Performance Improvement for Hotspot Prediction Model  
Using SBi-LSTM-XGBoost and SBi-GRU-XGBoost

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(Received July 1, 2019 Revised October 21, 2019 Accepted October 29, 2019, Available online October 29, 2019)

Abstract

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*Keywords:*

# Introduction

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# Related Works

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# Method

## Data Collections

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## Data Preprocessing

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|  | (1) |

## Exploration Data Analysis

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## Time Series Analysis

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|  | (2) |
|  | (3) |
|  | (4) |

## Data Splitting

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## Model Prediction Hotspot

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|  | (5) |
|  | (6) |
|  | (7) |
|  | (8) |
|  | (9) |
|  | (10) |

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|  | (11) |
|  | (12) |
|  | (13) |
|  | (14) |

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|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Algorithms | : | SBi-LSTM-XGBoost |  | Algorithms | : | SBi-GRU-XGBoost |
| Input | : | xtrue, ytrue, lstm\_pred |  | Input | : | xtrue, ytrue, gru\_pred |
| Output | : | xgb\_pred |  | Output | : | xgb\_pred |
| # 1. calculate residuals  residuals = ytrue - lstm\_pred[:, 0]    # 2. xgboost model on residuals  xgb\_model = XGBRegressor()    # 3. fitting models  xgb\_model.fit(xtrue, residuals)    # 4. predict models  predictions = xgb\_model.predict(xtrue)    # 5. Combine Model with XGBoost predictions  xgb\_predictions = lstm\_pred[:, 0] + predictions | | |  | # 1. calculate residuals  residuals = ytrue - grud\_pred[:, 0]    # 2. xgboost model on residuals  xgb\_model = XGBRegressor()    # 3. fitting models  xgb\_model.fit(xtrue, residuals)    # 4. predict models  predictions = xgb\_model.predict(xtrue)    # 5. Combine Model with XGBoost predictions  xgb\_predictions = grud\_pred[:, 0] + predictions | | |

## Model Evaluations

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|  | (15) |
|  | (16) |
|  | (17) |
|  | (18) |

# Results and Discussion

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## Data Collections

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Tabel 1. Metdadata of dataset

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| --- | --- | --- | --- | --- |
| **Characteristics** | **SST Nino 3.4** | **Index ONI** | **Index SOI** | **Hotspot** |
| Count | 276,00 | 276,00 | 276,00 | 276,00 |
| Mean | 0,01 | -0,03 | 0,39 | 595,02 |
| Std | 0,77 | 0,82 | 1,53 | 1664,50 |
| Min | -1,59 | -1,64 | -5,20 | 3,00 |
| 25% | -0,55 | -0,61 | -0,60 | 20,00 |
| 50% | -0,07 | -0,14 | 0,30 | 54,00 |
| 75% | 0,47 | 0,47 | 1,32 | 255,75 |
| Max | 2,72 | 2,64 | 4,80 | 14437,00 |

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| (a) | (b) |
|  |  |
| (c) | (d) |
| Fig 2. Results of Data Collections | |

## Data Preprocessing

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| (a) | (b) |
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| (c) | (d) |
| Fig 2. Results of normalized min-max | |

## Exploration Data Analysis

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| Fig 3. Hasil deteksi pencilan |

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| (a) | (b) |
|  |  |
| (c) | (d) |
| Fig4. Analisa distribusi data | |

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| (a) | (b) |
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| (c) | |
| Fig5. Analisa linieritas | |

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| (a) | (b) |
|  | |
| (c) | |
| Fig6. Analisa korelasi antar fitur | |

## Time Series Analysis

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Tabel 2. Statistical Analysis of Stationarity

