Signal reconstruction – An alternative approach for wind turbine monitoring

L. Vera-Tudela, P. Lind, M. Wächter, J. Peinke, M. Kühn

ForWind, Carl von Ossietzky University of Oldenburg

RAVE – Offshore Wind R&D Conference

14th October 2015, Bremerhaven

Content

1. Monitoring wind turbine signals
2. Normal behaviour models
3. Data for analysis
4. Neural networks & stochastic approach
5. Results
6. Conclusions & outlook

1. Monitoring signals

Motivation

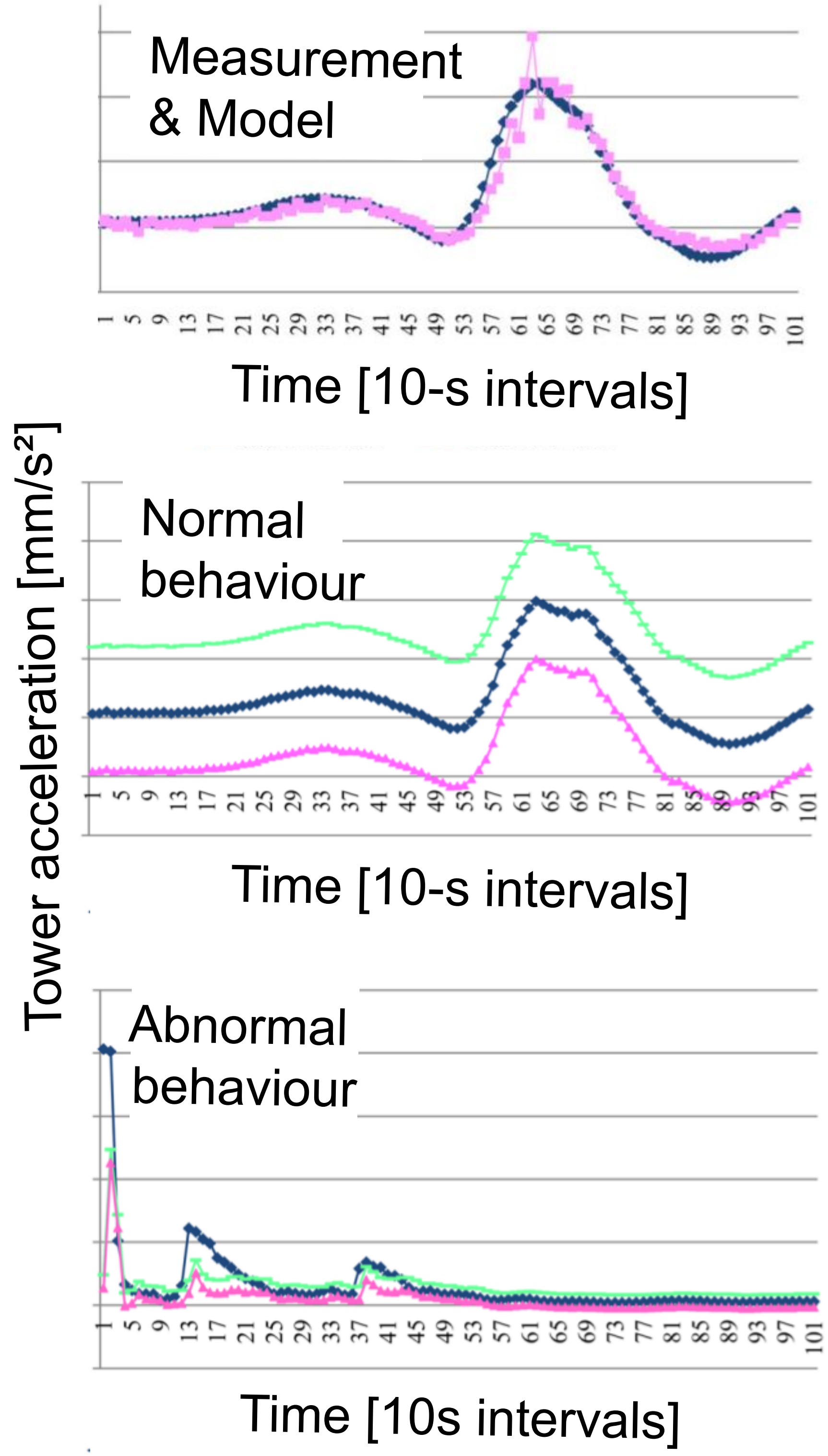
- Cost effective evaluation of wind turbine health

Utilisation

- Difference between measurements and expected behaviour is investigated to detect anomalies

Development

- 'Normal behaviour' models are created using available signals (with neural networks)



Monitoring wind turbine vibration
Based on SCADA data (Zhang, 2012)

