# 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.

Elaborate on why open tools are pivotal for industry advancements and research progress.

**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.

Discuss what constitutes "unstructured environments" and why they are a significant research challenge.

## 2 Methodology

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

### 2.1 Specific Traits of Domain Literature

Research in unstructured UGV robotics exhibits several distinguishing traits:

- Large-scale reviews or almanacs (aggregating 250+ papers) play a critical role in providing comprehensive overviews of the field.
- The volume of publications is significantly smaller than in mainstream AI, where research output is orders of magnitude higher.
- Research initiatives, such as DARPA and MBZIRC challenges, drive progress by clustering studies around specific problems.
- Long-term research is typically conducted by well-established teams with access to substantial resources.
- The field lacks standardized benchmarks or datasets, making cross-comparisons between studies challenging.

### 2.2 Connectivity in Robotics Research

The papers in this field are well connected, and the research is often conducted within "clusters" of research groups. An example of such clustering can be seen

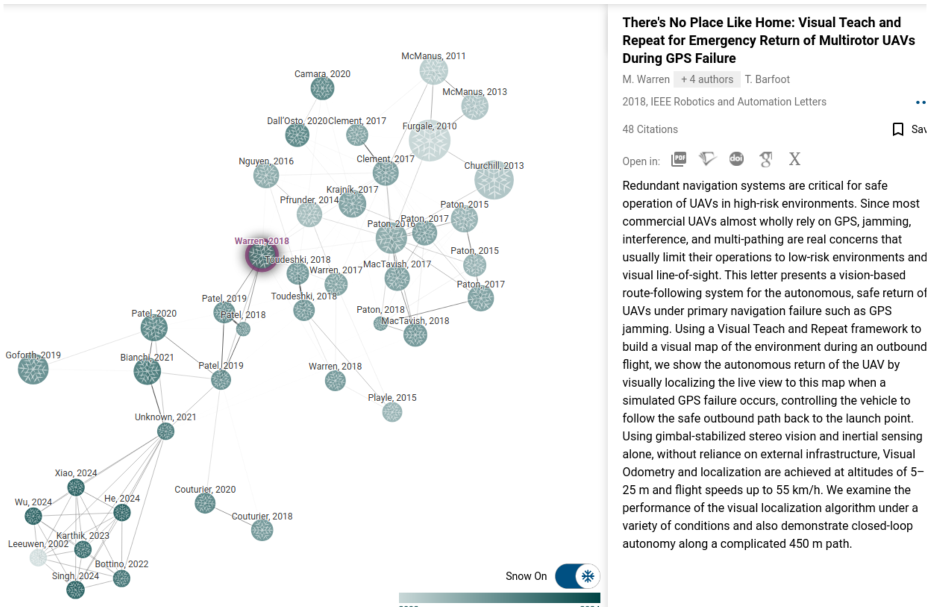


Fig. 1: Visual Teach-and-Repeat approach for emergency return of multirotor UAVs during GPS failure [**warren-ral19-no-place-like-Home**]. More information is available on Connected Papers: `https://www.connectedpapers.com/`.

in the work of Warren et al. (Figure 1), which demonstrates the modest size but tight connections of research within this domain.

Robotics research often fragments across variables such as indoor versus outdoor environments, aerial versus ground platforms, and real-time versus non-real-time systems. Addressing these distinctions narrows the scope of each research problem, creating a "pin-tip" scale for the research frontier. With a smaller research community, large-scale benchmarks or datasets are often absent.

This fragmentation explains why research frequently focuses on specific, everyday tasks that extend beyond current robotics capabilities. One example is the "returning home" problem, a fundamental yet challenging task. Relevant papers on such tasks tend to cluster around research centers, datasets, or individual experts.

Unlike mainstream AI, which experiences terminological saturation, robotics remains more fragmented. For instance, the seminal robotics paper "FastSLAM: A factored solution to the simultaneous localization and mapping problem" (2002) has accrued approximately 3,500 citations in 20 years. In contrast, the AI paper "BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding" (2018) achieved 50,000 citations in just five years.

Add reference to resourses with citation statistics.

These differences show that citation-based snowballing approaches are less effective for navigating robotics literature. Instead, comprehensive reviews, challengedriven studies, and large-scale almanacs are better suited to understanding the field.

What matters most in this field is the careful formulation of problems and the requirements they impose. These requirements drive the system design of solutions, followed by implementation and validation. Unlike AI, where isolated benchmarks play a central role, robotics focuses on real-world conditioins versatility robustness and iterative improvements.

**Here we will meticulously deconstruct the whole challange into set of requirements, investigate the available set of apporaches, tradeoffs and design the solution aspects. The CORE of literature analysis in robotics will be here. In such a manner we will ensure that we are solving the actual large-scale problem applicable beyond our setup. :**

### 2.3 Selection Criteria

The following criteria guided the selection of papers for this review:

- Preference was given to studies with implementations adaptable to our platform or those offering detailed ground truth data demonstrations.
- Industry standards and widely adopted tools, especially those wi
- Industry standards and widely adopted tools, especially those with robust GitHub repositories, community and versions updates were emphasized to ensure practical relevance and reproducibility.

### 2.4 Analysis Framework

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

Include visual diagrams or reference placeholders for MeROS-based design layers.

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

Amplify with examples of explosive technology disruptions, e.g., Kinect or ROS2.

## 3 State-of-the-Art

**Comment**: Larger piece for ROS. Other will be detailed in similar fashion + references

### 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.

Discuss strengths and limitations of existing methods.

### 3.3 Visual Perception and PTZ Cameras

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

Include examples of modular designs and calibrations.

### 3.4 Public and Private SOTA

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

Explore the coined term "Public SOTA" and its implications.

## 4 Research Gaps

### 4.1 Task-Requirement-Design Identification

Core research gaps

**We will concentrate our research efforts on them specifically:**

- 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.

Explore solutions like 360-degree cameras or alternative configurations.

### 4.2 Constraints and Challenges

Those are factors that can have decisive impact on feasibility of the work and they require our attention, but those fell out of the main focus of the research:

- 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 and design solution in such a manner to allow for the relaxations on this requirement.
- Scalability and integration with ROS platforms. As we touch lots of system aspects with limited resources, we will focus on the iterative implementations and open solutions.

Discuss relaxations on real-time requirements and focus on iterative implementations.

## 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.

Highlight the significance of open-source contributions and iterative validation in advancing the field.

## 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`

Note the gaps in available datasets and propose directions for addressing these limitations.