ABSTRAK

Otomatisasi sistem logistik pergudangan diperlukan untuk meningkatkan efisiensi, keamanan, dan produktivitas pemindahan barang. Trolley manual yang masih banyak digunakan memiliki keterbatasan berupa kelelahan operator, risiko kesalahan navigasi. Penelitian ini mengusulkan perancangan dan implementasi *automated logistic trolley* berbasis *line follower* dengan sistem kendali gerak menggunakan metode *Differential Drive Mobile Control*. Metode ini mengatur kecepatan roda kiri dan kanan secara independen melalui sinyal *Pulse Width Modulation* (PWM) sehingga trolley mampu bergerak maju, mundur, dan berbelok secara presisi berdasarkan perbedaan kecepatan kedua roda. Navigasi otomatis dilakukan menggunakan sensor *line follower* untuk mengikuti jalur distribusi tetap, serta sensor *ultrasonic* untuk mendeteksi hambatan guna meningkatkan keselamatan operasional. Sistem dikendalikan oleh mikrokontroler ESP32 yang mendukung konektivitas *Internet of Things* (IoT) untuk monitoring dan notifikasi status Trolley secara *real-time* melalui aplikasi Telegram. Selain mode otomatis, ditambahkan mode manual berbasis joystick Bluetooth sebagai mekanisme untuk pengendalian arah dan kecepatan trolley secara langsung ketika diperlukan. Metodologi meliputi perancangan perangkat keras, pengembangan algoritma kendali *differential drive*, integrasi komunikasi IoT, serta pengujian pada lingkungan gudang simulasi. Berdasarkan hasil pengujian-pengujian yang dilakukan, sistem automated logistic trolley menunjukkan kinerja yang sesuai dengan perancangan. Pengujian catu daya menunjukkan hasilk tegangan 25,5 *Volt* dari kebutuhan 24 *Volt* dengan error sekitar 6%, masih dalam batas toleransi operasional. *Step-down* untuk ESP32 stabil pada 5 V. Sensor *ultrasonic* memiliki rata-rata error ±0,1%, menunjukkan akurasi tinggi. Pada sistem komunikasi berbasis Telegram seluruh skenario konfigurasi, notifikasi, validasi input, dan *end-to-end* berjalan 100% berhasil. Pengujian Bluetooth menunjukkan waktu pairing tercepat 2,28 detik (1 m) dan terlama 12,59 detik (13 m). Rata-rata *delay* meningkat dari 53,3 ms (1 m) menjadi 536 ms (15 m), namun koneksi tetap stabil. Uji gerak *differential drive* membuktikan kesesuaian teori, dengan kecepatan 0,38–0,84 m/s (20 kg) dan 0,26–0,61 m/s (45 kg). Secara keseluruhan, sistem dinyatakan andal karena memiliki beberapa mode kendali yang saling mendukung sebagai sistem cadangan (backup). Namun demikian, proses transisi antar mode masih

memerlukan optimasi agar perpindahan kendali dapat berlangsung lebih cepat, stabil, dan tanpa konflik prioritas sistem.

Kata Kunci: *Automated Logictic Trolley*, *Line follower*, Kendali *differential drive*, Sensor *ultrasonic*, Monitoring IoT, Kontrol joystick Bluetooth, Telegram

ABSTRACT

Automation in warehouse logistics systems is required to improve the efficiency, safety, and productivity of goods transportation. Manual trolleys that are still widely used have several limitations, such as operator fatigue and the risk of navigation errors. This research proposes the design and implementation of an automated logistic trolley based on a line follower with a motion control system using the Differential Drive Mobile Control method. This method regulates the speed of the left and right wheels independently through Pulse Width Modulation (PWM) signals, enabling the trolley to move forward, backward, and turn precisely based on the speed difference between the two wheels. Automatic navigation is performed using a line follower sensor to follow a fixed distribution path, as well as an ultrasonic sensor to detect obstacles in order to enhance operational safety. The system is controlled by an ESP32 microcontroller that supports Internet of Things (IoT) connectivity for monitoring and real-time trolley status notifications through the Telegram application. In addition to the automatic mode, a manual mode based on a Bluetooth joystick is added as a backup mechanism to directly control the direction and speed of the trolley when necessary. The methodology includes hardware design, development of a differential drive control algorithm, integration of IoT communication, and testing in a simulated warehouse environment. Based on the conducted experiments, the automated logistic trolley system demonstrated performance consistent with the design specifications. The power supply test showed a voltage of 25.5 V from the required 24 V with an error of approximately 6%, which is still within operational tolerance. The step-down converter for the ESP32 remained stable at 5 V. The ultrasonic sensor showed an average error of ±0.1%, indicating high measurement accuracy. In the Telegram-based communication system, all configuration scenarios, notifications, input validation, and end-to-end processes achieved a 100% success rate. Bluetooth testing showed the fastest pairing time of 2.28 seconds at a distance of 1 m and the longest of 12.59 seconds at 13 m. The average delay increased from 53.3 ms at 1 m to 536 ms at 15 m; however, the connection remained stable. The differential drive motion test confirmed the theoretical model, with speeds ranging from 0.38–0.84 m/s for a 20 kg load and 0.26–0.61 m/s for a 45 kg load. Overall, the system is considered reliable because it provides multiple control modes that support each other as a backup system.

However, the transition process between control modes still requires optimization so that switching can occur faster, more stably, and without system priority conflicts.

Keywords: Automated Logistic Trolley, Line Follower, Differential Drive Control, Ultrasonic Sensor, IoT Monitoring, Bluetooth Joystick Control, Telegram