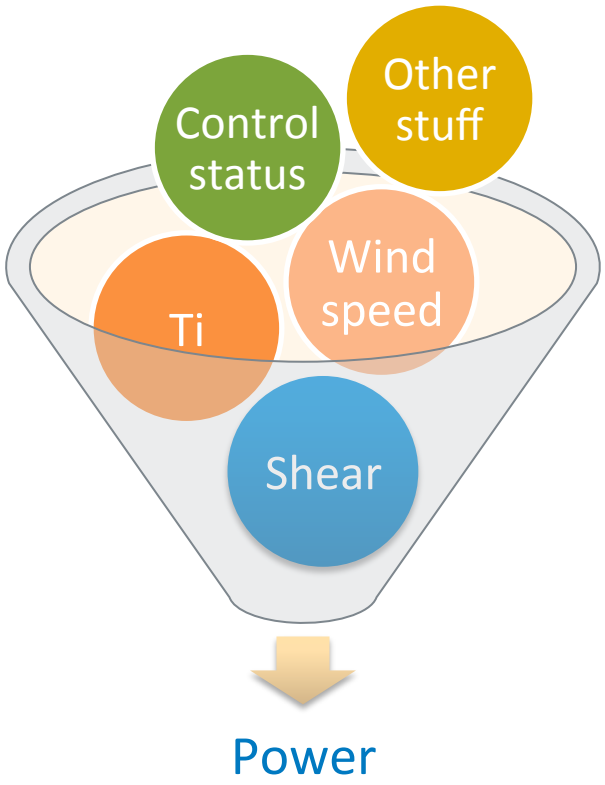
Multi-variable models

The concept

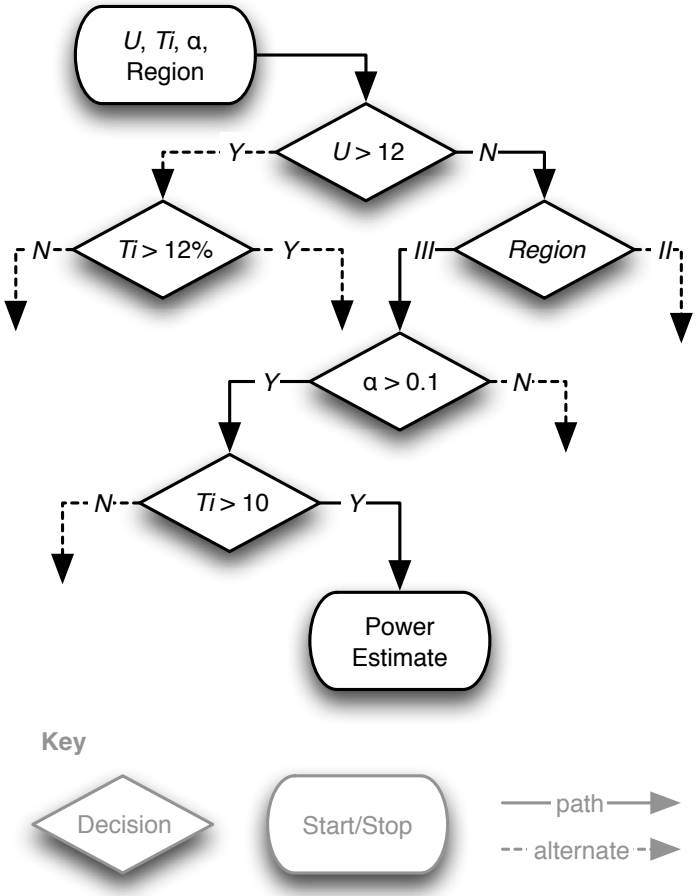


Some details

- Train model from experience
- Create a transfer function from inflow to power
- Use whatever inputs are available
  - Wind speed
  - Rotor-disk shear
  - Turbulence intensity
  - Turbine controller state
  - …
- Just need one output
  - 10-minute power, or
  - 10-minute difference in power v. OEM power curve

Example model using “random forests”

- **Train the model with 1000s of observations**
  - Create a tree, with lots of branches
  - Estimate 10-minute power
- **Use 100 trees in an ensemble**
  - Output is the ensemble mean
  - Get ensemble standard deviation as well
- **2 or 3 lines of code**



One branch of a regression tree in a Random Forest.

Source: Clifton, A., L. Kilcher, J.K. Lundquist, and P. Fleming. 2013. “Using machine learning to predict wind turbine power output.” Environmental Research Letters 8 (2)

Lots of details…

What tool?	
Neural networks	✔
Gaussian mixture models	✔
Random forests	✔
What inputs?	
Unwaked flows only	
IEC 61400-12-1 only	✖
Whatever is available	✔
What preprocessing?	
ICE 61400-12-1 prep?	✔
Anything else?	✔
What outputs?	
Absolute power	✔
Δ to OEM power curve	✖
Loads	?

- Can be applied to all similar turbines, e.g. GE 1.5 SLE
- Workflow:
  - Secure training data
  - Identify predictands at new site
  - Train model
  - Run model for new site
- R implementation at https://github.com/AndyClifton/PowerPerformance (buggier than a Colorado basement)
- Could do Python (but not this week)

Bulaevskaya, V., S. Wharton, A. Clifton, G. Qualley, and W. O. Miller. 2015. "Wind power curve modeling in complex terrain using statistical models." J. Renewable and Sustainable Energy 7 (1).

Clifton, A, and Rozenn Wagner. 2014. "Accounting for the effect of turbulence on wind turbine power curves." Journal of Physics: Conference Series 524 (1)

Let's talk!

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