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Chief Editor of JAR

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Subject: Revision and resubmission of manuscript 27 (Paper ID)

Dear Academic Committee JAR2024,

Thank you for your email and the opportunity to resubmit our paper, **“Autonomous Navigation and Collision Avoidance for Mobile Robots: Classification and Review”**. We have carefully considered the reviewers’ comments while preparing our revised manuscript. Below are our responses to the reviewers' comments:

Reviewer #1:

- “... Specifically, I don’t agree that mapping should be considered part of the Data Processing subject; it deserves its own category, as does planning.“

➢ Response:

Thank you for your insightful feedback.

To address your concern, we have emphasized the importance of mapping within our classification system. While we initially integrated mapping within the Data Processing subject to highlight **its interconnectivity with other processes**, we recognize the need to clearly delineate it. However, due to the six-page limit, creating an entirely separate section for mapping was not feasible. Our approach is t**o shed light on how these layers and modules are interconnected,** assuming that readers already understand the significance of each specific module. We aim to provide a clearer vision of how sensors, hardware, and algorithms bridge between these layers, which is particularly beneficial for beginner roboticists.

Here are the modifications made to emphasize mapping:

A) We explicitly included mapping in the perception layer, as highlighted in the following structure:

This classification interconnects the layers and phases as follows:

1) Layer 1 - Perception
   a) Phase I: Environment Perception, Self Location, Data Processing, and Mapping.

B) We described how mapping is integrated with data processing in the perception layer to generate a high-level environment representation, subsequently refined in the cognition layer. This integration is detailed as follows:

The phases are not isolated but interconnected, covering the perception, cognition, and operation layers of mobile robotics. For instance, in the perception layer, mapping is integrated with data processing to generate a high-level environment representation, which is then used in the cognition layer for path planning and obstacle avoidance. This pre-map is then refined in the cognition layer to incorporate detailed terrain characteristics and navigability information. In the cognition layer, adaptive behavior is facilitated by integrating a Graph Search Algorithm with a Collision Avoidance System (CAS).

C) We specified the use of mapping algorithms such as occupancy grid mapping, SLAM, and topological mapping to create initial pre-maps, emphasizing their critical role in navigation:

sensors to collect data, which is then processed to create an initial pre-map. Mapping algorithms like occupancy grid mapping [12], SLAM [2], and topological mapping generate this high-level representation of the environment. The pre-map distinguishes navigable and non-navigable areas and, plays a crucial role in subsequent stages, enabling the robot to determine its current location and plan a path to reach its destination.

D) We detailed the refinement process of these pre-maps in the cognition layer to ensure accuracy and navigability, using techniques like surfel-based mapping, Delaunay triangulation, and visibility constraints:

B. Phase IIA - Path Planning: Graph Construction

Once the perception processing unit in the perception layer extracts meaningful data and creates an initial pre-map using sensor data, the cognition layer refines it. Techniques like surfel-based mapping [30], Delaunay triangulation, and visibility constraints refine the map into a dense 3D representation [37], ensuring accuracy and navigability. This detailed mapping allows the cognition layer to plan precise paths. Table III presents usual map-building techniques for autonomous navigation."

We believe these revisions better highlight the role and importance of mapping within the framework of autonomous navigation.

- "Additionally, common filters based on Bayesian estimation or Gaussian processes are not included. Looking ahead, subjects like semantic information, which are fundamental for robots operating in dynamic environments, are also missing."

➢ Response:

Thank you for this valuable observation.

We have addressed this by incorporating references to Gaussian-based and Bayesian-based filters in our revised manuscript:

TABLE II
PHASE I - COMMON FILTERS.

Filters	Reference
Multi Sensor Fusion based Filters	
Kalman Filter	[16], [23]
Extended Kalman Filter (EKF)	[4], [29]
Vision System Filters	
High Dynamic Range (HDR) Algorithms	[33]
Gaussian-based filters	[9], [34]
Bayesian-based filters	[22], [28]

We have also briefly described their importance and role in data processing and localization of robots. Furthermore, we included other important techniques such as LiDAR particle filters, Iterative Closest Point (ICP), and Normal Distributions Transform (NDT) scan matching:

tion that established tools such as YOLO and OpenCV are widely used for detection and localization in the robotics Perception layer [35]. Visual SLAM algorithms [36], [37] and localization methods like Iterative Closest Point (ICP) [5] and Normal Distributions Transform (NDT) [35] scan matching are also crucial in this layer. Segmentation techniques, utilizing Gaussian-based models [34], further, enhance localization and visual navigation by accurately classifying navigable paths and reducing spatial requirements for map storage.