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| --- | --- | --- | --- | --- | --- |
| **Methods** | | **P-value** | **Critical values** | | |
| **1%** | **5%** | **10%** |
| ADF | |  |  |  |  |
|  | Lag 1 | 0,000 | -3,99 | -3,43 | -3,14 |
|  | Lag 6 | 0,000 | -3,99 | -3,43 | -3,14 |
|  | Lag 12 | 0,004 | -3,99 | -3,43 | -3,14 |
|  | Lag 24 | 0,074 | -4,00 | -3,43 | -3,14 |
| PP | |  |  |  |  |
|  | Lag 1 | 0,000 | -3,99 | -3,43 | -3,14 |
|  | Lag 6 | 0,000 | -3,99 | -3,43 | -3,14 |
|  | Lag 12 | 0,000 | -3,99 | -3,43 | -3,14 |
|  | Lag 24 | 0,000 | -3,99 | -3,43 | -3,14 |
| KPSS | |  |  |  |  |
|  | Lag 1 | 0,815 | 0,22 | 0,15 | 0,12 |
|  | Lag 6 | 0,304 | 0,22 | 0,15 | 0,12 |
|  | Lag 12 | 0,232 | 0,22 | 0,15 | 0,12 |
|  | Lag 24 | 0,201 | 0,22 | 0,15 | 0,12 |

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| (a) | (b) |
| Fig 7. Analisa ACF dan PACF | |

## Data Splitting

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| --- | --- |
|  |  |
| (a) | (b) |
|  |  |
| (c) | (d) |
| Fig8. Analisa distribusi data | |

## Model Prediction Hotspot

**4.6.1 Initialisation of neural network parameters and model**

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Tabel 3. Initialization of tuning hyperparameters

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| --- | --- |
| **Parameter tuning** | **Values** |
| Activation function | ReLU, SeLU, ELU, Softplus. |
| Optimizers | Adam, Adamax, RMSprop, SGD. |
| Dropout | 0.05, 0.10, 0.15, 0.20, 0.25 |
| Batch Size | 2, 4, 8, 16, 32 |
| Epoch | 1500 |

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Desain NN yang dibuat:

* 1 input layers dengan 4 neuron (hotspot, sst nina 3.4, index oni, index soi pada t-1 sebagai input)
* 3 hidden layers dengan 10 neuron. Setiap hidden layers mewakili 1 layes lstm atau gru. (Sehingga terdapat 3 layers lstm atau gru yang ditumpuk).
* 1 dropout layer
* 1 output layers (hotspot pada t+1 sebagai output)

Note :

Desain ini berlaku umum untuk M1 dan M2.

|  |
| --- |
|  |
| Fig 9. Desain Neural Network for LSTM-RNN dan GRU-RNN |

**4.6.2 Results of finding the best parameters.**

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Tabel 4. Results of hyperparameter tuning with gridsearch algorithm

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| --- | --- | --- | --- | --- | --- | --- |
| **Algorithms** | | **Parameter Tuning** | | | | |
| **Activation function** | **Optimizers** | **Dropout** | **Batch Size** | **Epoch** |
| SBi-LSTM | |  |  |  |  |  |
|  | Univariate | SeLU | SGD | 0,15 | 8 | 1500 |
|  | Multivariate | ReLU | RMSprop | 0.20 | 32 |  |
| SBi-GRU | |  |  |  |  |  |
|  | Univariate | SeLU | SGD | 0,25 | 8 | 1500 |
|  | Multivariate | ReLU | RMSprop | 0.20 | 16 | 1500 |

Univariate = hanya titik panas (M1)  
Multivariate = titik panas + enso (M2)

**4.6.3 Results of training and validation models**

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|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig 10. Results of training models univariate | |

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|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig11. Results of training models multivariate | |

**4.6.3 Results of prediction hotspot with univariate and multivariate models**

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|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig12. Results of training models univariate | |

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|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig13. Results of training models multivariate | |

tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus et malesuada fames ac turpis egestas. Nam exaugue, semper attempus, tincidunt anibh. Fusce efficitur ex nisl, sed gravida. – Analisa hasil dari proses training dan prediksi

tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus et malesuada fames ac turpis egestas. Nam exaugue, semper attempus, tincidunt anibh. Fusce efficitur ex nisl, sed gravida. – Hasil lengkap prediksi titik panas.

