Autonomous Ground Rover For Outdoor Surface Level Trash Collection

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Contents

Introduction

Outdoor cleaning, once labor-intensive, can now be automated using an autonomous rover with advanced sensors and the A* algorithm for efficient path planning.

Literature Survey

[1] Jinjun Rao, Haoran Bian, Xiaoqiang Xu and Jinbo Chen, "***Autonomous Visual Navigation System Based on a Single Camera for Floor-Sweeping Robot*,**" *Appl. Sci.* **2023**, vol *13*(3), 1562

Advantages:

- Dynamic Local Path Planning
- Leverages advancements in CV, AI, and cloud computing

Limitations:

- Single camera
- Can clean only light garbage

Literature Survey

[2] Latifinavid, M.; Azizi, A. "***Development of a Vision-Based Unmanned Ground Vehicle for Mapping and Tennis Ball Collection: A Fuzzy Logic Approach***." *Future Internet* **2023**.

Advantages:

- Accurate navigation & spatial awareness
- Precise collection control

Limitations:

- Enhanced detection capabilities
- Improved performance and accuracy

Literature Survey

[3] Zhang, Y.; Wu, Y.; Tong, K.; Chen, H.; Yuan, Y. *"**Review of Visual Simultaneous Localization and Mapping Based on Deep Learning**."* *Remote Sens.* **2023.**

Advantages:

- Handles large-scale environments
- Real-time localization
- Enhanced mapping accuracy
- Adapts to complex lighting
- Efficient data fusion

Disadvantages:

- Computationally expensive
- Limited by real-world datasets
- Requires extensive training data
- Susceptible to noise

Literature Survey

[4] Lu Chen, Yapeng Liu, Panpan Dong, Jianwei Liang, and Aibing Wang. "***An Intelligent Navigation Control Approach for Autonomous Unmanned Vehicles via Deep Learning-Enhanced Visual SLAM Framework.***" IEEE Systems, Man and Cybernetics Society Section, 2023

Advantages:

- Deep learning + SLAM
- Improved navigation accuracy
- Robust mapping algorithm
- Real-world simulations
- Multi-sensor fusion
- Adaptive localization

Limitations:

- Scalability issues
- Slow convergence
- High computational cost
- Limited outdoor testing

Literature Survey

[5] Lei He , Baoyun Wang , Yunshan Peng, and Xiucai Zhang. “***An Unmanned Sweeper Path Planning Algorithm for Structured Roads***” IEEE Vehicular Technology Society Section, 2024

Advantages:

- Efficient path planning
- *A* algorithm + ATSP**
- Pruning optimization
- Reduced energy consumption

Limitations:

- Limited scalability
- Complex NP-hard problem
- High computational demands
- Lane redundancy issues
- Assumption-dependent efficiency

Literature Survey

[6] Yanfang Deng1,2, Taijun Li1,2, Mingshan Xie 3, and Wenhan Chen 3. "***Robot Memorial Path Planning for Smart Access of Indoor Distributed Charging Piles."*** IEEE Access, 2023

Advantages:

- Efficient path planning
- LMPP (Local Memorial Path Planning) algorithm
- Real-time path planning

Limitations:

- Limited scenario testing
- Requires communication setup
- Assumption-based model
- Fixed charging pile positions
- No outdoor application

Literature Survey

[7] Lukas Huber , Jean-Jacques Slotine , and Aude Billard. “***Avoidance of Concave Obstacles Through Rotation of Nonlinear Dynamics*****”.** IEEE Transactions On Robotics, vol. 40, 2024

Advantages:

- Handles concave obstacles
- Multi-dimensional applicability
- Maintains smooth navigation
- Real-time adaptability
- Multi-obstacle capability

Disadvantages:

- Sensitive to obstacle shape
- Computational cost for trees
- Requires well-tuned parameters

Literature Survey

[8] Bisma Amjad, Qasim Zeeshan Ahmed, Pavlos I. Lazaridis, Maryam Hafeez, Faheem A. Khan, Zaharias D. Zaharis ***.“Radio SLAM: A Review on Radio-Based Simultaneous Localization and Mapping”.*** IEEE Access, 2023

