Distributed Probabilistic Forecasting For New Energy Systems Operation

Hélène Le Cadre, EnergyVille research center, Belgium

- ❖ Strategic role of **information** in new energy systems (reserve activation, flexbility management, multicommodity energy trading) -> need for new efficient **forecasting methods**.
- ❖ Multimodal dataset with **massive**, **heterogenous** and **geographically spread** data sources.

Goal: forecast weekly solar PV power production using multimodal data sources / features and forecasting methods.

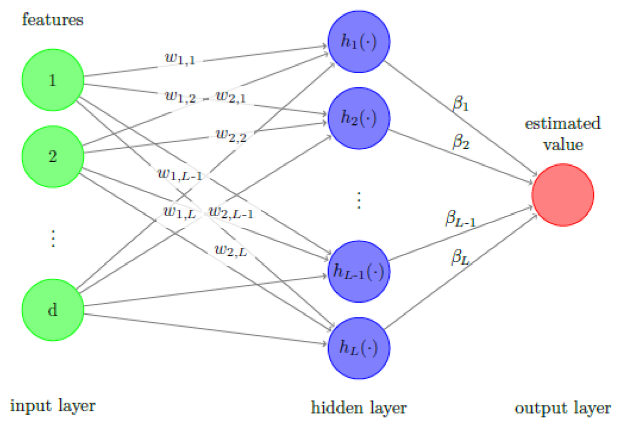
A set of experts

A) Prediction Interval (PI) based ELM

Single hidden layer feed-forward Neural Network

Random selectrion of input weights and thresholds

Output weights determined through matrix computation



$$f_L(\boldsymbol{x}) = \sum_{j=1}^{L} \beta_j h_j(\boldsymbol{x}) = h(\boldsymbol{x})\beta, \forall \boldsymbol{x} \in \mathbb{R}^d,$$

$$\hat{\beta} = \boldsymbol{H}^{+}\boldsymbol{T} \text{ with } \boldsymbol{H} = \begin{pmatrix} h(\boldsymbol{x_1}) \\ \vdots \\ h(\boldsymbol{x_{n_{train}}}) \end{pmatrix}$$

Training data corrupted by noise

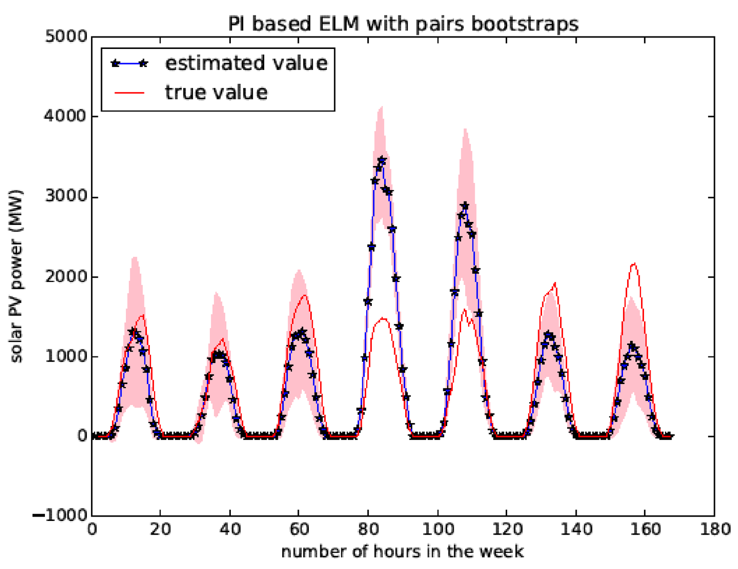
$$t_i = f_L(\boldsymbol{x_i}) + \epsilon(\boldsymbol{x_i})$$

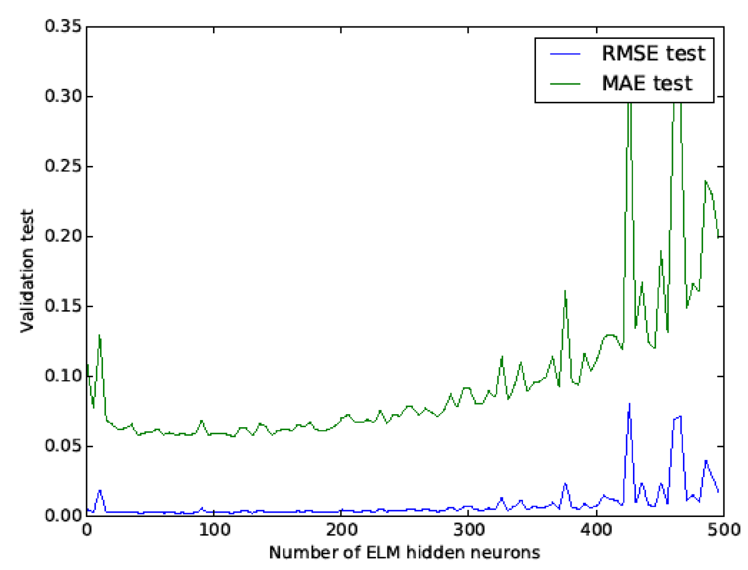
$\alpha \in [0;1]$ confidence level of the PI defined by its bounds