Table 4. Results of prediction hotspot using univariate SBi-LSTM

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 31 | 30 | 33 | 34 | 57 | 43 | 80 | 618 | 2314 | 2266 | 1307 |
| 2020 | 44 | 37 | 36 | 50 | 50 | 37 | 36 | 37 | 52 | 37 | 41 | 38 |
| 2021 | 30 | 29 | 29 | 32 | 51 | 49 | 51 | 83 | 68 | 64 | 46 | 34 |
| 2022 | 35 | 29 | 31 | 42 | 32 | 43 | 38 | 52 | 61 | 41 | 32 | 31 |
| 2023 | 31 | 28 | 31 | 31 | 39 | 45 | 46 | 48 | 121 | 1675 | 2108 | 282 |

Table 5. Results of prediction hotspot using multivariate SBi-LSTM

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 35 | 14 | 33 | 26 | 36 | 43 | 112 | 890 | 4102 | 3613 | 2180 |
| 2020 | 47 | 36 | 78 | 83 | 86 | 45 | 39 | 42 | 40 | 34 | 25 | 22 |
| 2021 | 39 | 62 | 35 | 32 | 40 | 46 | 58 | 37 | 59 | 51 | 34 | 31 |
| 2022 | 34 | 30 | 33 | 65 | 35 | 34 | 36 | 36 | 33 | 35 | 35 | 27 |
| 2023 | 32 | 37 | 38 | 44 | 80 | 24 | 23 | 22 | 175 | 4755 | 508 | 20 |

Table 6. Results of prediction hotspot using univariate SBi-GRU

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 55 | 55 | 59 | 60 | 85 | 70 | 106 | 528 | 2237 | 2159 | 1098 |
| 2020 | 70 | 62 | 61 | 77 | 77 | 62 | 61 | 63 | 80 | 63 | 68 | 64 |
| 2021 | 55 | 54 | 54 | 57 | 78 | 76 | 78 | 109 | 94 | 90 | 73 | 59 |
| 2022 | 61 | 54 | 56 | 68 | 57 | 69 | 64 | 79 | 88 | 68 | 57 | 55 |
| 2023 | 56 | 53 | 56 | 56 | 66 | 72 | 73 | 75 | 147 | 1441 | 1907 | 269 |

Table 7. Results of prediction hotspot using multivariate SBi-GRU

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 50 | 36 | 40 | 44 | 48 | 51 | 61 | 1669 | 5849 | 2948 | 1745 |
| 2020 | 53 | 53 | 64 | 72 | 157 | 69 | 66 | 88 | 48 | 44 | 27 | 27 |
| 2021 | 43 | 42 | 40 | 43 | 44 | 70 | 111 | 53 | 89 | 81 | 39 | 38 |
| 2022 | 34 | 34 | 43 | 42 | 40 | 35 | 44 | 45 | 35 | 40 | 42 | 30 |
| 2023 | 39 | 40 | 45 | 112 | 150 | 45 | 42 | 39 | 39 | 3526 | 608 | 46 |

tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus et malesuada fames ac turpis egestas. Nam exaugue, semper attempus, tincidunt anibh. Fusce efficitur ex nisl, sed gravida. – Analisa hasil dari prediksi selama 5 tahun 2019 – 2023.

Letak kebaharuan dari sisi penerapan SBi-LSTM-XGBoost dan SBi-GRU-XGBoost

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|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig9. Results of training models univariate | |

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|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig10. Results of training models multivariate | |

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Table 8. Results of prediction hotspot using univariate SBi-LSTM-XGBoost

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 13 | 12 | 32 | 54 | 43 | 96 | 809 | 4205 | 3969 | 1736 | 53 |
| 2020 | 43 | 32 | 35 | 61 | 43 | 32 | 35 | 41 | 39 | 41 | 26 | 38 |
| 2021 | 12 | 12 | 12 | 35 | 85 | 60 | 85 | 101 | 87 | 50 | 36 | 33 |
| 2022 | 29 | 12 | 34 | 27 | 35 | 30 | 38 | 81 | 47 | 26 | 35 | 13 |
| 2023 | 13 | 11 | 13 | 34 | 40 | 47 | 48 | 168 | 2238 | 3190 | 402 | 49 |