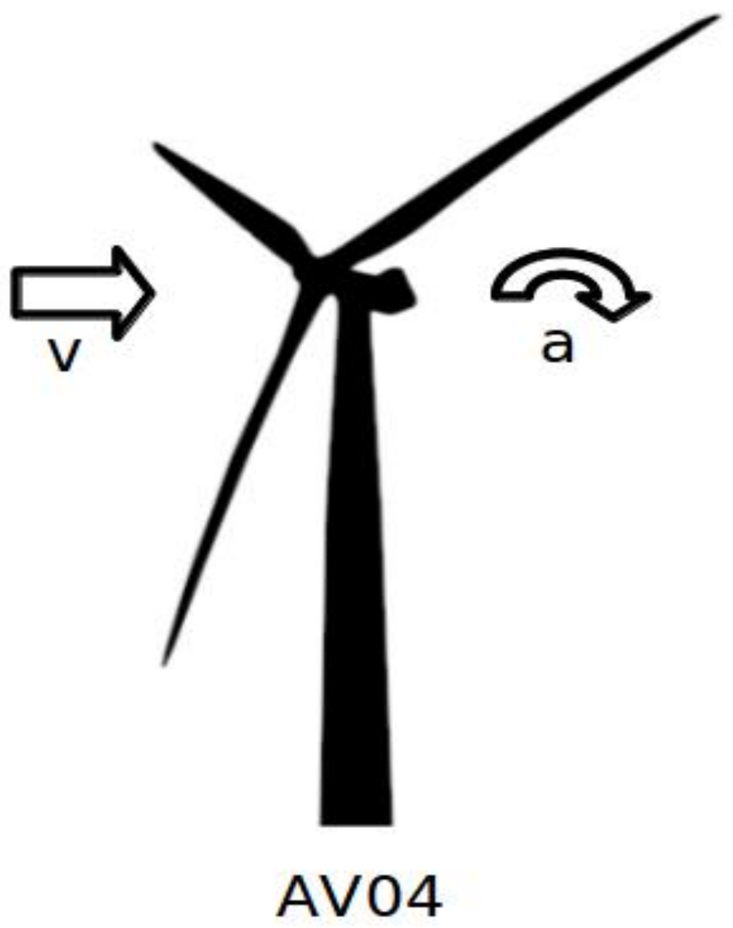
2. Normal behaviour model

Motivation

- Can we use the stochastic approach to develop a suitable normal behaviour model?

