[[1]](#footnote-1)

Implementation of Random Forest Model for a Web-Based Stroke Prediction System with FastAPI and Laravel Architecture

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# INTRODUCTION

S

troke remains one of the most pressing global health challenges, consistently ranking as the second leading cause of death and the third leading cause of disability worldwide [1]. According to the Global Burden of Disease Study 2019, stroke accounted for over 12 million new cases and 6.5 million deaths annually, with more than 143 million disability-adjusted life years (DALYs) lost (Feigin et al., 2022). Despite a reported decline in stroke prevalence from 10.9 per 713,783 population in 2018 to 8.3 per 638,178 in 2023, findings from the National Health Survey (*Riskesdas*) reveal that stroke remains one of the predominant causes of mortality in Indonesia, reflecting the ongoing clinical and societal burden associated with the disease [2], [3]. This escalating trend not only poses clinical challenges but also imposes substantial economic and psychosocial strain on patients and their families (Widodo & Wibowo, 2020). In response, public health efforts have increasingly shifted from curative treatment to proactive prevention and early risk identification, emphasizing community-based screening and management of modifiable risk factors such as hypertension, diabetes, and smoking (Owolabi et al., 2022; Rahmawati & Wulandari, 2020; Aulia & Handayani, 2022). Such preventive approaches are now recognized as the cornerstone of reducing stroke incidence and associated disability worldwide.

The rapid advancement of machine learning (ML) has created substantial opportunities to develop highly accurate predictive screening tools capable of analyzing complex clinical and demographic risk factors to produce actionable risk estimations. Recent studies have demonstrated that ML-based models can improve stroke risk prediction by up to 25–35% compared with conventional statistical approaches [4] (Wang et al., 2024; Lee et al., 2023).

However, building reliable and generalizable ML models remains a major challenge. The first challenge lies in designing models that maintain high predictive performance while effectively handling heterogeneous and imbalanced clinical data, which are common in real-world medical datasets [5] (Chen et al., 2022). The second involves ensuring usability and accessibility—transforming complex algorithms into intuitive, web-based applications that can be easily utilized by both healthcare professionals and the general population (Rashid et al., 2023). Without a well-designed user interface and implementation strategy, even the most accurate predictive models risk losing their practical and clinical relevance (Deng et al., 2021).

Penelitian ini bertujuan untuk menjawab tantangan tersebut dengan mengembangkan dan mengevaluasi sistem prediksi stroke berbasis web yang komprehensif. Secara spesifik, penelitian ini berfokus pada tiga tujuan utama: (1) membangun model klasifikasi berakurasi tinggi menggunakan algoritma

Random Forest, yang dikenal andal dalam menangani data kompleks dan mencegah overfitting; (2) merekayasa arsitektur sistem modern yang terpisah (decoupled) dengan membangun API berperforma tinggi menggunakan FastAPI untuk melayani model ML ; dan (3) mengimplementasikan antarmuka pengguna yang responsif menggunakan framework Laravel 11 untuk menyajikan hasil prediksi secara efektif.

Kontribusi utama penelitian ini terletak pada demonstrasi implementasi arsitektur berbasis API yang mengintegrasikan ekosistem Python (untuk ilmu data) dan PHP (untuk pengembangan web)—sebuah pendekatan yang masih jarang dieksplorasi dalam literatur informatika kesehatan. Arsitektur ini tidak hanya meningkatkan modularitas dan skalabilitas sistem tetapi juga menjembatani kesenjangan antara riset akademis dan aplikasi dunia nyata dengan menyediakan prototipe fungsional yang dapat diakses publik, berbeda dari banyak penelitian serupa yang berhenti pada tahap validasi model.

# Material and Methods

## Dataset

Penelitian ini menggunakan dataset publik bernama "Stroke Prediction Dataset" yang bersumber dari platform Kaggle [18]. Dataset ini terdiri dari 5.110 data observasi dengan 12 atribut yang mencakup informasi demografis, klinis, dan gaya hidup pasien. Setiap observasi memiliki variabel target biner stroke yang mengindikasikan apakah pasien pernah mengalami stroke (1) atau tidak (0).

Atribut dalam dataset ini merupakan kombinasi dari tipe data numerik (seperti age, avg\_glucose\_level, dan bmi) dan kategorikal (seperti gender, work\_type, dan smoking\_status). Salah satu karakteristik penting dari dataset ini adalah adanya masalah ketidakseimbangan kelas yang signifikan. Dari total data, hanya 249 kasus (sekitar 4.9%) yang termasuk dalam kelas positif (stroke), sementara sisanya (95.1%) adalah kelas negatif. Kondisi ini memerlukan perhatian khusus karena dapat menyebabkan model menjadi bias terhadap kelas mayoritas.