Table 9. Results of prediction hotspot using multivariate SBi-LSTM-XGBoost

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 11 | 18 | 28 | 65 | 49 | 104 | 812 | 4202 | 3973 | 1743 | 57 |
| 2020 | 30 | 26 | 58 | 62 | 45 | 24 | 32 | 62 | 39 | 48 | 27 | 12 |
| 2021 | 4 | 13 | 14 | 53 | 64 | 55 | 106 | 96 | 86 | 55 | 27 | 23 |
| 2022 | 13 | 14 | 37 | 23 | 33 | 24 | 50 | 73 | 38 | 14 | 16 | 12 |
| 2023 | 1 | 12 | 21 | 37 | 51 | 50 | 57 | 184 | 2236 | 3202 | 388 | 46 |

Table 10. Results of prediction hotspot using univariate SBi-GRU-XGBoost

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 13 | 12 | 32 | 42 | 43 | 94 | 808 | 4207 | 3968 | 1735 | 52 |
| 2020 | 46 | 33 | 36 | 60 | 44 | 33 | 36 | 44 | 38 | 44 | 29 | 39 |
| 2021 | 12 | 11 | 11 | 35 | 85 | 63 | 85 | 101 | 87 | 51 | 32 | 33 |
| 2022 | 29 | 11 | 34 | 29 | 35 | 30 | 39 | 82 | 46 | 29 | 35 | 13 |
| 2023 | 13 | 10 | 13 | 34 | 41 | 47 | 48 | 167 | 2238 | 3189 | 402 | 49 |

Table11. Results of prediction hotspot using multivariate SBi-GRU-XGBoost

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | | | | | | | | | | | |
| **Jan** | **Feb** | **Mar** | **Apr** | **Mei** | **Jun** | **Jul** | **Ags** | **Sep** | **Okt** | **Nov** | **Des** |
| 2019 |  | 14 | 14 | 25 | 70 | 51 | 105 | 814 | 4207 | 3985 | 1737 | 49 |
| 2020 | 31 | 24 | 57 | 61 | 33 | 25 | 32 | 70 | 34 | 48 | 26 | 13 |
| 2021 | 11 | 6 | 17 | 52 | 59 | 60 | 113 | 96 | 86 | 59 | 26 | 24 |
| 2022 | 14 | 14 | 36 | 14 | 31 | 24 | 49 | 73 | 35 | 20 | 21 | 13 |
| 2023 | 4 | 12 | 14 | 34 | 56 | 51 | 57 | 179 | 2239 | 3199 | 386 | 48 |

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## Model Evaluations

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Table 12. Summary Results of model evaluation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Experiment** | | **Model evaluations** | | | |
| **R** | **MAE** | **RMSE** | **MAPE** |
| SBi-LSTM | |  |  |  |  |
|  | Univariate | 0,6452 | 0,0341 | 0,0956 | 0,0568 |
|  | Multivariate | 0,7354 | 0,0312 | 0,0929 | 0,0494 |
| SBi-LSTM-XGBoost | |  |  |  |  |
|  | Univariate | 0,9999 | 0,0014 | 0,0019 | 0,0015 |
|  | Multivariate | 1,0000 | 0,0007 | 0,0010 | 0,0008 |
| SBi-GRU | |  |  |  |  |
|  | Univariate | 0,6449 | 0,0357 | 0,0986 | 0,0602 |
|  | Multivariate | 0,8068 | 0,0289 | 0,0808 | 0,0469 |
| SBi-GRU-XGBoost | |  |  |  |  |
|  | Univariate | 0,9999 | 0,0015 | 0,0020 | 0,0016 |
|  | Multivariate | 1,0000 | 0,0007 | 0,0008 | 0,0008 |

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|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
|  |  |
| (c) | (d) |
| Fig11. Summary Results of model evaluation | |

# Conclusion

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

##### Acknowledgment *(Heading 5)*

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g.” Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

##### References

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Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the reference list. Use letters for table footnotes.

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