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

Husni Teja Sukamana a,1,\*, Saepul Aripiyanto a,2, Aryajaya Alamsyah b,3, Amir Acalapati Henry a,5

a Departement of Informatics Technology , State Islamic University Syarif Hidayatullah, Jl. Ir. H. Djuanda No. 95, South Tangerang, 15412, Indonesia

b Department of Computer Science, Faculty of Mathematics and Natural Sciences, IPB University, Jl. Meranti, IPB Dramaga Campus. Bogor, 16680, West Java, Indonesia

1 husniteja@uinjkt.ac.id\*; 2 saepul.aripiyanto@uinjkt.ac.id; 3 kusinalamsyah@apps.ipb.ac.id; 4 amir.acalapati@uinjkt.ac.id;

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

Abstract

Iaculis nunc sed augue lacus viverra vitae congue eu consequat ac felis donec et odio pellentesque diam volutpat commodo sed egestas egestas fringilla phasellus faucibus scelerisque eleifend donec pretium vulputate sapien nec sagittis aliquam malesuada bibendum arcu vitae elementum curabitur vitae nunc sed velit dignissim sodales ut eu sem integer vitae justo eget magna fermentum iaculis eu non diam phasellus vestibulum lorem sed risus ultricies tristique nulla aliquet enim tortor at auctor urna nunc id cursus metus aliquam eleifend mi in nulla posuere sollicitudin aliquam ultrices sagittis orci a scelerisque purus semper eget duis at tellus at urna condimentum mattis pellentesque id nibh tortor id aliquet lectus proin nibh nisl condimentum id venenatis a condimentum vitae sapien pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas sed tempus urna et pharetra pharetra massa massa ultricies mi quis hendrerit dolor magna eget est lorem ipsum dolor sit amet consectetur adipiscing elit pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas integer eget aliquet nibh praesent tristique magna sit amet purus gravida quis blandit turpis cursus in hac habitasse platea dictumst quisque sagittis purus sit amet volutpat consequat mauris nunc congue nisi vitae suscipit tellus mauris a diam maecenas sed enim ut sem viverra aliquet eget sit amet tellus cras adipiscing enim eu turpis egestas pretium aenean pharetra magna ac placerat vestibulum lectus mauris.

*Keywords:*

# Introduction

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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. – Masalah Penelitian.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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. – Hubungan Kebakaran hutan dengan titik panas dan enso.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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. – Solusi Penelitian, Beberapa riset tentang prediksi titik panas.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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. – Tujuan Penelitian.

# Related Works

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus. – 1. Kenapa melakukan penelitian prediksi titik panas

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus. – 2. Bagaimana hubungan titik panas dengan enso

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque. – 3. Apa parameter untuk hyperparameter tuning dan metode untuk pencariannya

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus. – 4. Kenapa memilih metode SBi-LSTM, SBi-GRU, dan XGBoost.

# Method

## Data Collections

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

## Data Preprocessing

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

|  |  |
| --- | --- |
|  | (1) |

## Exploration Data Analysis

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

## Time Series Analysis

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

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

## Data Splitting

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

## Model Prediction Hotspot

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus. – Penjelasan SBi-LSTM

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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus. – Penjelasan SBi-GRU

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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Penjelasan XGBoost

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoqu. – The our perpose algorithm, SBi-LSTM-XGBoost dan SBi-GRU-XGBoost

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

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

# Results and Discussion

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

## Data Collections

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

Tabel 1. Metdadata of dataset

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
|  |  |
| (c) | (d) |
| Fig 1. Results of Data Collections | |

## Data Preprocessing

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Pemotongan data menggunakan clips di QGIS

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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. – Seleksi atribut titik panas, aggregasi data, penggabungan data.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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.. – Normalisasi Data

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

## Exploration Data Analysis

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Deteksi Pencilan

|  |
| --- |
|  |
| Fig 2. Hasil deteksi pencilan |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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. – Distribusi Data

