Development of a Teleoperation System for Smart-Gh Mobile Robot Based on IoT

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ABSTRACT

The deployment of mobile robot technology in greenhouse agriculture remains constrained by locomotion challenges arising from unstructured and unpredictable environmental conditions. An IoT-based teleoperation system presents an appropriate solution, as it enables operators to remotely control the robot while leveraging human decision-making capabilities in real time. This study develops a teleoperation system for the Smart-Gh Mobile robot based on IoT, capable of performing real-time greenhouse environment monitoring alongside remote pesticide spraying. The system was designed utilizing a Raspberry Pi as the primary processing unit, an ESP32 as the motor control microcontroller, Firebase Realtime Database as the communication platform between the control computer and the robot, and a wireless joystick as the operator control interface. A DHT22 sensor was employed to monitor temperature and humidity, with data visualized through ThingSpeak, while a webcam integrated with ZeroTier provides cross-network real-time video *streaming access. The DHT22 sensor demonstrated excellent accuracy, with an average temperature deviation of 1.27°C and a humidity deviation of 1.97% RH. The average end-to-end RTT was recorded at 1.472 seconds over WiFi and 1.870 seconds over mobile hotspot. Packet Loss on the PC–Raspberry Pi segment via Firebase reached 6.54% over WiFi and 30.92% over mobile hotspot. Teleoperation navigation testing within the greenhouse environment yielded a success rate of 80% across 10 trials, with failures attributed to limited camera field of view as well as elevated Latency and Packet Loss under mobile hotspot conditions. Firebase was identified as the primary Bottleneck, contributing 94–95% of the total end-to-end RTT, whereas the Raspberry Pi–ESP32 serial communication proved substantially more reliable, with Packet Loss approaching 0% and RTT values of 61.4 ms over WiFi and 227.8 ms over mobile hotspot. WiFi consistently delivered superior performance compared to mobile hotspot across all evaluated parameters*

Key words*: mobile robot, teleoperation, IoT, Firebase, greenhouse*

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