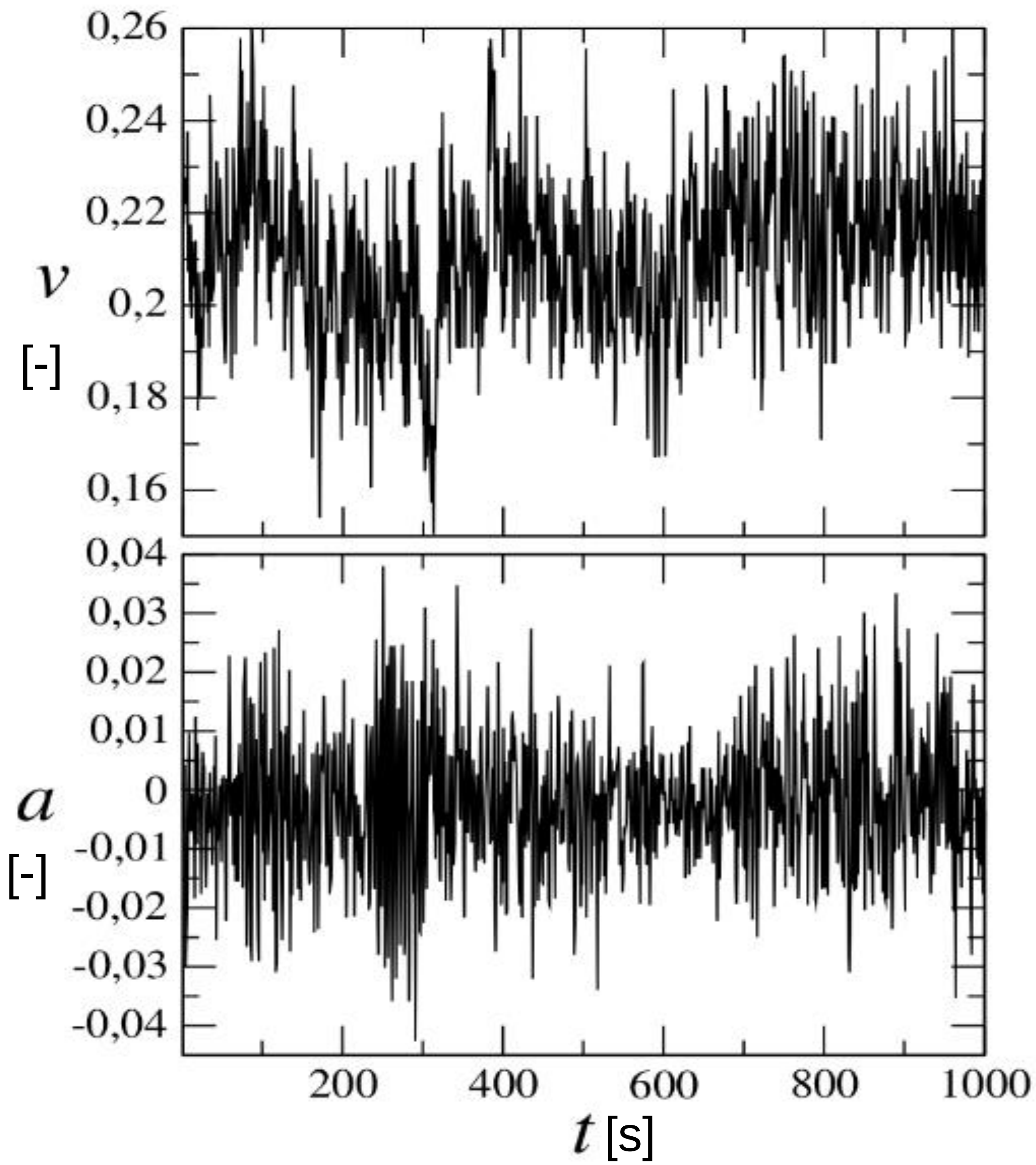
Methodology

- Investigate tower top acceleration with wind speed. Use data from turbine AV04
- Create a 'normal behaviour' model with neural network
- Repeat process with stochastic approach
- Compare models, response & report out



3. Data for analysis

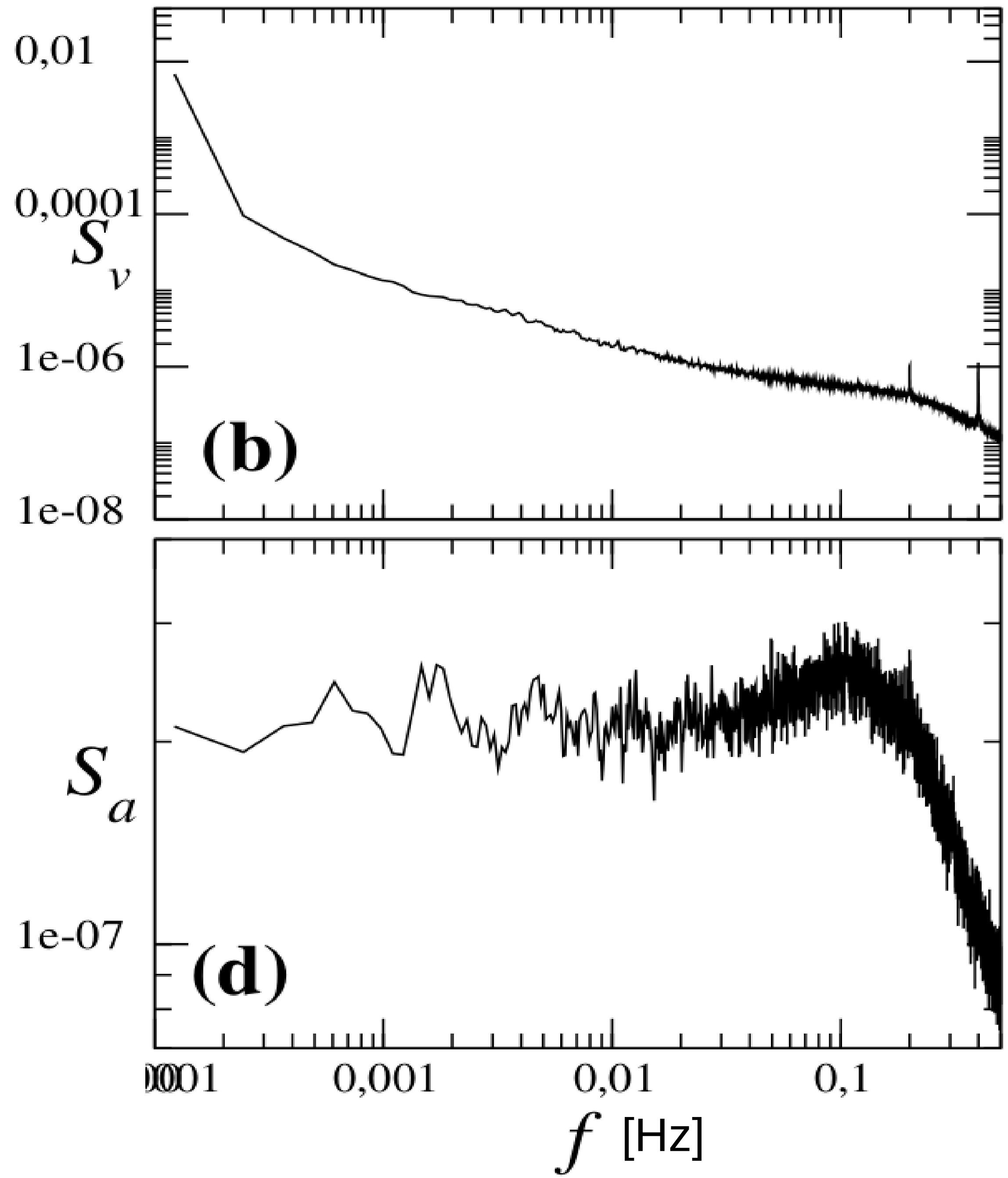
- Wind turbine AV04
- Target signal: tower top acceleration (a)
- Predictor signal: wind speed (v)
- Data sets:
  - Development – October 2014
  - Test – November 2014
- Presented signals are normalised