## Preprocessing Data

Untuk menyiapkan data sebelum proses pelatihan model, serangkaian langkah pra-pemrosesan data dilakukan secara sistematis.

1. ***Data Cleaning:*** Langkah pertama adalah menangani nilai yang hilang (*missing values*). Terdapat 201 baris (sekitar 3.9%) dengan nilai kosong pada atribut bmi yang kemudian dihapus dari *dataset*.
2. ***Feature Encoding:*** Variabel kategorikal diubah menjadi representasi numerik menggunakan teknik *One-Hot Encoding*. Proses ini membuat kolom biner baru untuk setiap kategori dalam fitur seperti gender, work\_type, dan smoking\_status, sehingga data dapat diproses oleh algoritma *machine learning*.
3. ***Penanganan Kelas Tidak Seimbang:*** Untuk mengatasi masalah ketidakseimbangan kelas, digunakan pendekatan ganda. Pertama, teknik *Synthetic Minority Over-sampling Technique* (SMOTE) diterapkan pada data latih untuk membuat sampel sintetis baru dari kelas minoritas (stroke). Kedua, mekanisme pembobotan kelas (*class weighting*) diatur pada algoritma *Random Forest* untuk memberikan penalti yang lebih besar saat terjadi kesalahan klasifikasi pada kelas minoritas. Kombinasi ini bertujuan untuk meningkatkan sensitivitas model terhadap kasus stroke.

## Machine Learning Model Creation

Model prediksi dikembangkan menggunakan algoritma Random Forest, sebuah metode ensemble learning yang dikenal kuat dan tahan terhadap overfitting dengan membangun banyak decision tree. Dataset yang telah diproses dibagi menjadi 80% data latih dan 20% data uji. Model dilatih pada data latih yang telah diseimbangkan, dan proses hyperparameter tuning dilakukan untuk menemukan konfigurasi parameter yang optimal, seperti jumlah pohon (n\_estimators) dan kedalaman maksimum (max\_depth). Kinerja model dievaluasi menggunakan metrik standar yang diturunkan dari Confusion Matrix, meliputi akurasi, presisi, recall, dan F1-Score.

## Architecture

Sistem aplikasi web ini dibangun menggunakan arsitektur terpisah (decoupled) yang memisahkan antara logika backend dan antarmuka frontend.

1. Backend Service: Model Random Forest yang telah dilatih diekspos sebagai layanan melalui sebuah API yang dibangun menggunakan FastAPI. FastAPI, sebuah framework web Python modern, dipilih karena performanya yang tinggi dan kemampuannya menghasilkan dokumentasi API secara otomatis. API ini bertanggung jawab menerima data input dari pengguna dan mengembalikan hasil prediksi dalam format JSON.
2. Frontend Application: Antarmuka pengguna (UI) dikembangkan menggunakan Laravel 11, sebuah framework PHP yang menganut pola desain MVC. Aplikasi Laravel menyediakan formulir input data bagi pengguna dan berkomunikasi dengan API FastAPI melalui permintaan HTTP untuk mengambil dan menampilkan hasil prediksi secara.

# Result and Discussion

## Hasil Evaluasi Performa Model

Model Random Forest yang dikembangkan dievaluasi pada data uji untuk mengukur performa prediktifnya. Hasil evaluasi menunjukkan kinerja yang sangat tinggi, dengan akurasi keseluruhan mencapai 97.5%. Metrik evaluasi yang lebih rinci, yang dihitung dari confusion matrix, menunjukkan performa yang seimbang dan andal. Model mencapai nilai weighted average untuk presisi sebesar 0.98, recall 0.97, dan F1-Score 0.98. Nilai recall yang tinggi untuk kelas positif (stroke) sangat penting dalam konteks medis, karena ini menandakan kemampuan model untuk mengidentifikasi sebagian besar kasus stroke secara efektif sambil meminimalkan jumlah kasus yang terlewatkan (false negatives).

Untuk memahami faktor-faktor yang paling memengaruhi prediksi, dilakukan analisis feature importance. Hasilnya mengonfirmasi bahwa age, avg\_glucose\_level, bmi, hypertension, dan heart\_disease adalah lima prediktor teratas. Temuan ini selaras dengan literatur medis yang ada mengenai faktor risiko stroke, yang menunjukkan bahwa model berhasil menangkap pola-pola yang relevan secara klinis dari data.

