UGV Backtracking Recovery With Active Visual Landmarks Navigation: Literature Review (Assignment)

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1 Introduction

Motivation for the topic of unstructured environments is multifaceted. Industries such as agriculture, mining, and military technology require advancements in autonomous systems, yet are hindered by the lack of open-source tools.

Problem Statement: Defining unstructured environments and their specific challenges will provide clarity. These environments lack predefined landmarks, pose navigation difficulties, and require robust adaptable systems.

2 Methodology

This section outlines the approach to gathering and analyzing the literature.

2.1 Selection Criteria

- Existence of ROS implementations or ground truth data.
- Inclusion of large-scale reviews or almanacs (250+ papers for aggregation).
- DARPA-like challenge-based research and industry benchmarks.
- Papers demonstrating superior benchmark performance.
- Industry standards and tools with robust GitHub presence.

2.2 Analysis Framework

The review leverages a structured "Task-Requirement-Design-Implementation-Validation" methodology.

Challenges-based research in robotics emphasizes organized progress, such as DARPA competitions, driving iterative advancements in solutions.

3 State-of-the-Art

3.1 The Critical Role of the ROS Platform

The Robot Operating System (ROS) has emerged as a cornerstone technology in the robotics field, providing an open-source framework that standardizes development and fosters collaboration across academia and industry. Its modular architecture allows researchers and developers to integrate diverse hardware and software components, enabling rapid prototyping and scalability for a wide range of applications.

One of ROS's most significant contributions is its community-driven ecosystem, where shared libraries, tools, and documentation accelerate innovation. ROS supports real-time applications, bridging the gap between laboratory research and field deployment. This feature has proven particularly valuable in unstructured environments, where dynamic conditions demand robust and flexible solutions. Moreover, the adoption of ROS by industry leaders has enhanced its relevance, making it a platform that seamlessly connects academic research with practical deployment.

In the context of this review, ROS plays a pivotal role in the development of modular designs, such as the MeROS framework. By leveraging ROS's tools for sensor integration, motion planning, and communication, MeROS exemplifies how a standardized platform can streamline the design and validation of complex robotic systems. However, despite its strengths, ROS is not without limitations. Challenges such as real-time processing constraints, hardware compatibility, and dependency management persist, leaving room for further enhancements.

3.2 Mapping Approaches

Summarize current techniques in mapping for unstructured environments.

3.3 Visual Perception and PTZ Cameras

Discuss the role of PTZ cameras in UGV platforms, emphasizing modular design and requirement-based development.

3.4 Public and Private SOTA

Contrast public SOTA with proprietary solutions. Highlight the reproducibility crisis in robotics academia due to platform-locked tools.

4 Research Gaps

4.1 Task-Requirement-Design Identification

Core research gaps

- PTZ camera integration challenges.
- Long-range navigation in unstructured environments:
  - Representation of places.
  - Route following between places with minimal memorization.
- Encapsulation of independent software-hardware modules.
- Cross-platform interfacing and requirements management.
- Calibration and processing for open-source tools.

4.2 Constraints and Challenges

- Planning and power management. Long-range navigation is limited by the energy capacity of the UGV and the efficiency of its spending.
- Environmental factors such as weather, light, and terrain complexity. This parameter has to be mentioned, to clearly denote limitations of considered conditions.
- Real-time processing requirements. The real-time processing of sensor data and decision-making are important for the robotisc, but we outline the problem in such a manner to allow for the relaxations on this requirement.
- Scalability and integration with ROS platforms.

5 Conclusion and Motivation

The proposed research aims to:

- Emphasize modular design and cross-platform usability.
- Identify critical bottlenecks halting advancements.
- Validate the feasibility of addressing these bottlenecks through:
  - Open-source calibration and integration tools.
  - Testing on Husky UGV or equivalent platforms.
  - Clear documentation and interfaces following MeROS philosophy.

6 Datasets and Resources

A few datasets can serve as a basis for this research or as a sign of missing data:

- Wild Scenes Dataset: `https://arxiv.org/pdf/2404.18477`
- Wild Places Dataset: `https://csiro-robotics.github.io/Wild-Places`
- Freiburg Forest: `https://paperswithcode.com/dataset/freiburg-forest`