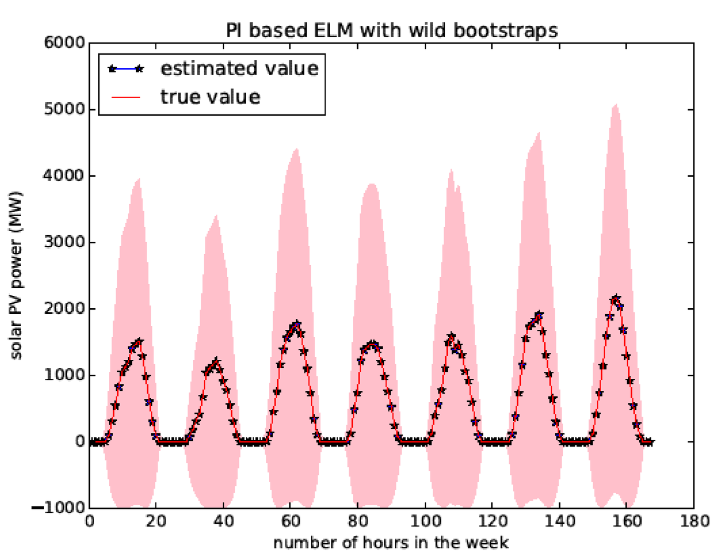
$$L_\alpha(\boldsymbol{x_i}) := \hat{y}(\boldsymbol{x_i}) - z_{1-\frac{\alpha}{2}}\sqrt{\sigma_t^2(\boldsymbol{x_i})}$$

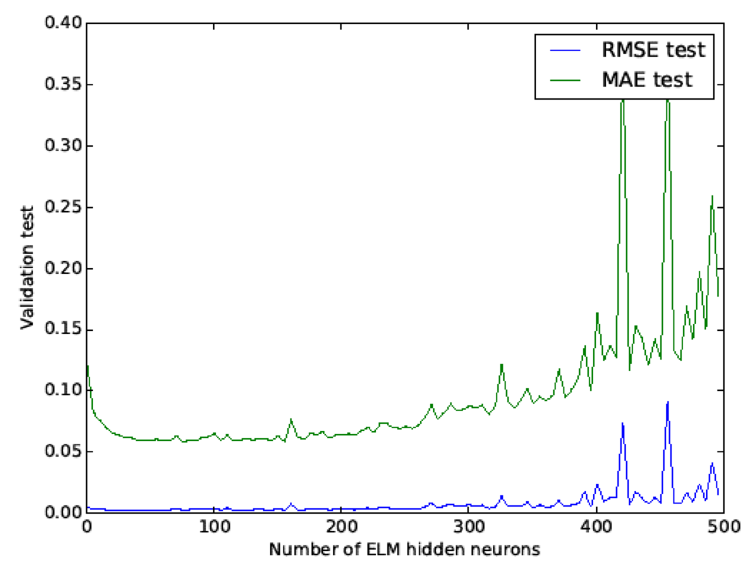
$$U_\alpha(\boldsymbol{x_i}) := \hat{y}(\boldsymbol{x_i}) + z_{1-\frac{\alpha}{2}}\sqrt{\sigma_t^2(\boldsymbol{x_i})}.$$

Computed **via bootstrap techniques**. For α=90% pairs / wild bootstrap and cross-validation





