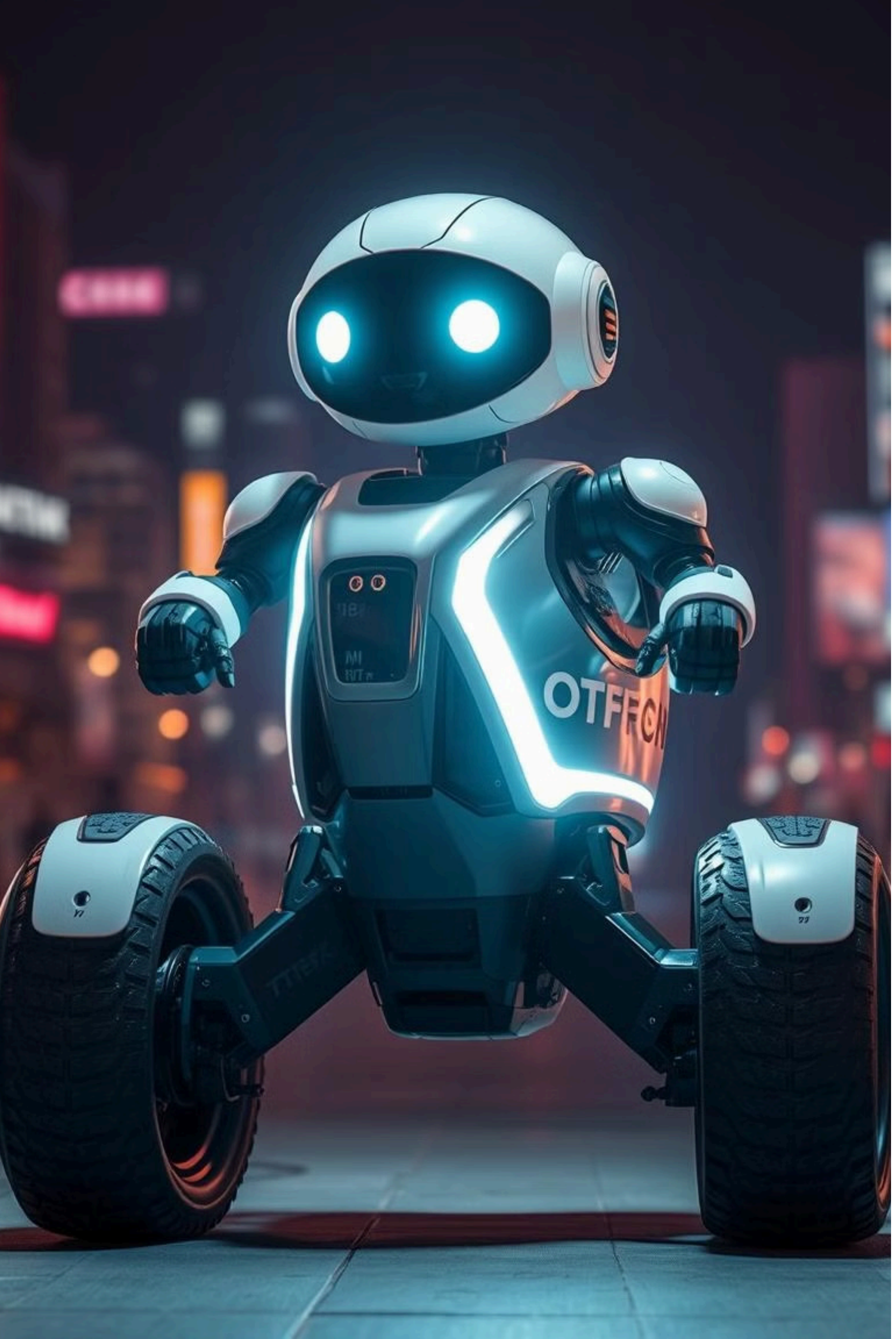

Four-Wheeled Robot for Enhanced Threat Detection

22AIE214 | 22MAT230

CB.SC.U4AIE23202

CB.SC.U4AIE23205

CB.SC.U4AIE23207

CB.SC.U4AIE23271

Introduction

- Public spaces require advanced security solutions to detect potential threats proactively.
- Traditional surveillance systems are often static and may not respond quickly to dynamic threats.
- Our project introduces a four-wheeled autonomous robot designed for real-time threat detection.
- The system integrates **ROS**, **ORB-SLAM**, and **YOLO v3** for localization, object detection, and navigation.
- By continuously monitoring its environment, the robot identifies threats, tracks their position, and alerts security personnel.
- The goal is to enhance situational awareness and improve response time in high-risk environments.

Objective

- Develop a mobile four-wheeled robotic platform for threat detection.
- Integrate real-time sensor fusion for reliable environmental perception.
- Employ deep learning methods to identify potential threats.
- Enable robust, autonomous navigation in dynamic public spaces.
- Implement continuous monitoring and alerting mechanisms for rapid threat response.

Literature Review

Title	Author & Published Year	Key Works	Limitations
Human-robot Interaction Method Combining Human Pose Estimation and Motion Intention Recognition	Yalin Cheng et.al 2021	• : The paper presents a modular framework for human-robot interaction (HRI) that utilizes RGB images for human pose estimation, reducing reliance on depth cameras. • A model is developed to predict human intentions from joint information, allowing the robot to respond appropriately to perceived threats or actions.	• The human pose estimation network is primarily effective for detecting a single person, which may limit its application in crowded environments. • The performance of the framework can be affected by the quality of the input images, such as background complexity and lighting conditions.
Recognizing Human Actions as the Evolution of Pose Estimation Maps	Mengyuan Liu, Junsong Yuan 2018	• The paper emphasizes the importance of pose estimation maps, which provide detailed information about human body movements. • The paper introduces a spatial rank pooling technique to aggregate pose estimation maps into a compact representation.	• The effectiveness of the proposed method relies heavily on the quality of the input video data. • Method may struggle to accurately capture fast or abrupt movements, which are critical for detecting sudden threatening actions.

