CRANE COMPASS- REAL TIME CRANE ORIENTATION AND VISUALIZATION SYSTEM USING MAGNETOMETER

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Introduction:

The Crane-Compass is a sophisticated cyber-physical system designed to modernize small-scale crane operations through the integration of IoT connectivity and real-time magnetometric tracking. In modern industrial environments, precision and safety are paramount, yet smaller systems often suffer from positioning errors caused by sensor noise and mechanical drift. This project addresses these challenges by utilizing an HMC5883L magnetometer and an Arduino Uno to provide high-resolution orientation data, allowing the crane to determine its exact heading within a range. A standout innovation is the implementation of incremental machine learning to mitigate magnetic interference, ensuring long-term reliability through self-correcting bias algorithms. Beyond physical control, the system features a Python Flask backend that streams live telemetry to a web-based visualization dashboard, enabling centralized remote oversight. Safety is strictly enforced via automated threshold monitoring that halts the NEMA-17 stepper motor and triggers alerts if deviations exceed By bridging the gap between embedded hardware and data science, the Crane-Compass offers a scalable, data-driven prototype that is highly relevant to the evolving landscape of Industry 4.0 and autonomous material handling.

Objectives:

The goal of this work is to devise a smart crane setup with functionalities such as orientation measurement through a magnetometer, the use of machine learning for drift correction, control of the stepper and DC motor, alarm generation when threshold or limit is crossed and real-time monitoring through LCD, serial output, and web dashboard. The project envisages the system model to be in a position to not only increase accuracy but also bolster usability while at the same time add elements of automation**.**

Methodology:

Crane-Compass project is structured around a multi-layered approach that integrates hardware interfacing, signal processing, and real-time data visualization. The process begins with the physical assembly of the crane structure, incorporating a NEMA-17 stepper motor for high-precision jib rotation and dual DC motors for hoisting operations, all managed by an Arduino Uno microcontroller .The core of the system’s intelligence lies in its data acquisition phase, where an HMC5883L 3-axis magnetometer captures the Earth's magnetic field components (X,Y,Z) via the I2C protocol. To ensure accuracy, the raw data undergoes a rigorous calibration process utilizing hard-iron and soft-iron offset values stored in the EEPROM. Once calibrated, the system calculates the crane's heading using the *atan*2 trigonometric function, which is then refined through an exponential moving average filter to eliminate high-frequency signal jitter and environmental noise.A significant technical feature is the implementation of an incremental Machine Learning (ML) regression filter. This algorithm continuously compares the expected motor position with the magnetic heading to identify and correct sensor drift in real-time. This adaptive correction is crucial for maintaining precision in industrial environments where metallic structures might interfere with magnetic readings.The software architecture facilitates communication through a Python-based Flask backend. The Arduino streams structured JSON data packets over a serial connection, which the Flask server parses to populate a dynamic web dashboard. This dashboard provides users with real-time telemetry, including current angle, motor status, and safety alerts.Safety protocols are embedded directly into the control loop; a threshold monitoring algorithm serves as a digital fail-safe. If the deviation between the intended and measured heading exceeds a $\pm 5^\circ$ limit, the system automatically triggers an emergency stop, freezing all motor activity and alerting the operator via the 16x2 I2C LCD and the web interface. This comprehensive integration of mechanical engineering, embedded software, and data science ensures a robust and reliable navigation system.

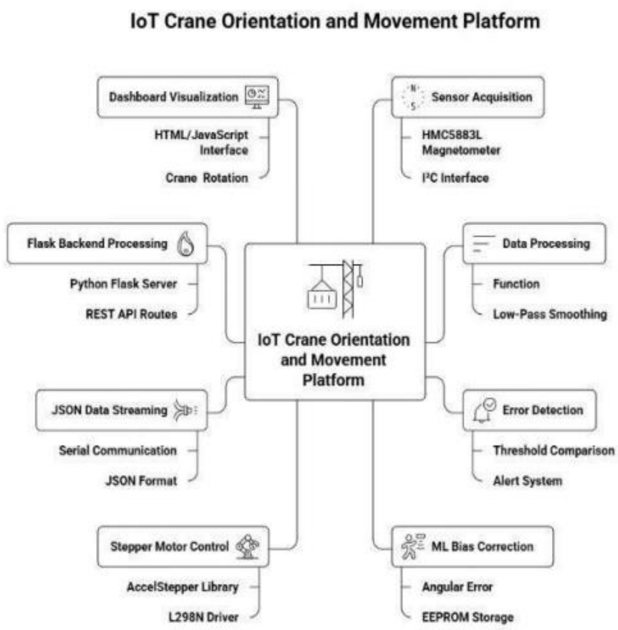

Fig 1: Methodology

Result and Conclusion:

The developed Crane Compass system successfully demonstrated real-time orientation tracking and synchronized mechanical response using an HMC5883L magnetometer and a NEMA17 stepper motor. Experimental observations confirmed that with normal operating conditions, the system maintained consistent heading acquisition and smooth stepper alignment. The ML bias correction algorithm gradually reduced angular deviation between magnetometer heading and motor position, improving stability over the non-ML baseline. The threshold-based safety algorithm also operated effectively, triggering alerts when abrupt changes exceeded thresholds of 5°, preventing overshooting of the motor and maintaining controlled operation. Data logging was enabled using the serial monitoring script that captured magnetometer readings and motor angles for performance evaluation. A joystick-controlled dual DC-motor module for moving loads along four axes-lifting, lowering, forward, and backward motion-was integrated into the system without interfering with the compass module. From these elements, a combined system was developed that demonstrated reliable orientation tracking, controlled actuation, and robust behavior during operation

Total samples: 451
CLASS METRICS
Accuracy: 93.57%
Precision: 95.94%
Recall: 93.57%
F1 Score: 94.72%