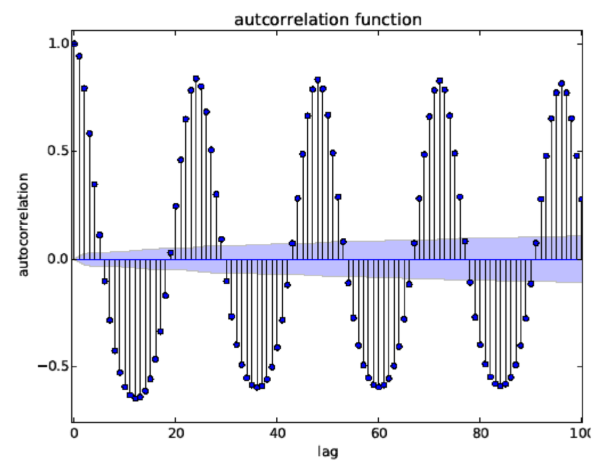


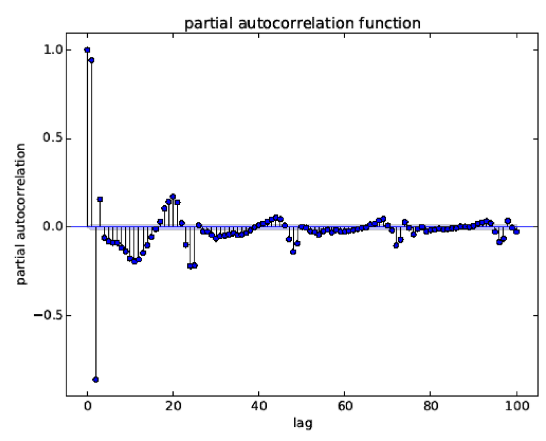


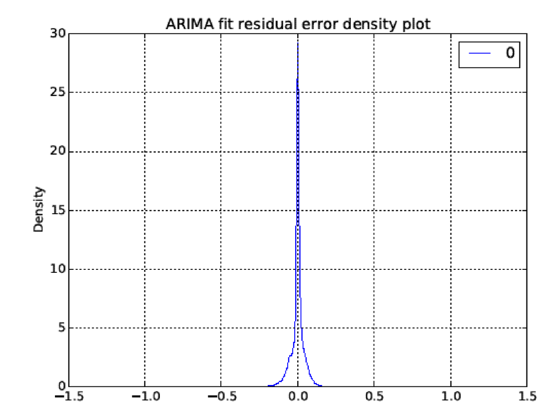
performance \ bootstrap	pairs	wild	resampling
PICP	0.601	1.0	1.0
Score	0.187	0.953	0.953
MAE (MW)	−0.088	$4.785.10^{-15}$	$5.800.10^{-15}$
Mean absolute error (MW)	0.095	$4.602.10^{-14}$	$4.501.10^{-14}$
RMSE (MW)	0.012	$7.254.10^{-15}$	$7.206.10^{-15}$

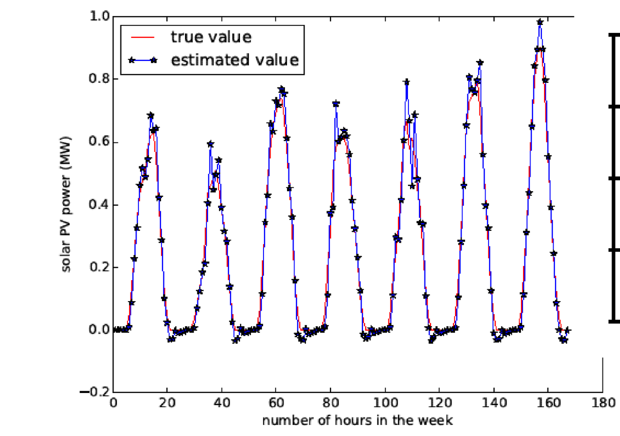
B) Rolling forecast ARIMA

Stationarization of the time series by removing moving average and trend. ARIMA model fitted based on ACF and PACF plots