Example of velocity (v) and acceleration (a)

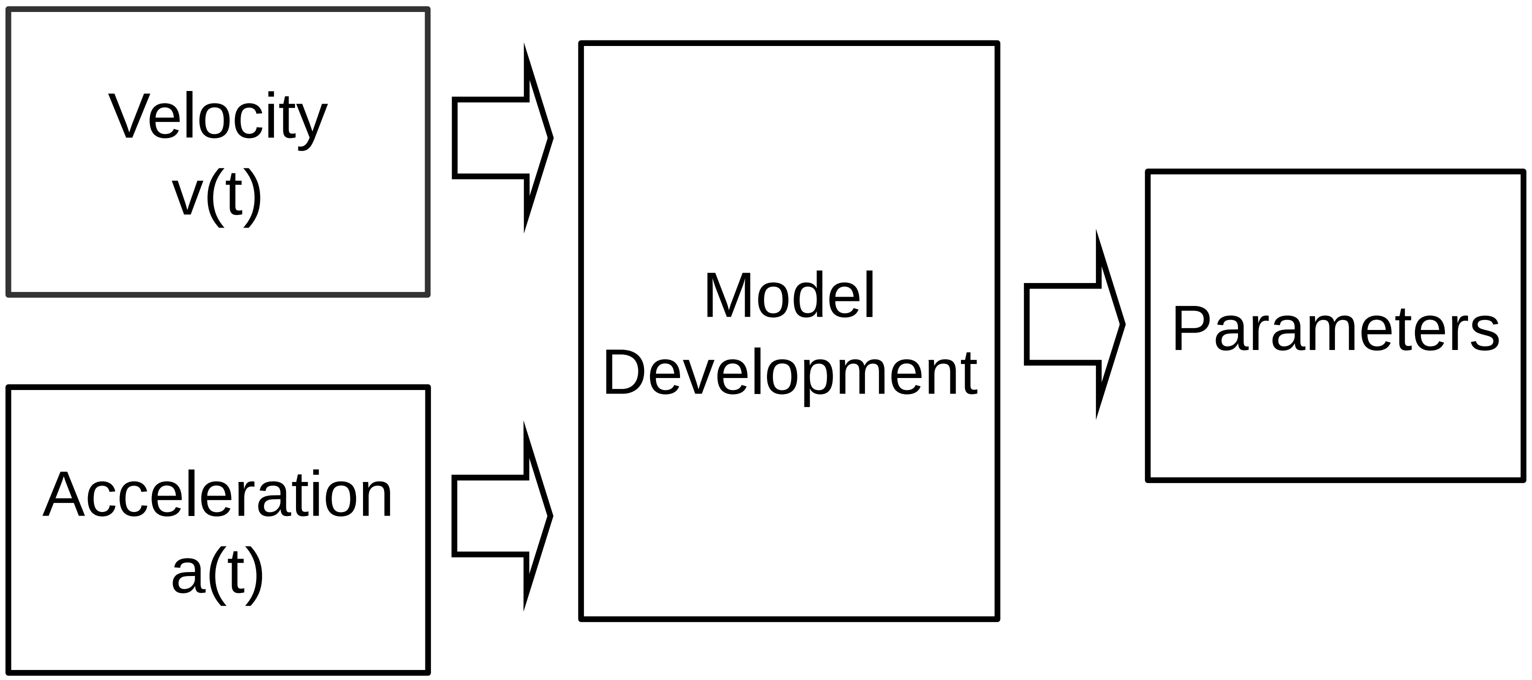
3. Data for analysis

- Wind turbine AV04
- Target signal: tower top acceleration (a)
- Predictor signal: wind speed (v)
- Data sets:
  - Development – October 2014
  - Test – November 2014
- 1 Hz sampling data



