Long-Term Wind Speed Prediction based on Optimized Support Vector Regression

by

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Agenda

- Introduction
  - Wind Speed Problem
  - Related Work
  - Problem Definition
- Proposed WOA-SVR Algorithm
- Experimental Results and Discussion
- Conclusion and Future Works
Introduction

Wind energy one of the fastest rising energy resources are wind energy since it is renewable, plentiful and clean. One of the most important main sources of renewable energy is the energy of the wind. One of the drawbacks for the reliability and precision of the power system is the fluctuation and nonlinear of wind.
Wind speed prediction is classified into three categories, named as,

- **Short term prediction** could point to forecasting data for a few hours ahead no more.
- **Medium term prediction** is for a duration ranging from about a few hours to three days
- **Long-term prediction** point to duration more than three days ahead; yet, there is no ultimate end of the duration
Introduction

Algorithms Used for Wind Speed Prediction

- Structural break model and Bayesian theory
- Neural Network
- Support Vector Regression (SVR)
Introduction
Introduction

Linear data in 2D (Discrete Data)

Linear data in 2D (Continuous Data)
Introduction

Non-Linear data in 2D
(Discrete Data)

Non-Linear data in 2D
(Continuous Data)
Introduction

Non-Linear data in 2D (Discrete Data)

Non-Linear data in 3D (Discrete Data)

Kernel Function (i.e., RBF)

Input space - - - - - - - - - - - - - - - - - - - - - - - - - - Feature space
Introduction
Introduction

Overfitting

- Very small $\gamma$ or
- Very large $d$

Optimal value
of $\gamma$ or $d$

Underfitting

- Very large $\gamma$ or
- Very small $d$

Fit (Good generalization)
Introduction

Kernel parameter

Kernel Function

Features

Target

Penalty Parameter

SVR

Optimization Algorithm
Introduction
Introduction

Optimization Algorithms

- Conventional algorithms
- Meta-heuristic optimization algorithms
  - Individual-based Optimization Algorithms
  - Population-based Optimization Algorithms
    - Evolutionary Algorithms
    - Swarm Optimization Algorithms
Introduction

$x \in [1 - 10]$
$y \in [5 - 8]$
Introduction
Acc = 62%
Acc = 60%
Acc = 64%
Acc = 55%
Acc = 66%
Acc = 60%
Acc = 60%
Acc = 60%
Acc = 66%
Acc = 60%
Acc = 59%
Acc = 60%
Acc = 63%
Acc = 80%
Acc = 63%
Acc = 50%
Acc = 53%
Introduction

- Acc = 62%
- Acc = 60%
- Acc = 64%
- Acc = 55%
- Acc = 66%
- Acc = 60%
- Acc = 59%
- Acc = 60%
- Acc = 80%
- Pos = [1,6]
Introduction

Acc = 60%

Acc = 62%

Acc = 64%

Acc = 55%

Acc = 66%

Acc = 80%

Acc = 63%

Acc = 50%

Exploitation

Acc = 53%

Acc = 60%

Acc = 59%

Acc = 60%
Introduction
Introduction

Acc = 62%
Acc = 60%
Acc = 64%
Acc = 66%
Acc = 55%
Acc = 66%
Acc = 66%
Acc = 60%
Acc = 62%
Acc = 63%
Acc = 70%
Acc = 59%
Acc = 60%
Acc = 55%
Acc = 53%
Acc = 60%
Introduction
Introduction

Acc = 60%
Acc = 62%
Acc = 53%
Acc = 50%
Acc = 64%
Acc = 66%
Acc = 55%
Acc = 66%
Acc = 59%
Acc = 60%
Acc = 60%
Acc = 60%
Acc = 80%
Acc = 63%
Acc = 50%
Acc = 53%
Introduction
Introduction

- Using Whale Optimization Algorithm (WOA) to
  - Optimize Kernel function parameter
  - Optimize Penalty parameter
  - Feature selection

- Comparing our results with Traditional SVR and PSO
1) In the collected data set, there are some problems such as missing values. To overcome this problem, linear interpretation is used to fill these gaps and solve this problem.
Data scaling (Data normalization)

