RANCANG BANGUN ALGORITMA ADAPTIF SISTEM PERINGATAN DINI GEMPA BUMI BERDASARKAN FLUKTUASI GAS RADON STASIUN TELEMONITORING SIBOLGA

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INTISARI

Indonesia terjadi gempa bumi berkekuatan magnitudo > M5,0 sebanyak 186 kali selama 2024. Salah satu daerah zona merah adalah Sumatera bagian utara, hingga Mei 2025 sudah terjadi gempa M > 5.0 sebanyak 5 kali (BMKG, 2025). Beberapa penelitian menunjukkan adanya korelasi antara fenomena alam dengan kejadian gempa bumi. Naiknya Gas radon sebagai fenomena alam telah diteliti dan dinilai paling efektif menjadi prekursor gempa bumi. Stasiun telemonitoring Sibolga yang mengukur konsentrasi gas radon masih menghadapi kendala dengan belum adanya algoritma untuk mengolah data menjadi prediksi gempa bumi yang andal. Menurut USGS, prediksi gempa ideal mencakup tiga elemen: waktu, magnitudo, dan lokasi. Oleh karena itu, penelitian bertujuan membangun algoritma adaptif untuk memprediksi tiga elemen berdasarkan fluktuasi konsentrasi gas radon stasiun telemonitoring Sibolga.

Penelitian dilaksanakan di Laboratorium Sistem Sensor dan Telekontrol (SSTK), Departemen Teknik Nuklir dan Teknik Fisika Fakultas Teknik Universitas Gadjah Mada dan stasiun telemonitoring gas radon Sibolga (1.7409804°LU, 98.7762854°BT). Algoritma adaptif prediksi waktu, magnitudo, dan lokasi gempa bumi pada stasiun telemonitoring Sibolga diperoleh dengan mengolah data fluktuasi konsentrasi gas radon 1-17 hari sebelum prediksi gempa bumi secara statistik untuk memprediksi waktu gempa dalam rentang 1–4 hari setelah prediksi, selanjutnya galat hasil prediksi dianalisis terhadap nilai absolut rata-rata harian menggunakan regresi polinomial untuk mendapatkan faktor koreksi sebagai umpan balik yang bertujuan memperbarui model algoritma prediksi.

Berdasarkan hasil penelitian, algoritma adaptif prediksi waktu berhasil diperoleh dengan sensitivitas 77,39% dan presisi 85,14%, algoritma adaptif prediksi magnitudo berhasil diperoleh dengan nilai MAE M0,39; MSE M0,42; dan RMSE M0,65, dan algoritma adaptif prediksi klaster lokasi berhasil diperoleh dengan nilai MAE 1,4; MSE 4,23; dan RMSE 2,06. Hasil rancang bangun algoritma adaptif sudah tercapai dengan berhasil mengurangi galat prediksi terhadap prediksi sebelumnya sehingga layak diimplementasikan lebih lanjut sebagai sistem peringatan dini gempa bumi yang andal di Indonesia.

Kata kunci: *Gempa bumi, Fluktuasi Gas Radon, Sistem Peringatan Dini, Algoritma Adaptif*

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DESIGN OF ADAPTIVE ALGORITHM FOR EARTHQUAKE EARLY WARNING SYSTEM BASED ON RADON GAS FLUCTUATION ON SIBOLGA TELEMONITORING STATION

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ABSTRACT

Indonesia experienced 186 earthquakes with a magnitudo of > M5.0 in 2024. One of the red zone areas is northern Sumatra, until May 2025 there have been 5 earthquakes with magnitudo of > 5.0 (BMKG, 2025). Several studies have shown correlation between natural phenomena and earthquakes. Radon gas as natural phenomenon has been studied and is considered effective precursor to earthquakes. Sibolga telemonitoring stations that measure radon gas concentrations still face obstacles with absence of algorithm to process the data into reliable earthquake predictions. According to the USGS, ideal earthquake prediction should include three elements: time, magnitudo, and location. Therefore, this study aims to build adaptive algorithm to predict three elements based on the fluctuation of radon gas concentration Sibolga telemonitoring station.

The research was conducted at the Sensor and Telecontrol System Laboratory (SSTK), Department of Nuclear Engineering and Engineering Physics, Faculty of Engineering, Gadjah Mada University and the Sibolga radon gas telemonitoring station (1.7409804°N, 98.7762854°E). The adaptive algorithm for predicting the time, magnitudo, and location of earthquakes at the Sibolga telemonitoring station was obtained by processing data on radon gas concentration fluctuations 1-17 days before the earthquake prediction statistically to predict the earthquake time within 1-4 days after the prediction, then the *error* of the prediction results was analyzed a*gain*st the daily average absolute value using polynomial regression to obtain a correction factor as feedback aimed at updating the prediction algorithm model.

Based on the research results, the adaptive time prediction algorithm was successfully obtained with a sensitivity of 77.39% and a precision of 85.14%, the adaptive magnitudo prediction algorithm was successfully obtained with a MAE value of M0.39; MSE M0.42; and RMSE M0.65, and the adaptive location cluster prediction algorithm was successfully obtained with a MAE value of 1.4; MSE 4.23; and RMSE 2.06. The results of the adaptive algorithm design have been achieved by successfully reducing the prediction *error* a*gain*st the previous prediction so that it is worthy of further implementation as a reliable earthquake early warning system in Indonesia.

Key words: Earthquake, radon gas fluctuations, early warning system, earthquake prediction algorithm.

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