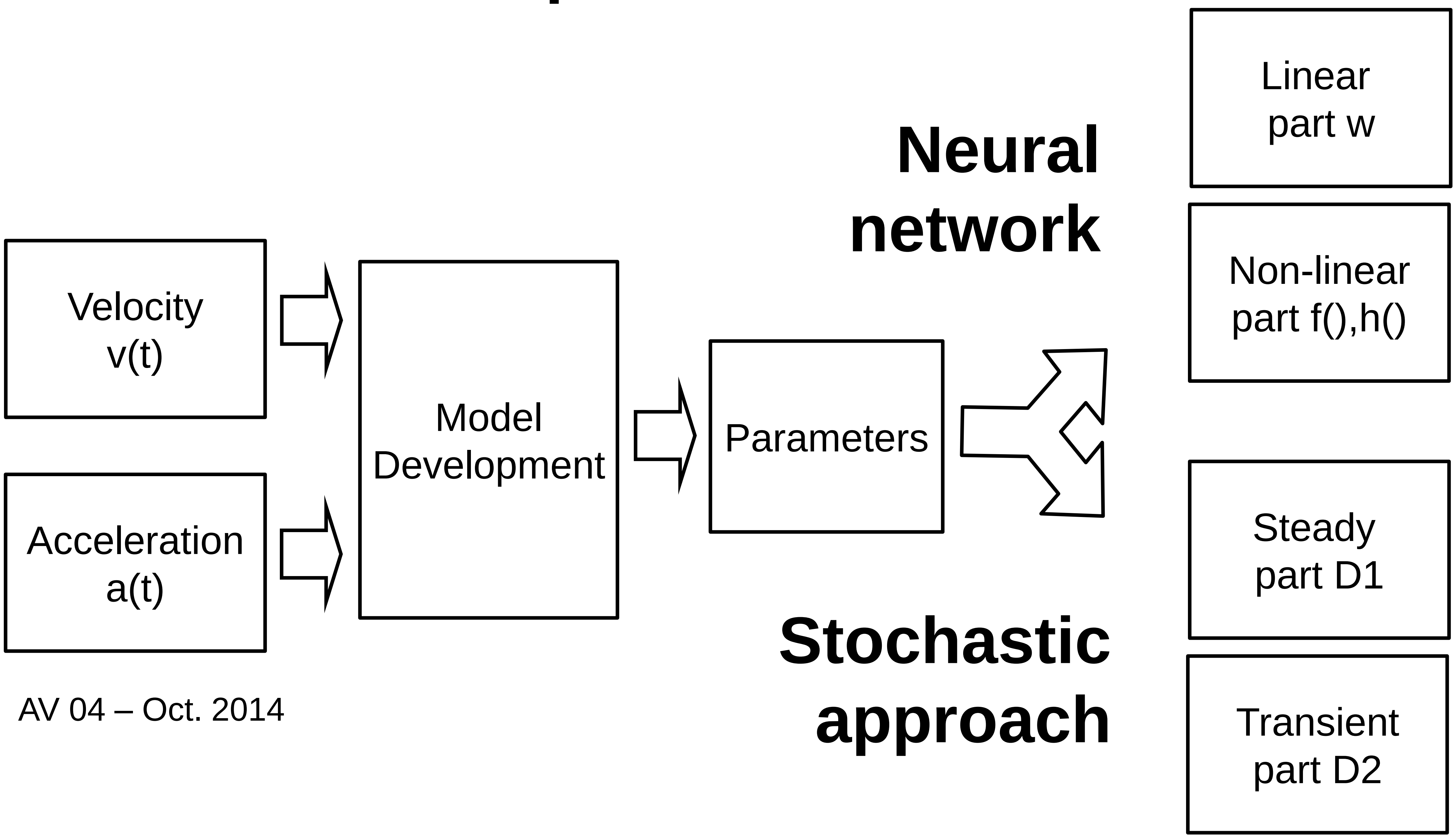
Example of velocity (v) and acceleration (a)

