Grey Relation Analisys in multiple wake wind forecast

November 15, 2020

1 Grey Relation Analisys (GRA)

Y - reference sequence of lenght $n \in N$.

$S = \{X_1, ..., X_m\}$ - set of $m \in N$ comparative sequences each of length n.

Goal:
To every comparative sequence $X \in S$ assign a number which represents similarity of sequences X and Y.

$g : S \longrightarrow (0, 1]$ - Measure of similarity of comparative sequences to reference sequence Y.

$$g(X_k) = \frac{1}{n} \sum_{i=1}^{n} \frac{\Delta_{min} + \xi \Delta_{max}}{\Delta_k(i) + \xi \Delta_{max}} \tag{1}$$

Where $\Delta_k(i) = |Y(i) - X_k(i)|$, $\Delta_{min} = \min\limits_{i,k} |Y(i) - X_k(i)|$ and $\Delta_{max} = \max\limits_{i,k} |Y(i) - X_k(i)|$ for $i \in \{1, .., n\}$ and $k \in \{1, .., m\}$. Also, $\xi \in (0, 1)$, default is $\xi = 0.5$.

Note:
Because $\Delta_k(i) \geq \Delta_{min} \;\; \forall i, k \Longrightarrow \Delta_k(i) + \xi \Delta_{max} \geq \Delta_{min} + \xi \Delta_{max} \Longrightarrow g(X) \in (0, 1] \;\; \forall X \in S$.

Note:
$g(X)$ depends on all comparative sequences in S, not just X and Y.

2 GRA in wind speed forecasting with wake

We have p wind turbines $T_1, .., T_p$ on a wind farm.

Free range (expected) wind speed is v_0.

Goal:
Predict v_i the expected wind speed in turbine T_i for $i \in \{1, .., p\}$.

Wind speed v_i depends on the turbines in front of the T_i.

Single wake models:
Models for predicting wind speed v_i under the condition that there is only one turbine T_j in front of turbine T_i. Jansen's, Frandsen's and bilateral Gaussian model (the best).

Multiple wake model:
Models for predicting wind speed v_i under the condition that there is multiple turbines in front of T_i. Jansen's, Frandsen's and bilateral Gaussian

Multiple wake models are computationally infeasible if we consider all turbines that affect given turbine T_i. That is why we use GRA to find turbines whose effect on T_i is the largest. In this way we effectively low the number of turbines in the model to a wanted constant.

For every turbine T_j where $j \in \{1, .., p\}$ and $j \neq i$ we define a sequence v_{ij} of effective wind speed of turbines T_i regarding only wake effect of turbine T_j. For this predictions we use bilateral Gaussian model (or any single wake model).

We have dataset of n free range wind speeds (our reference sequence) $v_0(1), .., v_0(n)$. Based on this sequence we can calculate sequences $v_{i,j}(1), .., v_{i,j}(n)$ for $j \in \{1, .., p\}$ and $j \neq i$.

So we have: v_0 as our reference sequence and $S = \{v_{ij} | j \in \{1, .., p\} \quad j \neq i\}$ as our set of comperative sequences. Next, we run $GRA(v_0, S)$. As result we get array of GRA coefficients for every turbine $T_j \quad j \neq i$ in S. We sort this array in ascending order and pick first k turbines.

These k turbines are the ones whose effect on wind speed v_i in turbine T_i is the greatest. Why? Because the more dissimilar the sequences v_0 and v_{ij} are the greater effect of turbine T_j on wind speed v_i is.

We now use only these k turbines in prediction of wind speed v_0, using some multiple wake model.

We repeat this process for every turbine T_i for $i \in \{1, .., p\}$ predicting wind speed v_i under the wake effect of other turbines.