Generally, every feature could be linearly scaled to the range \([-1, 1]\) or \([0, 1]\). Selecting the target range depends on the nature of the data. Consider

\[
x_i^{\text{scale}} = \frac{x_i - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}}
\]
The dataset is divided into two subsets namely training and testing datasets using k-fold cross validation algorithm (K=3).
**Proposed WOA-SVR Algorithm**

1. **Wind Dataset**
2. **Data Preprocessing**
3. **Preprocessed Dataset**
4. **Testing set**
5. **Training set**
6. **Determine the possible range of parameters C, γ and features subset**
7. **Initialize WOA Parameters**
8. **Define the initial cost function**
9. **Generate initial population randomly according to the available ranges**
10. **Train SVR classifier**
11. **SVR Model**
12. **Test SVR model**
13. **Fitness Evaluation using (MAPECV)**
14. **Satisfying stopping criterion?**
   - Yes
   - NO: Generate New Solution

**Optimized Parameters** (C, γ and features subset)

**Prediction Model**

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum number of iteration (Generation)</td>
<td>10</td>
</tr>
<tr>
<td>Number of search agents size (Population)</td>
<td>20</td>
</tr>
<tr>
<td>Dimension</td>
<td>17</td>
</tr>
<tr>
<td>b in WOA</td>
<td>3</td>
</tr>
<tr>
<td>Lowe bound of C</td>
<td>1</td>
</tr>
<tr>
<td>Upper bound of C</td>
<td>1000</td>
</tr>
<tr>
<td>Lowe bound of γ</td>
<td>1</td>
</tr>
<tr>
<td>Upper bound of γ</td>
<td>100</td>
</tr>
<tr>
<td>Lowe bound of feature</td>
<td>1</td>
</tr>
<tr>
<td>Upper bound of feature</td>
<td>15</td>
</tr>
</tbody>
</table>
WOA use mean abstract percent error (MAPE) to determine the goodness or quality of each search agent or solution:

$$\min f = MAPE_{CV} = \frac{1}{l} \sum_{i=1}^{l} \left| \frac{Act_i - Pred_i}{Act_i} \right| \times 100 \quad (17)$$
Proposed WOA-SVR Algorithm

- Wind Dataset
- Data Preprocessing
- Preprocessed Dataset
- Testing set
- Training set

**Data Preprocessing**
- Initialize WOA Parameters
- Define the initial cost function
- Generate initial population randomly according to the available ranges

**Wind Dataset**
- Train SVR classifier
- SVR Model
- Test SVR model
- Fitness Evaluation using (MAPE,ε)

- WOA Generate initial population randomly according to the available ranges

- NO
- Generate New Solution

- Optimized Parameters (C, γ and features subset)
- Prediction Model
Proposed WOA-SVR Algorithm

1. **Data Preprocessing**
   - Wind Dataset

2. **Preprocessed Dataset**
   - Initialize WOA Parameters
   - Define the initial cost function
   - Generate initial population randomly according to the available ranges

3. **Training set**
   - Train SVR classifier
   - SVR Model
   - Test SVR model
   - Fitness Evaluation using (MAPE$_{CV}$)

4. **Testing set**
   - Satisfying stopping criterion ?
     - Yes
     - Optimization Parameters ($C, \gamma$ and features subset)
     - Prediction Model
   - NO
     - Generate New Solution

The proposed WOA-SVR algorithm includes the following steps:

- **Data Preprocessing** involves initial data preparation.
- **Preprocessed Dataset** is then used to initialize parameters and define the initial cost function.
- A population is generated randomly according to available ranges.
- The **Training set** is used to train the SVR classifier, produce the SVR model, and test the model.
- Fitness evaluation is performed using the Coefficient of Variation (MAPE$_{CV}$).
- A decision is made based on the stopping criterion.
  - If satisfied, the optimized parameters ($C, \gamma$ and features subset) are selected, and a prediction model is generated.
  - If not, a new solution is generated.

The proposed WOA-SVR algorithm aims to optimize parameters and improve prediction accuracy.
Proposed WOA-SVR Algorithm

Wind Dataset

Data Preprocessing

Preprocessed Dataset

Testing set

Training set

Optimized Parameters ($C$, $\gamma$ and features subset)

Prediction Model

Initialize WOA Parameters

Define the initial cost function

Generate initial population randomly according to the available ranges

Train SVR classifier

Test SVR model

Fitness Evaluation using ($MAPE_{CV}$)

Satisfying stopping criterion?