4. Models development



AV 04 – Oct. 2014

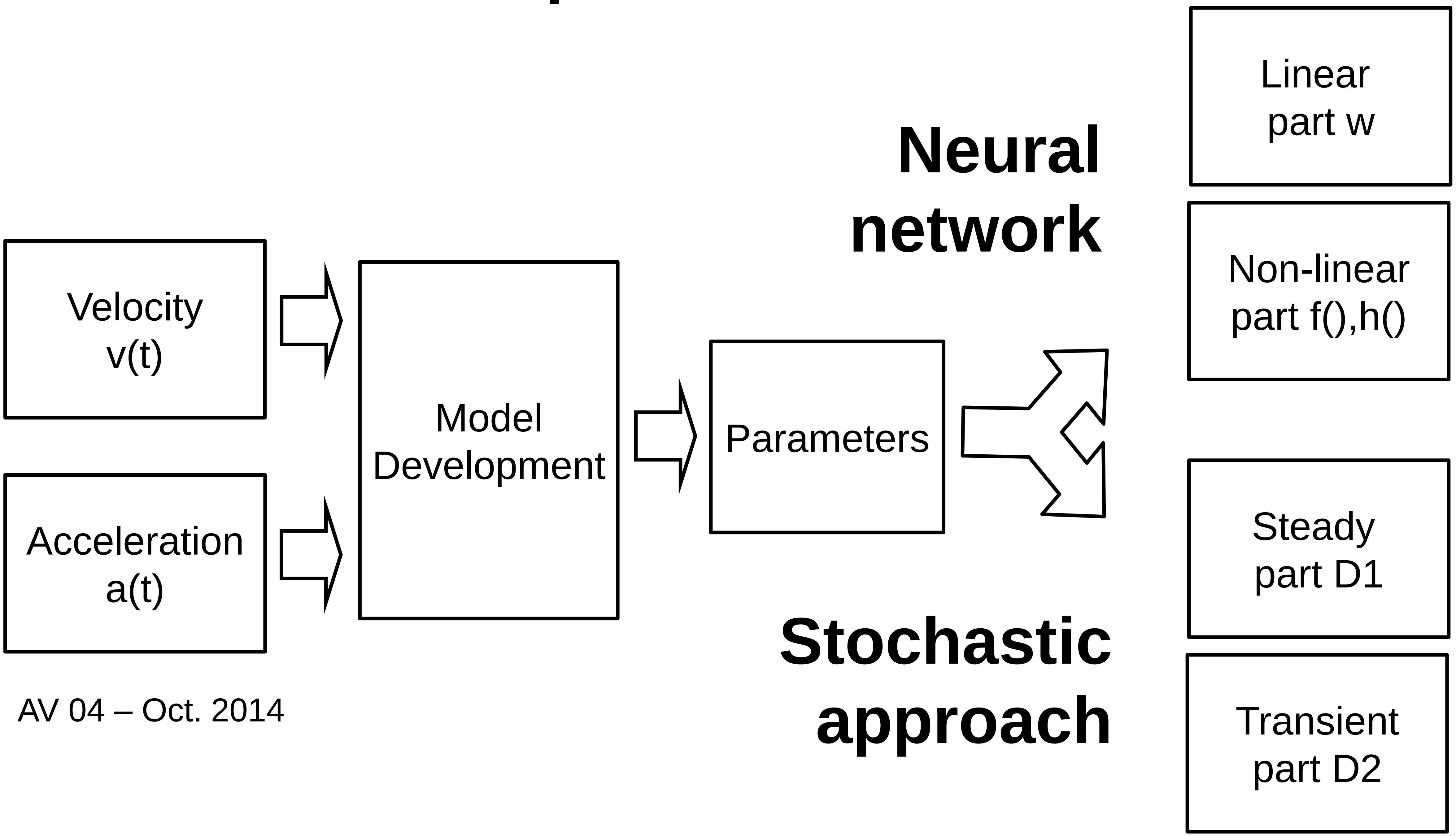
4. Models development



AV 04 – Oct. 2014

4. Models development

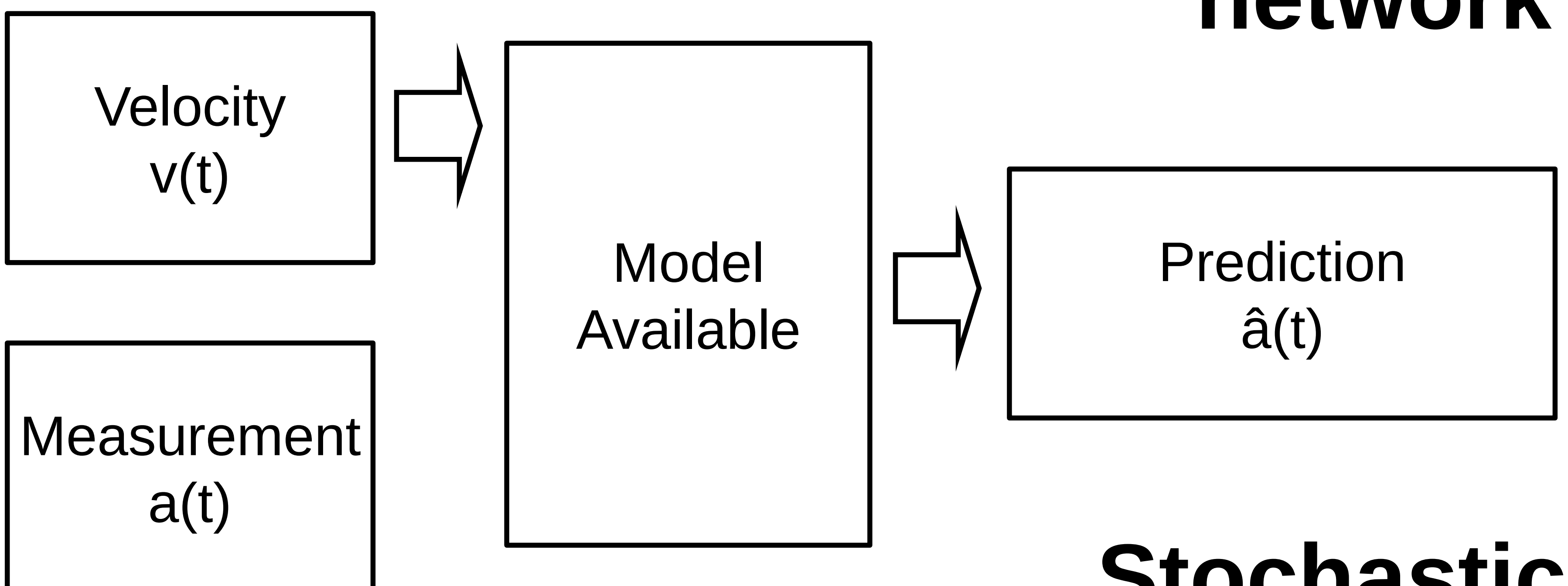
$$\hat{y}(x,w) = f\left(\sum_{j=0}^{n_h}\omega_j h\left(\sum_{i=0}^{n_i}\omega_{ji}x_i\right)\right)$$