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
|  |  |
| (c) | (d) |
| Fig3. Analisa distribusi data | |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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.. – Linieritas

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
|  | |
| (c) | |
| Fig3. Analisa linieritas | |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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. – Korelasi antar fitur

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
|  | |
| (c) | |
| Fig3. Analisa korelasi antar fitur | |

## Time Series Analysis

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibu. – Analisis Stasioneritas

Tabel 2. Statistical Analysis of Stationarity

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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 |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibu. – Analisis ACF dan PACF

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig 2. Analisa ACF dan PACF | |

## Data Splitting

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
|  |  |
| (c) | (d) |
| Fig3. Analisa distribusi data | |

## Model Prediction Hotspot

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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Pencarian Parameter Terbaik

Tabel 3. Initialization of tuning hyperparameters

|  |  |
| --- | --- |
| **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 |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Desain Neural Network untuk LSTM dan GRU

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 3. Desain Neural Network for LSTM-RNN dan GRU-RNN |

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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Hasil pencarian parameter terbaik.

Tabel 3. Results of hyperparameter tuning with gridsearch algorithm

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **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**

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibu. – Hasil training model prediksi berdasarkan perncarian parameter.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig3. Results of training models univariate | |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibu. – Hasil training model prediksi berdasarkan perncarian parameter.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig3. Results of training models multivariate | |

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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis 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 prediksi titik panas berdasarkan pencarian parameter terbaik.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig3. Results of training models univariate | |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibu. – Hasil prediksi titik panas berdasarkan pencarian parameter terbaik.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig3. 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.

Fig3. 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 |

Fig3. 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 |

Fig3. 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 |

Fig3. 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

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus. – Hasil prediksi titik panas berdasarkan kebaharuan penelitian.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig3. Results of training models univariate | |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Hasil prediksi titik panas berdasarkan kebaharuan penelitian.

|  |  |
| --- | --- |
|  |  |
| (a) | (b) |
| Fig3. Results of training models multivariate | |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis. – Hasil lengkap prediksi titik panas.

Fig3. 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 |

Fig3. 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 |

Fig3. 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 |

Table 3. 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 |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique. – Hasil analisa antara prediksi SBi-LSTM, SBi-LSTM-XGBoost, SBi-GRU, SBi-GRU-XGBoost.

## Model Evaluations

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus etnetus. – Evaluasi model univariate

Table 4. Results of model evaluation using univariate models

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Runing** | **SBi-LSTM** | | | |  | **SBi-GRU** | | | |
| **Model evaluations** | | | |  | **Model evaluations** | | | |
| **R** | **MAE** | **RMSE** | **MAPE** |  | **R** | **MAE** | **RMSE** | **MAPE** |
| 1 | 0,6430 | 0,0343 | 0,0956 | 0,0566 |  | 0,6473 | 0,0338 | 0,0973 | 0,0581 |
| 2 | 0,6389 | 0,0344 | 0,0961 | 0,0569 |  | 0,6457 | 0,0337 | 0,0974 | 0,0577 |
| 3 | 0,6417 | 0,0344 | 0,0960 | 0,0569 |  | 0,6460 | 0,0352 | 0,0971 | 0,0594 |
| 4 | 0,6409 | 0,0342 | 0,0958 | 0,0569 |  | 0,6463 | 0,0343 | 0,0979 | 0,0586 |
| 5 | 0,6436 | 0,0358 | 0,0951 | 0,0581 |  | 0,6479 | 0,0335 | 0,0972 | 0,0576 |
| 6 | 0,6420 | 0,0341 | 0,0958 | 0,0566 |  | 0,6462 | 0,0337 | 0,0983 | 0,0583 |
| 7 | 0,6390 | 0,0347 | 0,0959 | 0,0572 |  | 0,6484 | 0,0356 | 0,0969 | 0,0597 |
| 8 | 0,6359 | 0,0345 | 0,0963 | 0,0571 |  | 0,6482 | 0,0341 | 0,0973 | 0,0581 |
| 9 | 0,6417 | 0,0351 | 0,0955 | 0,0575 |  | 0,6452 | 0,0334 | 0,0977 | 0,0577 |
| 10 | 0,6400 | 0,0352 | 0,0958 | 0,0578 |  | 0,6484 | 0,0337 | 0,0965 | 0,0574 |
| 11 | 0,6456 | 0,0339 | 0,0960 | 0,0570 |  | 0,6475 | 0,0353 | 0,0964 | 0,0591 |
| 12 | 0,6427 | 0,0342 | 0,0957 | 0,0567 |  | 0,6439 | 0,0336 | 0,0974 | 0,0577 |
| 13 | 0,6419 | 0,0342 | 0,0963 | 0,0571 |  | 0,6456 | 0,0335 | 0,0975 | 0,0577 |
| 14 | 0,6442 | 0,0344 | 0,0954 | 0,0567 |  | 0,6458 | 0,0341 | 0,0973 | 0,0583 |
| 15 | 0,6458 | 0,0344 | 0,0952 | 0,0568 |  | 0,6462 | 0,0335 | 0,0973 | 0,0575 |