Advantages

- Robustness to lighting conditions
- Penetration Capability
- Short Range Effectiveness
- Reduced Sensitivity to Environmental Variability

Limitations

- Predefined Parameters
- Dependence on Training Data
- High Computational Requirements
- Overfitting Risks

Literature Survey

[9] Chengjun Tian, Haobo Liu, Zhe Liu, Hongyang Li, Yuyu Wang. ***"Research on Multi-Sensor Fusion SLAM Algorithm Based on Improved Gmapping".*** IEEE Access, 2023

Advantages

- Enhanced Accuracy
- Clearer Maps
- Utilization of Diverse Data

Disadvantages

- Complex Scenario Testing
- Algorithm Comparisons
- Dynamic Object Detection
- Enhanced Image Processing

Literature Survey

[10] Edwin Salcedo, Yamil Uchani, Misael Mamani, M. J. Ciudad Fernandez "***Towards Continuous Floating Invasive Plant Removal Using Unmanned Surface Vehicles and Computer Vision.***" IEEE Access, 2024

Advantages:

- Cost-effective design
- Real-time monitoring
- Computer vision integration
- Autonomous navigation
- Customizable data sets
- Collision avoidance system

Disadvantages:

- Limited by water conditions
- Needs large datasets
- Limited in real-world testing
- Computational power requirements
- Manual intervention possible

Research Gap

- **Limited Outdoor Use :** Lacks robustness for uneven outdoor terrains
- **Incorporation Challenges :** Difficult integration with low-cost platforms
- **Improved Navigation Accuracy :** Needs better accuracy for uneven terrains
- **Obstacle Avoidance Limitations :** Struggles with dynamic and concave obstacles
- **Energy Efficiency :** No focus on energy-efficient path planning

Problem Statement

To develop an autonomous rover utilizing the A* algorithm for optimal path planning and machine learning for accurate trash detection and efficient collection.

Research Objectives

- Design and fabricate the structural frame of the rover
- Assemble and test the required hardware components
- Prepare the autonomous algorithms and programs
- Test and make improvements to path planning and trash detection
- Enable the rover to operate autonomously

Existing Design

- **Obstacle Avoidance:** Basic sensors for navigation
- **Autonomous Operation:** Cleans without supervision
- **Scheduling:** Users can set cleaning times
- **Compact Design:** Accesses tight spaces easily
- **User-Friendly:** Intuitive app-based controls

Proposed Design

Image detection and processing:

- YOLO (You Only Look Once) is an object detection algorithm for real-time classification

