

DAFTAR ISI

| | |
|-----------------------------------------------------------------------|---------------|
| HALAMAN JUDUL | i |
| HALAMAN PERSEMBAHAN | iv |
| HALAMAN MOTTO | v |
| PRAKATA | vi |
| DAFTAR ISI | viii |
| DAFTAR TABEL | xii |
| DAFTAR GAMBAR | xv |
| DAFTAR LAMBANG | xvii |
| INTISARI | .xviii |
| ABSTRACT | xix |
| I PENDAHULUAN | 1 |
| 1.1. Latar Belakang Masalah | 1 |
| 1.2. Batasan Masalah | 4 |
| 1.3. Tujuan dan Manfaat Penelitian | 5 |
| 1.4. Tinjauan Pustaka | 5 |
| 1.5. Metodologi Penelitian | 8 |
| 1.6. Sistematika Penulisan | 8 |
| II DASAR TEORI | 10 |
| 2.1. Konsep Peramalan (<i>Forecasting</i>) | 10 |
| 2.2. Konsep Dasar Runtun Waktu | 11 |
| 2.2.1. Jenis-Jenis Data Runtun Waktu | 12 |
| 2.2.2. Pola Data Runtun Waktu | 13 |
| 2.2.3. Jenis-Jenis Model Runtun Waktu | 14 |
| 2.2.4. Proses Stokastik | 15 |
| 2.2.5. <i>Wide-Sense</i> Stasioner dan <i>Strictly</i> Stasioner | 16 |
| 2.3. Uji Stasioneritas | 16 |
| 2.4. Proses (W-S) Stasioner | 17 |
| 2.4.1. Proses <i>White Noise</i> | 18 |
| 2.4.2. Proses <i>Autoregressive</i> (AR) | 18 |
| 2.4.3. Proses <i>Moving Average</i> (MA) | 19 |
| 2.4.4. Proses <i>Autoregressive Moving Average</i> (ARMA) | 20 |
| 2.4.5. Proses <i>Autoregressive Integrated Moving Average</i> (ARIMA) | 21 |
| 2.5. Fungsi Autokorelasi Parsial (PACF) | 21 |

| | | |
|-----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------|
| 2.6. | Uji <i>Lagrange Multiplier</i> (LM) | 23 |
| 2.7. | <i>Element Wise Multiplication</i> | 26 |
| 2.8. | Konsep Pembelajaran Mesin (<i>Machine Learning</i>) | 27 |
| 2.8.1. | Jenis Metode Pembelajaran Mesin | 28 |
| 2.9. | Pra-Pemrosesan Data | 29 |
| 2.9.1. | <i>Data Scaling</i> | 30 |
| 2.9.2. | <i>Data Splitting</i> | 31 |
| 2.10. | <i>Overfitting</i> dan <i>Underfitting</i> | 32 |
| 2.11. | Metrik Evaluasi | 34 |
| 2.12. | Konsep <i>Deep Learning</i> | 34 |
| 2.13. | Konsep Dasar Jaringan Saraf Tiruan (<i>Artificial Neural Network</i>) | 35 |
| 2.13.1. | Arsitektur Jaringan Saraf Tiruan | 35 |
| 2.13.2. | Jenis Jaringan Saraf Tiruan | 37 |
| 2.13.3. | <i>Multilayer Perceptron</i> (MLP) | 38 |
| 2.13.4. | <i>Backpropagation</i> | 39 |
| 2.14. | <i>Hyperparameter</i> | 39 |
| 2.15. | Fungsi Aktivasi | 42 |
| 2.15.1. | <i>Sigmoid</i> atau <i>Logistic</i> | 43 |
| 2.15.2. | <i>Hyperbolic Tangent</i> | 43 |
| 2.15.3. | ReLU | 44 |
| 2.16. | Regularisasi | 44 |
| 2.16.1. | <i>Dropout</i> | 45 |
| 2.17. | <i>Gradient Descent</i> | 46 |
| 2.18. | <i>Adaptive Moment Estimation</i> (Adam) | 47 |
| III OPTIMISASI SPARROW SEARCH ALGORITHM (SSA) PADA PEMODELAN RUNTUN WAKTU BIDIRECTIONAL GATED RECURRENT UNIT (BiGRU) | | 48 |
| 3.1. | <i>Recurrent Neural Network</i> (RNN) | 48 |
| 3.1.1. | Jenis-Jenis <i>Recurrent Neural Network</i> | 49 |
| 3.1.2. | Arsitektur <i>Recurrent Neural Network</i> | 52 |
| 3.2. | <i>Bidirectional Recurrent Neural Network</i> (Bi-RNN) | 54 |
| 3.2.1. | Struktur Bi-RNN | 55 |
| 3.2.2. | Pelatihan Bi-RNN | 56 |
| 3.3. | <i>Long Short-Term Memory</i> (LSTM) | 57 |
| 3.4. | <i>Gated Recurrent Unit</i> (GRU) | 61 |
| 3.5. | <i>Bidirectional Long Short-Term Memory</i> (BiLSTM) | 64 |