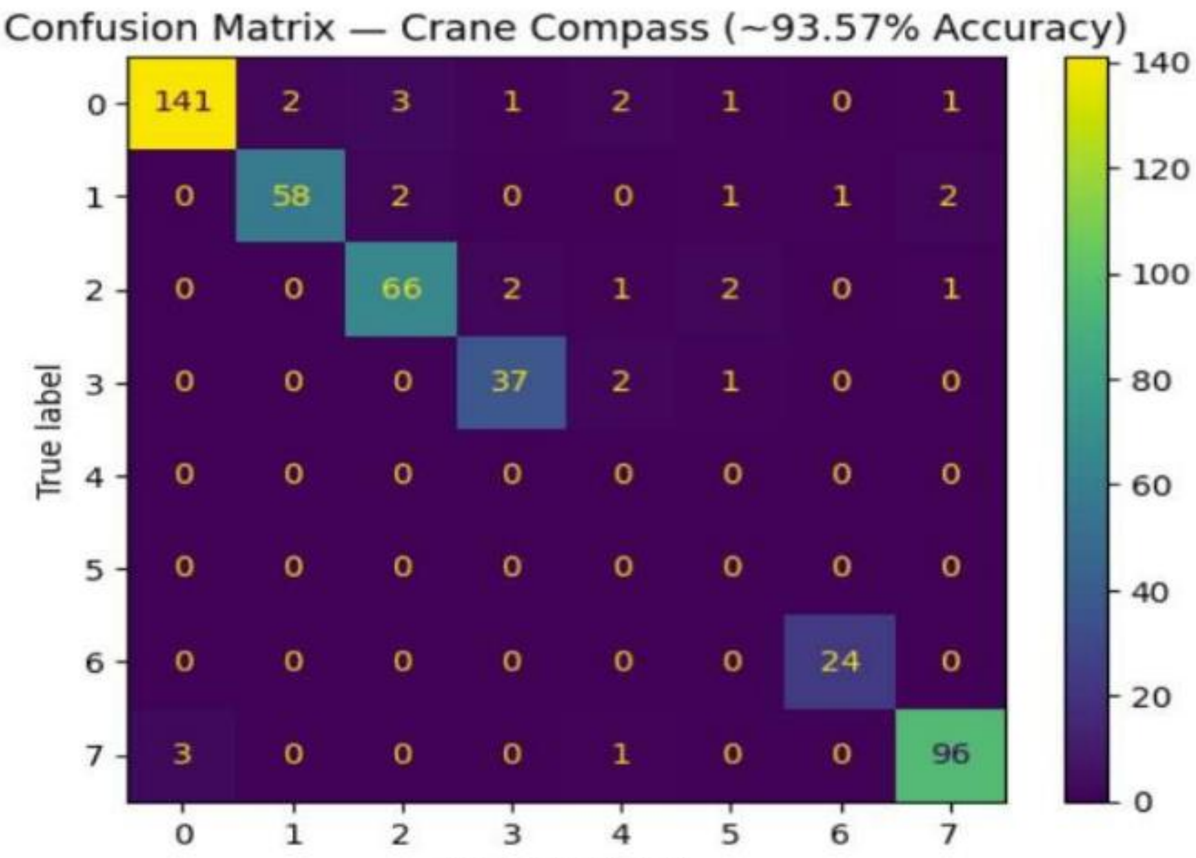

Fig: Confusion Matrix

Conclusion:

The Smart Crane Compass–Based Control and Monitoring System demonstrates a practical and modern approach to automating crane orientation by unifying sensing, processing, actuation, and IoT supervision within one integrated framework. The system uses the HMC5883L magnetometer for heading estimation, a NEMA17 stepper for jib rotation, DC motors for hoisting, and an Arduino controller for synchronized actuation. Together, these elements deliver stable, precise, and repeatable motion control while continuously tracking the crane's directional state and load-handling conditions. A major strength of the project is its staged development methodology. Each level—starting from basic sensor readings and actuator motion, progressing to digital filtering, ML-assisted bias correction, and finally remote IoT streaming—adds new capabilities without compromising earlier functionality. This incremental strategy results in improved accuracy even under magnetic noise, enhanced responsiveness of the motors, and reliable long-term heading prediction. The IoT backend built on Flask further expands the system's capabilities by offering live dashboards, data logging, remote monitoring, and operator alerts. Safety is integrated throughout the design, including anomaly detection thresholds, emergency-stop routines, and on-screen/web-based warnings to prevent unsafe operations. Overall, the project proves that traditional crane mechanisms can be modernized effectively using embedded systems, lightweight machine learning, and internet-connected monitoring. It establishes a strong foundation for future upgrades such as full PID-based closed-loop control, wireless communication modules, predictive maintenance models, and industrial-scale SCADA integration.

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Future Scope:

The future scope of this project includes:

1. Multi-Sensor Fusion and Advanced Filtering: Incorporating additional sensors like the MPU-9250 (gyroscope and accelerometer) would allow for Kalman filter integration. This would eliminate orientation drift, enhance dynamic response, and provide full three-dimensional tracking (roll, pitch, and yaw) for more complex crane geometries.
2. Enhanced Machine Learning and Cloud Analytics: The current incremental bias learner could be replaced with advanced regression or neural network models to predict systematic errors based on variables like motor current and load weight. Furthermore, streaming data to cloud platforms like AWS or Azure IoT would enable long-term trend analysis and predictive maintenance for equipment wear
3. Wireless Connectivity and Mobile Integration: Developing wireless sensor nodes using BLE or LoRa would reduce wiring complexity on the crane boom and simplify maintenance. Additionally, a dedicated mobile application for Android or iOS could provide operators with remote joystick control and real-time fault notifications directly on their devices.