Table 4. Summary Results of model evaluation using univariate models

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Experiment** | **SBi-LSTM** | | | |  | **SBi-GRU** | | | |
| **Model evaluations** | | | |  | **Model evaluations** | | | |
| **R** | **MAE** | **RMSE** | **MAPE** |  | **R** | **MAE** | **RMSE** | **MAPE** |
| Minimum | 0,6359 | 0,0339 | 0,0951 | 0,0566 |  | 0,6439 | 0,0334 | 0,0964 | 0,0574 |
| Maximum | 0,6458 | 0,0358 | 0,0963 | 0,0581 |  | 0,6484 | 0,0356 | 0,0983 | 0,0597 |
| Avegare | 0,6418 | 0,0345 | 0,0958 | 0,0571 |  | 0,6466 | 0,0341 | 0,0973 | 0,0582 |

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam iderat eget justo mollis posuere autsem. Donec porttitor molestie ultricies. Sed tristique urna sit amet dui semper accumsan insem. Proin sapien nisi, varius in aliquet non, convallis tincidunt est. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus. – Evaluasi model multivariate

Table 4. Results of model evaluation using multivariate models

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Runing** | **SBi-LSTM** | | | |  | **SBi-GRU** | | | |
| **Model evaluations** | | | |  | **Model evaluations** | | | |
| **R** | **MAE** | **RMSE** | **MAPE** |  | **R** | **MAE** | **RMSE** | **MAPE** |
| 1 |  |  |  |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |  |
| 8 |  |  |  |  |  |  |  |  |  |
| 9 |  |  |  |  |  |  |  |  |  |
| 10 |  |  |  |  |  |  |  |  |  |
| 11 |  |  |  |  |  |  |  |  |  |
| 12 |  |  |  |  |  |  |  |  |  |
| 13 |  |  |  |  |  |  |  |  |  |
| 14 |  |  |  |  |  |  |  |  |  |
| 15 |  |  |  |  |  |  |  |  |  |

Table 4. Summary Results of model evaluation using univariate models

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Experiment** | **SBi-LSTM** | | | |  | **SBi-GRU** | | | |
| **Model evaluations** | | | |  | **Model evaluations** | | | |
| **R** | **MAE** | **RMSE** | **MAPE** |  | **R** | **MAE** | **RMSE** | **MAPE** |
| Minimum |  |  |  |  |  |  |  |  |  |
| Maximum |  |  |  |  |  |  |  |  |  |
| Avegare |  |  |  |  |  |  |  |  |  |

# 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

The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

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.

Unless there are six authors or more give all authors’ names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

1. G. Eason, B. Noble, and I.N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955. (*references*)
2. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.
3. I.S. Jacobs and C.P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.
4. K. Elissa, “Title of paper if known,” unpublished.
5. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
6. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
7. M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.