| | | |
|-----------|----------------------------------------------------------------------------------------------|-----------|
| 3.6. | <i>Bidirectional Gated Recurrent Unit (BiGRU)</i> | 64 |
| 3.7. | <i>Hyperparameter Optimization (HPO)</i> | 67 |
| 3.8. | <i>Swarm Intelligence Optimization</i> | 68 |
| 3.9. | <i>Sparrow Search Algorithm (SSA)</i> | 71 |
| 3.9.1. | Karakteristik Biologi <i>Sparrows</i> | 71 |
| 3.9.2. | Model Matematika dan Algoritma SSA | 73 |
| 3.9.3. | Contoh Aplikasi <i>Sparrow Search Algorithm (SSA)</i> | 78 |
| 3.10. | Diagram Alur | 85 |
| 3.10.1. | BiGRU, BiLSTM, GRU, dan LSTM tanpa Optimisasi SSA | 85 |
| 3.10.2. | BiGRU, BiLSTM, GRU, dan LSTM dengan Optimisasi SSA | 85 |
| IV | STUDI KASUS | 88 |
| 4.1. | Studi Kasus 1: Nilai Tukar Mata Uang USD-IDR Harian | 88 |
| 4.1.1. | Deskripsi Data | 88 |
| 4.1.2. | Persiapan Data | 89 |
| 4.1.3. | Pemodelan Runtun Waktu dengan Metode <i>Autoregressive Integrated Moving Average (ARIMA)</i> | 90 |
| 4.1.4. | Normalisasi Data, <i>Series to Supervised</i> , dan <i>Data Reshaping</i> | 97 |
| 4.1.5. | Inisialisasi Parameter Pemodelan Runtun Waktu | 97 |
| 4.1.5.1. | Parameter Model tanpa SSA | 98 |
| 4.1.5.2. | Parameter Model dengan SSA | 99 |
| 4.1.6. | Pemodelan Runtun Waktu tanpa Optimisasi SSA | 100 |
| 4.1.6.1. | Metode 1: <i>Long Short-Term Memory (LSTM)</i> | 100 |
| 4.1.6.2. | Metode 2: <i>Gated Recurrent Unit (GRU)</i> | 102 |
| 4.1.6.3. | Metode 3: <i>Bidirectional Long Short-Term Memory (BiLSTM)</i> | 104 |
| 4.1.6.4. | Metode 4: <i>Bidirectional Gated Recurrent Unit (Bi-GRU)</i> | 105 |
| 4.1.7. | Pemodelan Runtun Waktu dengan Optimisasi SSA | 107 |
| 4.1.7.1. | Metode 1: <i>Long Short-Term Memory (LSTM)</i> | 107 |
| 4.1.7.2. | Metode 2: <i>Gated Recurrent Unit (GRU)</i> | 110 |
| 4.1.7.3. | Metode 3: <i>Bidirectional Long Short-Term Memory (BiLSTM)</i> | 112 |
| 4.1.7.4. | Metode 4: <i>Bidirectional Gated Recurrent Unit (Bi-GRU)</i> | 114 |
| 4.1.8. | Ringkasan dan Perbandingan Performa Model | 117 |
| 4.1.9. | Penerapan Model Runtun Waktu | 119 |

| | |
|---------------------------------------------------------------------------------------------------------------|------------|
| 4.2. Studi Kasus 2: Nilai Saham Garuda Indonesia (Persero) Tbk PT (GIAA.JK) Mingguan | 121 |
| 4.2.1. Deskripsi Data | 121 |
| 4.2.2. Persiapan Data | 122 |
| 4.2.3. Pemodelan Runtun Waktu dengan Metode <i>Autoregressive Integrated Moving Average</i> (ARIMA) | 123 |
| 4.2.4. Normalisasi Data, <i>Series to Supervised</i> , dan <i>Data Reshaping</i> | 130 |
| 4.2.5. Inisialisasi Parameter Pemodelan Runtun Waktu | 130 |
| 4.2.5.1. Parameter Model tanpa SSA | 131 |
| 4.2.5.2. Parameter Model dengan SSA | 131 |
| 4.2.6. Pemodelan Runtun Waktu tanpa Optimisasi SSA | 133 |
| 4.2.6.1. Metode 1: <i>Long Short-Term Memory</i> (LSTM) | 133 |
| 4.2.6.2. Metode 2: <i>Gated Recurrent Unit</i> (GRU) | 135 |
| 4.2.6.3. Metode 3: <i>Bidirectional Long Short-Term Memory</i> (BiLSTM) | 137 |
| 4.2.6.4. Metode 4: <i>Bidirectional Gated Recurrent Unit</i> (Bi-GRU) | 139 |
| 4.2.7. Pemodelan Runtun Waktu dengan Optimisasi SSA | 140 |
| 4.2.7.1. Metode 1: <i>Long Short-Term Memory</i> (LSTM) | 141 |
| 4.2.7.2. Metode 2: <i>Gated Recurrent Unit</i> (GRU) | 143 |
| 4.2.7.3. Metode 3: <i>Bidirectional Long Short-Term Memory</i> (BiLSTM) | 146 |
| 4.2.7.4. Metode 4: <i>Bidirectional Gated Recurrent Unit</i> (Bi-GRU) | 148 |
| 4.2.8. Ringkasan dan Perbandingan Performa Model | 150 |
| 4.2.9. Penerapan Model Runtun Waktu | 153 |
| V PENUTUP | 154 |
| 5.1. Kesimpulan | 154 |
| 5.2. Saran | 155 |
| DAFTAR PUSTAKA | 155 |
| LAMPIRAN | 159 |