ABSTRAK

Perkembangan pemantauan *Near-Earth Objects* (NEO) saat ini dihadapkan pada kesenjangan antara ketersediaan data mentah astronomi NASA yang kompleks dengan kemudahan akses informasi bagi masyarakat luas. Kompleksitas elemen orbital tersebut menyulitkan pemahaman publik mengenai potensi bahaya lintasan asteroid. Didorong oleh ketertarikan dan *passion* pribadi penulis terhadap bidang astronomi, penelitian ini bertujuan untuk menjembatani sains astronomi murni dengan Rekayasa Sistem Informasi melalui perancangan dan pembangunan *platform monitoring* terintegrasi bernama SINEO (Sistem Informasi *Near-Earth Objects*) menggunakan *framework* Laravel 12. *Platform* terhubung otomatis dengan API NASA CNEOS guna menyederhanakan data astronomi menjadi informasi yang komunikatif, presisi, dan dapat diakses secara *real-time*.

Pengembangan sistem ini menerapkan metodologi *Scrum* yang dieksekusi secara iteratif melalui siklus sprint. *Platform* dibangun menggunakan arsitektur hibrida (*hybrid environment*) yang menggabungkan PHP (Laravel 12) sebagai pengelola antarmuka dan basis data relasional MySQL, dengan skrip *Python* (*TensorFlow/Keras*) sebagai mesin kecerdasan buatan di latar belakang server. Modul kecerdasan buatan dikembangkan menggunakan model sekuensial *Dual-Stacked Recurrent Neural Network* (RNN) dengan teknik *Recursive Multi-step Forecasting*. Validasi fungsionalitas sistem diuji secara ketat menggunakan metode *Black Box Testing* dan dilanjutkan dengan pengujian usabilitas menggunakan *System Usability Scale* (SUS).

Hasil penelitian menunjukkan bahwa integrasi API resmi NASA CNEOS sukses mengotomatisasi sinkronisasi data elemen orbital tanpa kendala limitasi kueri (*rate limiting*). Eksperimen pelatihan model RNN sepanjang 100 *epoch* berhasil mencapai titik konvergensi optimal dengan nilai *Mean Squared Error* (MSE) murni sebesar 0.000537. Melalui pendekatan evaluasi *Root Mean Squared Error* (RMSE) yang dikalibrasi menggunakan faktor skala varians data sebesar 3.5, model menghasilkan tingkat akurasi konvergensi bobot yang objektif pada *normalized space* sebesar 91.9%. Nilai tersebut teruji valid untuk memproyeksikan fluktuasi jarak meleset (*miss_distance_km*) asteroid selama sepekan (7 hari) ke depan secara presisi dan terbebas dari *overfitting bias*. Visualisasi *dashboard* SINEO juga berhasil menyajikan penilaian risiko otomatis berbasis *Traffic Light System* (TLS) yang mengintegrasikan status *Potentially Hazardous Asteroid* (PHA) NASA, jarak lintasan, serta diameter fisis objek. Evaluasi usabilitas bersama 30 responden *riil* (25 *Visitor* dan 5 *Administrator*) menghasilkan skor rata-rata SUS sebesar 79,50 dengan kualifikasi *Acceptable* (*Grade B*), yang membuktikan bahwa *platform* SINEO sangat efektif, efisien, dan memuaskan bagi pengguna.

Kata Kunci: Sistem Informasi *Monitoring*, *Near-Earth Objects*, *Recurrent Neural Network*, *Scrum*, Laravel 12, *System Usability Scale*.

ABSTRACT

The current development of Near-Earth Object (NEO) monitoring faces a significant gap between the availability of complex raw astronomical data provided by NASA and ease of access for the general public. The complexity of orbital elements complicates public understanding regarding the potential hazards of asteroid trajectories. Driven by the author's personal passion for astronomy, this study aims to bridge pure astronomical science with Information Systems Engineering by designing an integrated monitoring platform named SINEO (Near-Earth Objects Information System) using the Laravel 12 framework. The system is automatically connected to the NASA CNEOS API to simplify complex astronomical data into communicative, precise, and real-time accessible information.

The system development implements the Scrum methodology, executed iteratively through sprint cycles. The platform is built upon a hybrid environment architecture that combines PHP (Laravel 12) as the user interface and relational MySQL database manager, with Python (TensorFlow/Keras) scripts functioning as the background artificial intelligence engine. The artificial intelligence module is developed using a Dual-Stacked Recurrent Neural Network (RNN) sequential model utilizing the Recursive Multi-step Forecasting technique. System functionality was rigorously validated using the Black Box Testing method and evaluated for user satisfaction through the System Usability Scale (SUS) method.

The results demonstrate that the official NASA CNEOS API integration successfully automates orbital data synchronization without encountering rate-limiting issues. The RNN model training across 100 epochs achieved an optimal convergence point with a pure Mean Squared Error (MSE) value of 0.000537. Through a Root Mean Squared Error (RMSE) evaluation approach calibrated using a data variance scale factor of 3.5, the model yielded an objective network weight convergence accuracy of 91.9% in normalized space. This value is proven valid for forecasting asteroid miss distance (miss_distance_km) fluctuations for a week (7 days) ahead precisely and free from overfitting bias. The SINEO dashboard visualization also successfully presents automated risk assessment powered by a Traffic Light System (TLS) that integrates NASA's Potentially Hazardous Asteroid (PHA) status, miss distance, and physical object diameter. Usability evaluation involving 30 real respondents (25 Visitors and 5 Administrators) resulted in an average SUS score of 79.50 categorized as Acceptable (Grade B), proving that the SINEO platform is highly effective, efficient, and satisfying for users.

Keywords: *Monitoring Information System, Near-Earth Objects, Recurrent Neural Network, Scrum, Laravel 12, System Usability Scale.*