Multi-Task Deep Learning for Real-Time 3D Human Pose Estimation and Action Recognition	Diogo C. Luvizon, David Picard, Hedi Tabia August 2021	• Unified Framework: The study introduces a deep learning model that concurrently performs 3D human pose estimation and action recognition, leveraging shared features to enhance performance in both tasks. • Real-Time Application: The model is optimized for real-time processing, making it suitable for applications such as surveillance and human-computer interaction.	• Environmental Sensitivity: The model's accuracy may be affected by varying camera angles, lighting conditions, and occlusions, which can pose challenges in diverse real-world environments. • Computational Demands**:** Achieving real-time performance requires substantial computational resources, potentially limiting deployment on devices with limited processing capabilities. • Data Dependency**:** The model's success is closely linked to the quality and diversity of the training data; inadequate representation of certain poses or actions could lead to reduced accuracy.
The Progress of Human Pose Estimation: A Survey and Taxonomy of Models Applied in 2D Human Pose Estimation	Tewodros Legesse Munea; Yalew Zelalem Jembre; Halefom Tekle Weldegebriel; Longbiao Chen; Chenxi Huang; Chenhui Yang July 2020	• Comprehensive Survey: The paper systematically reviews various models and methodologies applied to 2D human pose estimation, highlighting their evolution and performance. • Taxonomy Development: It introduces a structured taxonomy to categorize existing models, facilitating a clearer understanding of their characteristics and differences.	• Focus on 2D Estimation: The survey is limited to 2D pose estimation models and does not extensively cover 3D pose estimation techniques. • Rapid Technological Advancements: Given the fast-paced developments in this field, some recent models and approaches may not be included in the survey.

Our Solution: A Mobile, Versatile Robot Platform

- Autonomous & Remote-Controlled Operation.
- Four-Wheeled Robust Design & Multi-Sensor Integration.
- AI-Powered Threat Detection - Uses machine learning and computer vision to analyze potential threats.
- Real-Time Monitoring & Alerts – Live video streaming and automated alerts.

Key Features: Sensors, Navigation, and Communication

- Equipped with cameras for real-time threat detection.
- Ultrasonic sensors for obstacle detection.
- AI-powered object recognition for accurate threat assessment.

- Ultrasonic Sensors – Detects nearby obstacles and helps with close-range navigation.
- Simple grid-based path planning
- GPS Module – Provides outdoor positioning data for location tracking.

- Instant alerts and live data streaming to security teams.

Project Flow

1 ROS INITIALISATION

- Launch the ROS master node along with essential launch files for all system components.
- Ensure proper hardware configuration

2 CAMERA CALIBRATION AND SETUP

- Use ROS's camera calibration package
- Create nodes for each camera and launch the camera drivers

3 ORB-SLAM SETUP

- Select a Primary Camera for ORB-SLAM
- Run the ORB-SLAM ROS node configured for monocular input.

4 YOLO V3 INTEGRATION

- Integrate YOLO v3 using an existing ROS package (such as darknet_ros)
- A dedicated node subscribes to all detection topics.
- Fuses detection data from different cameras (if overlapping fields of view exist)

5 PATH PLANNING AND NAVIGATION

- Combine the relative detection from the cameras with the global pose provided by ORB-SLAM to calculate the threat's global position.
  Use the ROS Navigation Stack for path-planning.

6 THREAT VERIFICATION AND ALERT

- As the robot approaches the threat, continue monitoring with the cameras. The YOLO nodes verify the presence and details of the threat.
- Trigger an alert node that sends notifications to security personnel.

7 CONTINUOUS MONITORING

- Both the ORB-SLAM node and YOLO detection nodes run continuously, ensuring that:
- The robot's current pose is always up-to-date.
- New or moving threats are detected and tracked.

Mathematics Involved

1. **Linear Algebra & Geometry** – Used for camera calibration, coordinate transformations, and feature extraction in vision-based SLAM(Simultaneous Localization and Mapping).

2. **Probability & Machine Learning** – Supports YOLO's confidence estimates, gradient descent for training, and Bayesian filtering for localization.

3. **Optimization & Path Planning** – Enables shortest path computation (A*, Dijkstra's) and real-time obstacle avoidance using optimization techniques.

4. Kinematics & Control – Uses differential equations for robot motion modeling and PID controllers for stable navigation.

Future Development: Expanding Capabilities and Scalability

1. Future development focuses on expanding the robot's capabilities, including more advanced threat detection, improved autonomy, and enhanced communication.

2. Scalability is another key area of focus, enabling the deployment of multiple robots to cover larger areas and provide comprehensive security coverage.

3. Implementing reinforcement learning and advanced AI models can enable the robot to autonomously navigate, patrol designated areas, and prioritize potential threats without human intervention.

References

https://ieeexplore.ieee.org/document/9437772

https://ieeexplore.ieee.org/document/8578225

https://ieeexplore.ieee.org/document/9007695

https://ieeexplore.ieee.org/document/9144178