$$\frac{dx}{dt} = D^{(1)}(x) + \sqrt{D^{(2)}(x)}\Gamma_t$$

4. Models prediction

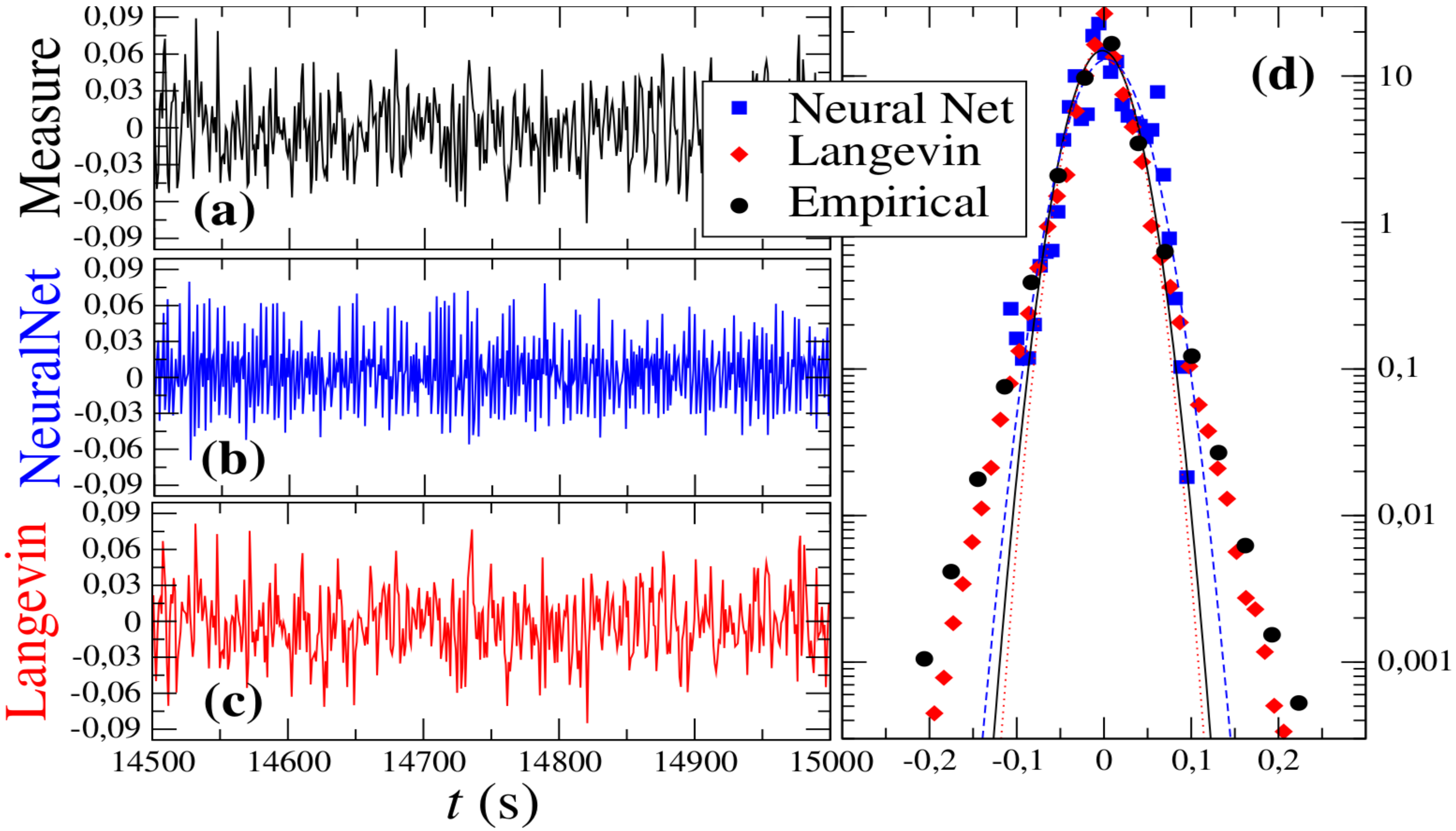
Neural network



AV 04 – Nov. 2014

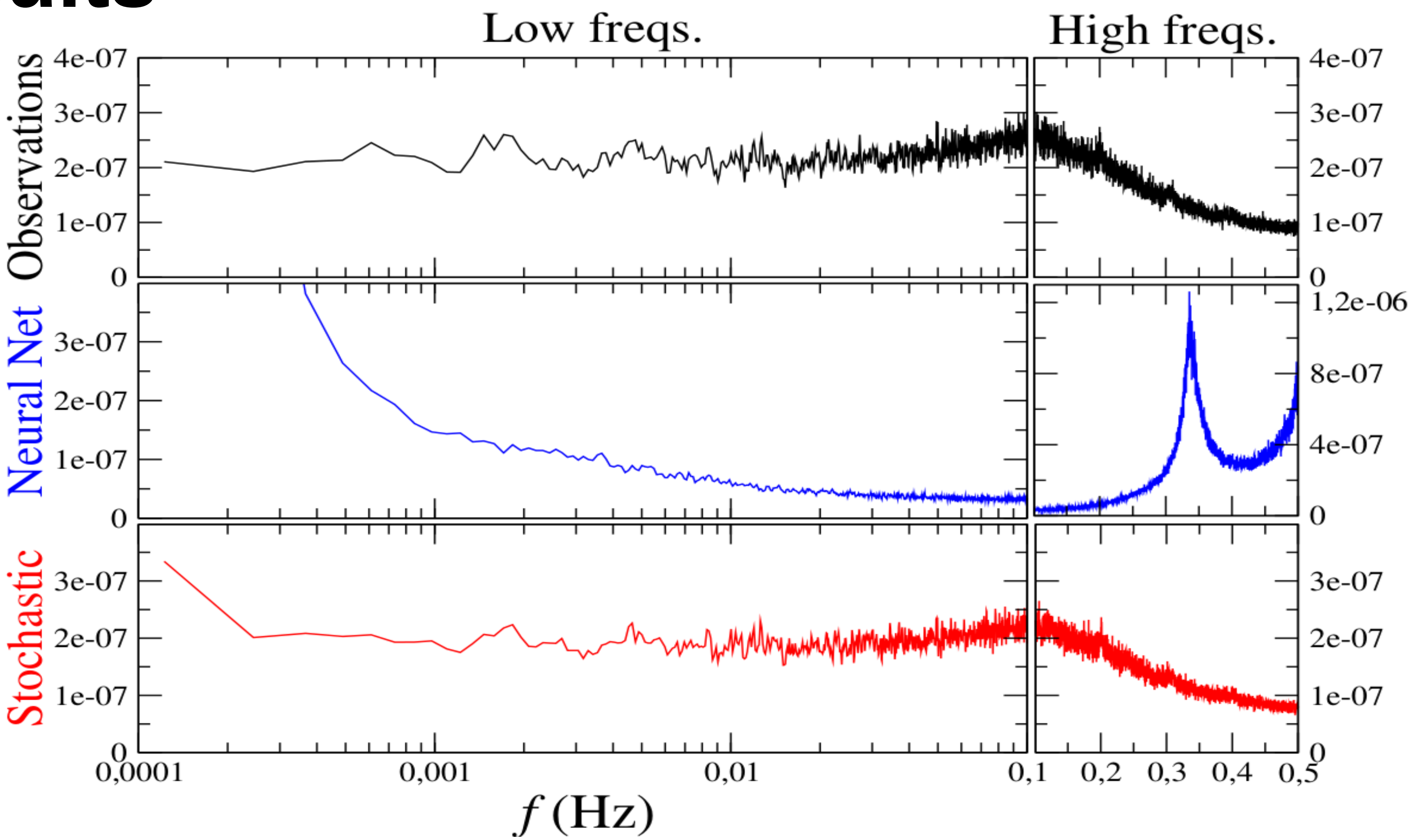
Stochastic approach

5. Results



- Stochastic approach better estimates distribution moments (4th → non-gausian)
- Neural netwoks reconstructs a Gaussian, original signal is non-gaussian

5. Results



- Reconstructed signals have similar average response
- Neural networks reconstruction does not reproduce frequency content
- Stochastic approach better reconstructs variance in signal
- Frequency content is maintained with stochastic approach

6. Conclusions & outlook

- The stochastic approach is suitable to create normal behaviour models
- Both methodologies follow similar steps to construct models
- Neural networks reconstruct central part of original signal
- Stochastic approach better reconstructs complete frequency content

→ Stochastic approach available for R: https://cran.r-project.org/web/packages/Langevin/

→ Analysis will be extended for different sampling ratios

→ Complete procedure & results will be published