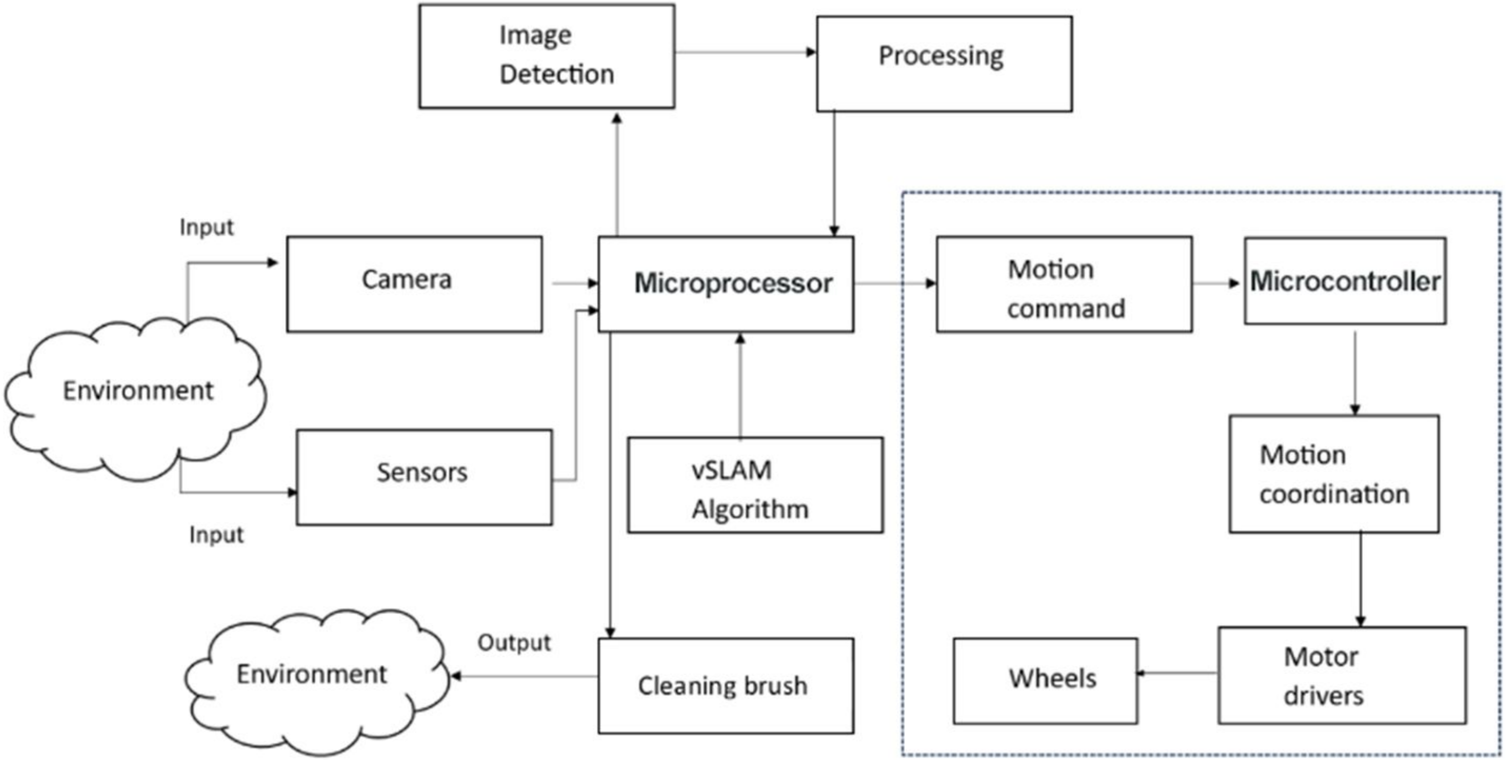
Mapping and localization:

- vSLAM algorithms are used to generate maps that facilitate rover localization

Motion of the Rover:

- The rover utilizes A* for path planning to navigate and clean

Implementation



Conclusion and Future Scope

During Phase 1 of the project, hardware components were integrated into the structural framework, achieving level 0 autonomy.

Future Scope

1. **Enhanced Autonomy**: Smarter AI for obstacle avoidance and path planning
2. **Advanced Mapping**: 3D mapping, GPS integration for larger areas
3. **Modular Upgrades**: Add-ons for specialized cleaning and waste handling
4. **Smart Waste Management**: Automatic sorting and IoT-based monitoring
5. **Energy Efficiency**: Solar charging, optimized battery use
6. **Commercial Use**: Applications in smart cities, agriculture, and industry

References

[1] R. J. Ong and K. N. F. Ku Azir, "**Low Cost Autonomous Robot Cleaner using Mapping Algorithm based on Internet of Things (IoT)**," IOP Conf. Ser.: Mater. Sci. Eng., vol. 767, p. 012071, 2020.

[2] M. Kulshreshtha, S. S. Chandra, P. Randhawa, G. Tsaramirsis, A. Khadidos, and A. O. Khadidos, "**OATCR: Outdoor Autonomous Trash-Collecting Robot Design Using YOLOv4-Tiny," Electronics**, vol. 10, no. 18, p. 2292, Sep. 2021

[3] Jinjun Rao, Haoran Bian, Xiaoqiang Xu and Jinbo Chen, "**Autonomous Visual Navigation System Based on a Single Camera for Floor-Sweeping Robot,**" *Appl. Sci.* **2023**, vol *13*(3), 1562

[4] Latifinavid, M.; Azizi, A. **Development of a Vision-Based Unmanned Ground Vehicle for Mapping and Tennis Ball Collection: A Fuzzy Logic Approach**. *Future Internet* **2023**, *15*, 84.

[5] Zhang, Y.; Wu, Y.; Tong, K.; Chen, H.; Yuan, Y. **Review of Visual Simultaneous Localization and Mapping Based on Deep Learning**. *Remote Sens.* **2023**, *15*, 2740.