## Implementasi dan Fungsionalitas Sistem Web

Model yang telah divalidasi kemudian diimplementasikan ke dalam sebuah sistem aplikasi web yang fungsional. Antarmuka pengguna (UI) menyediakan formulir input data yang intuitif bagi pengguna untuk memasukkan informasi demografis dan klinis mereka. Setelah data dikirim, aplikasi Laravel berkomunikasi secara real-time dengan API FastAPI untuk memproses input dan mengembalikan hasil prediksi.

Sistem menyajikan hasil prediksi dengan umpan balik visual yang jelas: notifikasi berwarna merah untuk potensi risiko tinggi dan berwarna hijau untuk risiko rendah. Pendekatan ini memastikan hasil dapat diinterpretasikan dengan cepat oleh pengguna dari berbagai latar belakang. Sistem juga menyertakan disclaimer yang menyatakan bahwa hasil prediksi bukanlah diagnosis medis formal, melainkan alat skrining awal.

## Pembahasan

Performa model Random Forest dengan akurasi 97.5% sangat kompetitif jika dibandingkan dengan penelitian-penelitian sebelumnya, yang umumnya melaporkan akurasi di rentang 90-95% [10], [12]. Keberhasilan ini dapat diatribusikan pada kekuatan algoritma Random Forest dalam menangani interaksi non-linear antar fitur serta efektivitas kombinasi teknik SMOTE dan class weighting dalam mengatasi bias pada dataset. Validitas klinis model juga diperkuat oleh hasil analisis feature importance yang sejalan dengan faktor risiko stroke yang telah diakui secara medis [7], [8].

Dari perspektif rekayasa perangkat lunak, implementasi arsitektur terpisah (decoupled) menggunakan FastAPI dan Laravel 11 terbukti berhasil, menghasilkan sistem yang fungsional, modular, dan dapat diskalakan. Meskipun demikian, penelitian ini memiliki keterbatasan, yaitu ketergantungan pada satu dataset publik dan perlunya validasi klinis eksternal untuk menguji generalisasi model di dunia nyata.

# Conclusion

Penelitian ini berhasil mengembangkan dan mengevaluasi sistem prediksi stroke berbasis web. Model klasifikasi yang dibangun menggunakan algoritma Random Forest menunjukkan kinerja yang sangat baik pada data uji, mencapai akurasi sebesar 97,5% dengan metrik presisi, recall, dan F1-Score yang seimbang. Keberhasilan ini didukung secara signifikan oleh teknik pra-pemrosesan data yang efektif, terutama dalam menangani masalah ketidakseimbangan kelas. Lebih lanjut, implementasi arsitektur perangkat lunak modern yang terpisah (decoupled) menggunakan FastAPI untuk API backend dan Laravel 11 untuk aplikasi frontend terbukti tangguh dan efektif. Sistem yang dihasilkan berfungsi sebagai prototipe valid yang berhasil menjembatani kesenjangan antara riset AI akademis dan aplikasi praktis di bidang kesehatan, menyediakan alat yang intuitif dan mudah diakses untuk skrining risiko stroke tahap awal.

Untuk pengembangan di masa depan, beberapa area direkomendasikan untuk perbaikan. Pertama, model harus divalidasi pada dataset yang lebih besar dan beragam, idealnya dari rekam medis elektronik dunia nyata, untuk memastikan generalisasi yang lebih baik. Mengeksplorasi algoritma yang lebih canggih, seperti gradient boosting machines (XGBoost, LightGBM) atau model deep learning, juga dapat memberikan potensi peningkatan akurasi. Dari perspektif aplikasi, penyempurnaan di masa depan dapat mencakup manajemen profil pengguna, pelacakan riwayat risiko, dan rekomendasi gaya hidup yang dipersonalisasi. Terakhir, melakukan studi validasi klinis bekerja sama dengan para profesional kesehatan adalah langkah penting berikutnya untuk mengevaluasi dampak dan kegunaan sistem di dunia nyata sebelum implementasi secara luas.

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Dr. Author was a recipient of the International Association of Geomagnetism and Aeronomy Young Scientist Award for Excellence in 2008, and the IEEE Electromagnetic Compatibility Society Best Symposium Paper Award in 2011.

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Mr. Author’s awards and honors include the Frew Fellowship (Australian Academy of Science), the I. I. Rabi Prize (APS), the European Frequency and Time Forum Award, the Carl Zeiss Research Award, the William F. Meggers Award and the Adolph Lomb Medal (OSA).

1. [↑](#footnote-ref-1)