Acknowledgment
This research was funded by the German Federal Ministry of Economic Affairs and Energy as part of the research project "OWEA Loads" (FKZ 41V6451)

L. Vera-Tudela, P. Lind, M. Wächter, J. Peinke, M. Kühn

ForWind, Carl von Ossietzky University of Oldenburg

RAVE – Offshore Wind R&D Conference

14th October 2015, Bremerhaven

Appendix

Other results

- Evaluation of bias an variance
- Mean absolute error (MAE)
- Standard deviation of (SD of MAE)

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n} |\hat{y}_i - y_i|$$

$$\mathrm{SD\ of\ AE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(|\hat{y}_i - y_i| - \frac{1}{n}\sum_{i=1}^{n}|\hat{y}_i - y_i|\right)^2}$$

→ Reconstructed signals have similar average response

→ Stochastic approach better reconstructs variance from original signal

Approach	MAE [%]	SD of MAE [%]
Neural network	0.0312	0.0315
Stochastic	0.0266	0.0305

Other results

Approach	Mean	Std. Dev.	Skew	Kurtosis
Measurements	-0.0021	0.0267	0.0206	8.8910
Neural network	0.0029	0.0308	0.2139	0.1057
Stochastic	-0.0016	0.0249	-0.0009	3.1993

Inter step differences