

ABSTRAK

Sistem navigasi otonom untuk eksplorasi gua telah dikembangkan dan diimplementasikan pada *Differential Drive Mobile Robot* (DDMR) menggunakan algoritma *Vector Field Histogram* (VFH) berbasis sensor LiDAR. Penelitian ini bertujuan untuk merancang sistem *obstacle avoidance* yang mampu mendeteksi rintangan statis dan mempertahankan eksplorasi berkelanjutan tanpa pemetaan. Robot dikonfigurasi dengan empat roda penggerak independen yang dilengkapi encoder, sensor LiDAR *single-point* 180°, serta Raspberry Pi 4 sebagai *on-board computer* dan Arduino Mega 2560 sebagai mikrokontroler. Pengujian sistem VFH menunjukkan kesesuaian implementasi algoritma dengan hasil perhitungan manual, dengan nilai *error* kurang dari 2% pada seluruh parameter navigasi yang diuji. Sensor LiDAR mampu mendeteksi rintangan pada sisi kiri, kanan, dan depan robot dengan tingkat keberhasilan 100% serta rata-rata *error* pengukuran antara 1,18% hingga 2,5%. Pengujian eksplorasi berkelanjutan dilakukan dalam tiga skenario dengan konfigurasi *obstacle* yang berbeda, yaitu satu *obstacle*, tiga *obstacle* formasi segitiga, dan lima *obstacle* formasi acak. Tingkat keberhasilan tertinggi dicapai pada skenario kedua (60%), diikuti skenario pertama dan ketiga (masing-masing 40%), dengan tingkat keberhasilan keseluruhan sebesar 46,7%. Total jarak tempuh dari seluruh percobaan adalah 208,2 meter dengan rata-rata 13,88 meter per percobaan. Kegagalan yang terjadi disebabkan oleh faktor fisik robot berupa *slip* roda, perbedaan karakteristik motor, keterbatasan sudut pandang sensor LiDAR 180°, serta kebuntuan lokal pada lingkungan dengan kepadatan *obstacle* tinggi. Hasil penelitian menunjukkan bahwa algoritma VFH terbukti valid secara matematis dan mampu menghasilkan keputusan navigasi yang tepat, namun keberhasilan implementasi di lapangan sangat bergantung pada kondisi mekanik robot, karakteristik permukaan area pengujian, serta kemampuan sensor dalam mendeteksi lingkungan secara menyeluruh.

Kata Kunci: *Obstacle avoidance*, VFH, LiDAR, *Differential drive mobile robot*, Eksplorasi Gua.

ABSTRACT

An autonomous navigation system for cave exploration has been developed and implemented on a Differential Drive Mobile Robot (DDMR) using the Vector Field Histogram (VFH) algorithm based on LiDAR sensors. This study aims to design an obstacle avoidance system capable of detecting static obstacles and maintaining continuous exploration without mapping. The robot is configured with four independently driven wheels equipped with encoders, a 180° single-point LiDAR sensor, as well as a Raspberry Pi 4 as an on-board computer and an Arduino Mega 2560 as a microcontroller. VFH system testing showed conformity between algorithm implementation and manual calculation results, with error values below 2% on all tested navigation parameters. The LiDAR sensor was able to detect obstacles on the left, right, and front sides of the robot with a 100% detection success rate and an average measurement error ranging from 1.18% to 2.5%. Continuous exploration testing was conducted in three scenarios with different obstacle configurations: single obstacle, three obstacles in triangular formation, and five obstacles in random formation. The highest success rate was achieved in the second scenario (60%), followed by the first and third scenarios (40% each), with an overall success rate of 46.7%. The total travel distance from all trials was 208.2 meters with an average of 13.88 meters per trial. Failures that occurred were caused by physical robot factors such as wheel slip, differences in motor characteristics, limited field of view of the 180° LiDAR sensor, and local minima in environments with high obstacle density. The research results show that the VFH algorithm is mathematically valid and capable of producing correct navigation decisions, but the success of field implementation is highly dependent on the robot's mechanical conditions, the surface characteristics of the testing area, and the sensor's ability to comprehensively detect the environment.

Keywords: *Obstacle avoidance, VFH, LiDAR, Differential Drive Mobile Robot, Cave Exploration.*