Probabilistic wind power forecasting using statistical meta-Gaussian models

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Challenges

Statistical forecasting methods should allow

- Large variations in forecast uncertainty
- Skewness both up- and downwards
- Mixed distributed
  - Positive probability masses at zero and max production
- Multi-modality
  - Strong wind speeds $\Rightarrow$ close to zero or max production
Gaussian approaches

- Transformation of wind power measurements
  - Logistic, probit, asymmetric logistic, ...
  - such that transformed wind power is conditionally Gaussian for any predictor value

- meta-Gaussian (MGA)
  - Transformation of data to multivariate Gaussian
  - Apply properties of multivariate Gaussian to derive forecast distribution
    - multivariate Gaussian => conditional Gaussian
meta-Gaussian method (MGA)

1. Transformation of each variable to standard Gaussian
   - Estimate cdf and apply probability integral transform, or
   - Estimate relation between quantiles (chosen)
     - Estimation by means of local linear least squares
     - Ensures non-decreasing and flexible non-linear transformations

2. Assume transformed data are multivariate Gaussian
   - Marginal Gaussians does not imply multivariate Gaussian!

3. Estimate its parameters
   - Means and covariances

4. Compute parameters of the conditional Gaussian

5. Re-transformation to original scale
MGA details

- Transformations of mixed distributed variables
  - Randomly replace “discrete” data with corresponding quantiles of standard Gaussian distribution
  - Alternative: use parameter estimation methods for censored multivariate Gaussian data

- Resampling => reduced estimation uncertainty => improved forecast skill
  - Repeat the MGA algorithm for each sample and combine
  - Apply sampling separately to
    - estimate transformations
    - estimate parameters of the multivariate Gaussian
Example: Transformations

Transformations to standard Gaussian

- Wind power
- Wind speed forecast
- Wind direction forecast
Example: fitted MGA model
Example of wind power forecast

Wind Power Production

HyWind

Time zone: UTC

Percentiles: 95, 90, 75, 50, 25, 10, 5

kWh

2010-12-30
Thursday

2010-12-31
Friday

2011-01-01
Saturday
Example: MGA applied to nowcasting

How important are NWP forecasts compared to latest power measurement data?

Experiment with 3 statistical MGA models based on
- latest power production measurement
- NWP forecast of wind speed and wind direction
- combination of both
Experiences

- MGA is used in operational wind power forecasting for a few wind farms

- MGA have not been compared with other methods
  - Except for BMA in precipitation forecasting for single model ensembles (similar or better scores)

- Multivariate Gaussian assumption is poor in some cases
  - MGA forecasts not as reliable as quantile regression forecasts
  - Wind speed and direction forecasts are better predictors than 2D wind vector!
  - Bi-modality probably not well handled
Concluding remarks

• MGA potentially useful in multivariate forecasting problems
  - Especially for common predictor variables

• MGA can be used for “any” variable
  - e.g. temporal change in production (ramps)

• Future work
  - How good is MGA compared to other methods?
  - How to include multiple NWP/ensembles