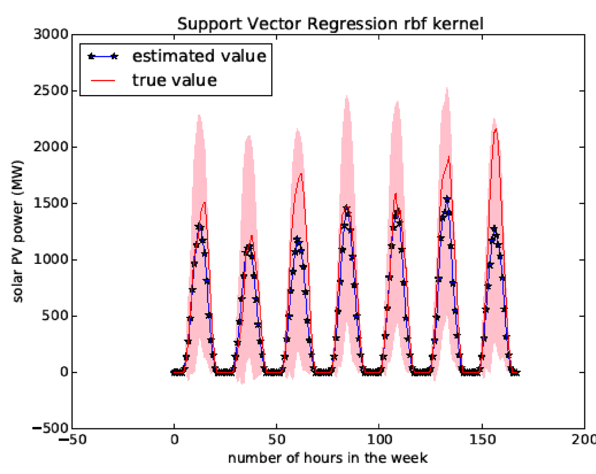


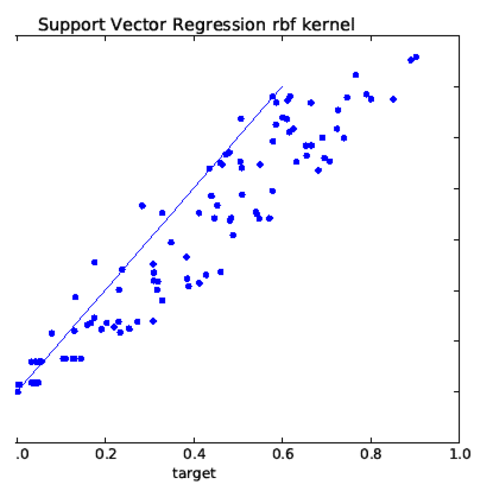




performance	rolling ARIMA
MAE (MW)	-0.021
Mean absolute error (MW)	51.010
RMSE (MW)	0.394

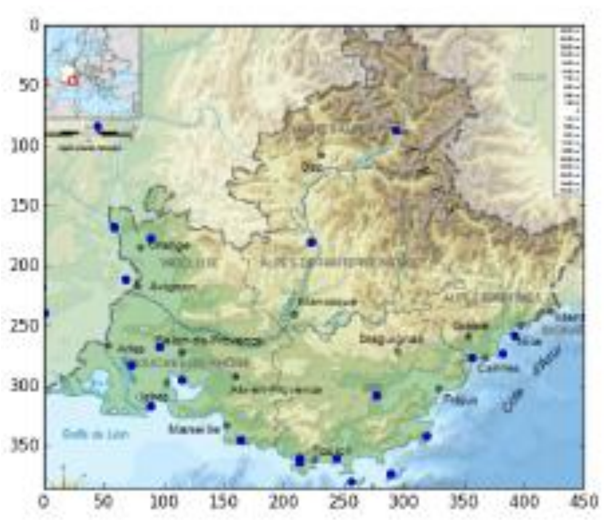
C) SVR forecast





performance \ kernel	RBF
MAE	-5.908
Mean Absolute Error	5.908
RMSE	2.274

Feature / Expert selection

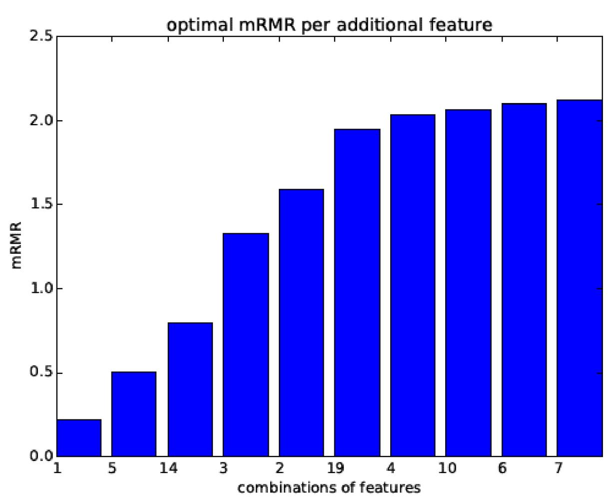


A set of meteorological stations spread over a region.

Goal is to **forecast regional solar PV power**.

Each station is associated with an **expert** .

Station observations are **historical regional PV power** and **meterological features**.



Automatic feature selection based on **mRMR** criterion derived from Mutual Information

Let x ~ pX(x) and y ~ pY(y) two features

$$I(x,y) := \int\int p_{X,Y}(x,y) log \frac{p_{X,Y}(x,y)}{p_X(x)p_Y(y)} dxdy.$$

Experts activated based on the **randomized EWA forecaster.**

Features	PICP	Score	Nb of Experts	Experts Index	mRMR
Wind Speed	0.904	0.093	8/13	4, 6, 12, 1, 11, 8, 3, 9	800
Wind Dir.	0.889	0.095	8/13	4, 12, 6, 1, 8, 11, 3, 9	780
Cloud Cover	0.910	0.094	8/13	4, 12, 6, 1, 11, 8, 3, 9	2.10^3
Precipitation	0.916	0.098	8/13	4, 6, 1, 12, 11, 8, 3, 9	5.10^3
Temperature	0.907	0.098	8/13	4, 12, 6, 1, 11, 8, 3, 9	10^3
Pressure	0.875	0.090	8/13	4, 6, 12, 1, 11, 8, 3, 9	100
Sun Zenith	0.886	0.091	8/13	4, 6, 12, 1, 8, 11, 3, 9	80
Sun Azimuth	0.913	0.097	8/13	4, 12, 6, 1, 8, 11, 3, 9	3.10^3

Derivation of a **convergence bound** on the expected regret for the group of activated experts.