Yes

No

Generate New Solution

SVR Parameters ($C$, $\gamma$ and features subset)

SVR Parameters ($C$, $\gamma$ and features subset)

Test SVR model using testing dataset

SVR Model

Satisfying stopping criterion?
Proposed WOA-SVR Algorithm

Calculate fitness function for each whale and select the best one to be the optimal solution.
When the termination criteria are satisfied, the operation ends; otherwise, we proceed with the next generation operation. In the proposed algorithms, the WOA is terminated when a maximum number of iterations are reached.
Proposed WOA-SVR Algorithm

1. **Wind Dataset**
   - Data Preprocessing
     - Preprocessed Dataset

2. **Data Preprocessing**
   - Dataset
     - Testing set
     - Training set

3. **Preprocessed Dataset**
   - Determine the possible range of parameters $C$, $\gamma$ and features subset

4. **Initialize WOA Parameters**
   - Define the initial cost function

5. **Generate initial population randomly according to the available ranges**
   - Train SVR classifier
     - SVR Model
     - Test SVR model
     - Fitness Evaluation using (MAPE$_{CV}$)

6. **Satisfying stopping criterion?**
   - Yes
     - SVR Parameters ($C$, $\gamma$ and features subset)
     - Optimization Parameters ($C$, $\gamma$ and features subset)
   - NO
     - Generate New Solution

7. **Optimized Parameters ($C$, $\gamma$ and features subset)**
   - Prediction Model

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Return SVR optimal parameters and prediction Model
Proposed WOA-SVR Algorithm

Each whale proceeds to its next locations.
Experimental results and discussion

- **Description of Experimental Data**

  - The used data in this paper is measured on an average daily basis from a meteorological station at Helwan University, Cairo, Egypt, these data were gathered for the year 2016.

  - In this paper, sixteen meteorological factors
Experimental results and discussion

□ **Description of Experimental Data**

- The time of the study ranges from January 1, 2016, to December 22, 2016, except some missing days. The data set includes 197 wind samples.
- These data are complete and daily average weather data that collected and employed from the Space Weather Monitoring Center (SWMC) in Egypt.
Experimental results and discussion

- Evaluation metrics
  - Convergence
  - Forecasting Accuracy Measurements
    - MAE
    - MSE
    - MAPE
    - RMSE
Experimental results and discussion

- Comparison of Convergence:

![Comparison of Convergence Graph]

The graph above compares the convergence of WOA (red) and PSO (black) algorithms over iterations. The x-axis represents the iteration number, while the y-axis shows the fitness value. The graph illustrates how the fitness values decrease as the iterations progress, indicating the algorithms' convergence to a solution.
## Experimental results and discussion

### Forecasting Accuracy Measurements

<table>
<thead>
<tr>
<th>Measure</th>
<th>SVR</th>
<th>WOA-SVR</th>
<th>PSO-SVR</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAPE (%)</td>
<td>0.7010</td>
<td>0.2600</td>
<td>0.3238</td>
</tr>
<tr>
<td>MAE</td>
<td>0.5229</td>
<td>0.2243</td>
<td>0.2724</td>
</tr>
<tr>
<td>MSE</td>
<td>0.5380</td>
<td>0.2112</td>
<td>0.2488</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.7290</td>
<td>0.4282</td>
<td>0.4738</td>
</tr>
</tbody>
</table>
Conclusion

- In this paper, a novel optimization algorithm based on the Whale Optimization Algorithm (WOA) and SVR called WOA-SVR was proposed to optimize the SVR parameters. This algorithm is employed to enhance the performance of SVR in order to reduce the regression for wind speed prediction.

- The performance of WOA-SVR algorithms is estimated and compared using wind datasets as real-world cases.

- From the experimental results, it can be concluded that WOA-SVR algorithm achieved MAPE, MAE, MSE and RMSE lower than PSO-SVR and traditional SVR.
Future Works

- Multi-kernel learning SVR for wind speed prediction,
- Chaotic swarm optimization for SVR parameters optimization,
- Present a comparative analysis of a swarm optimization algorithms and Kernel functions
- It is an important issue to check the reliability and stability of proposed algorithm, and this can be done by increasing the dataset size.
Questions!?
Thanks and Acknowledgement