Additionally, we acknowledged the importance of segmented maps, which were previously cited in a very discrete manner (on Table III below). To address this, we have now explicitly referenced segmentation along the text, as we did with the importance of particle filter algorithms (ICP-NDT). This makes their relevance clearer:

TABLE III
PHASE IIA PATH PLANNING: GRAPH CONSTRUCTION

Method	**Reference**
Graph Search Maps	
Voronoi Diagram	[38], [39]
Exact Cell Decomposition	[9], [39]
Height Segmented Map	[40]
Surfel-Based Map	[30]
Approximate Cell Decompositon	[13], [14], [17], [23], [39]
Lattice Graph	[41]–[44]
Potential Field Maps	
Extended Potential Field Approach	[39], [45], [46]
Others Methods of Map Building	
Genetic Algorithm (GA)	[16], [39]
CNN Feature Map	[47]
Spatio-Temporal Voxel Layer (STVL)	[4]
Dense 3D Mapping	[5], [6], [37]

We believe these additions address your concerns and improve the comprehensiveness of our manuscript.

- "Personally, I find the standard classification of SENSORS-PERCEPTION-DECISION more comfortable. However, if the authors can justify their choices, the paper could generate an interesting discussion at the conference."

  Thank you for your insightful comment. Our approach deviates from the traditional SENSORS-PERCEPTION-DECISION classification, which could lead to a redundant emphasis on sensors and perception. Instead, we adopted a **classification inspired by the "Introduction to Autonomous Mobile Robots" by Siegwart**, Nourbakhsh, and Scaramuzza, specifically the "Reference control scheme for mobile robot systems" from page 10. This model effectively illustrates the interconnections between modules and layers, which is crucial for understanding modern frameworks such as ROS2.

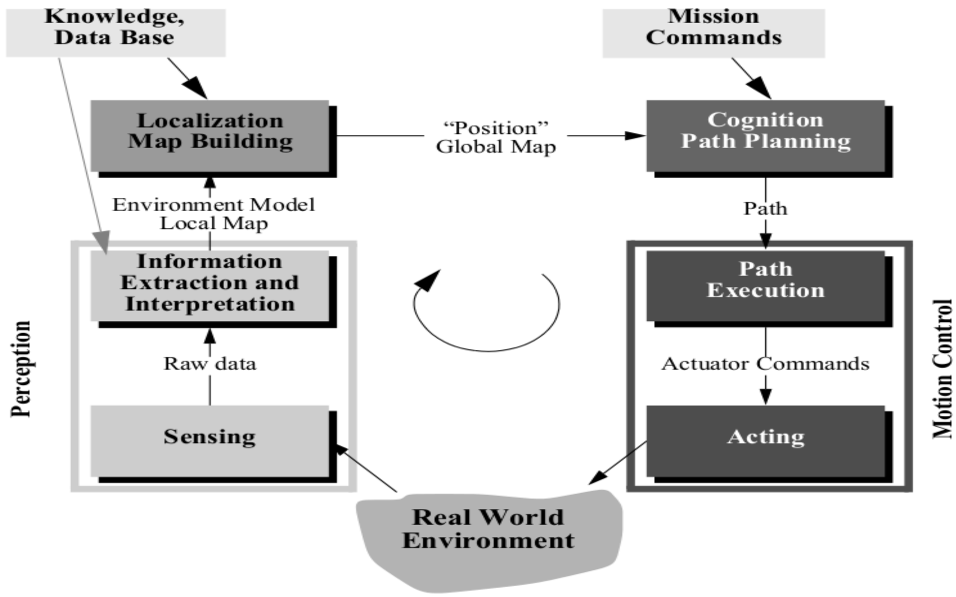

Figure 1.15
Reference control scheme for mobile robot systems used throughout this book.

Our goal was to highlight how these layers and modules interconnect, providing a comprehensive view of the system's integration rather than focusing solely on the importance of each module in isolation. We aim to shed light on how algorithms bridge these layers, **analogous to the Sense-Plan-Act principle widely used in autonomous driving and ADAS systems.** This approach not only aligns with the industry standards but also enhances the reader's understanding of the system's holistic operation.

We believe this perspective offers valuable insights, particularly for those new to the field, by clarifying how different components interact within the broader context of autonomous mobile robots.

- In Table 1, please replace "ltimeter" with "altimeter" and "Wirelles" with "Wireless.
  - Response:

    Thanks for the observation, we have fixed the typos.

Reviewer #2:

- *"I felt that the paper is quite short for all the information that it provides, only four pages with so many topics and different research lines that in most cases merely appear in a Table."*

- Response: Thank you for your observation. We agree that the paper's length limits our ability to provide a detailed description of each algorithm, technique, and technology. The vast number of specialized and customized methods in robotics necessitates a concise presentation. Our main goal is to motivate researchers to delve into the valuable references provided in the tables. This approach is **inspired by the "[11] L. Chen et al. (2022)**" article, which effectively surveyed autonomous vehicles. Similarly, our work aims to guide readers towards in-depth studies of various methods applied to mobile robots.

  This study applied a systematic literature review approach to summarize the existing classifications and technologies in the field of autonomous navigation. In parallel with the analytical rigor demonstrated by [11] in the autonomous vehicle domain. We aim to systematically identify and categorize significant contributions across the spectrum of autonomous mobile robots.

- *"In my opinion, it is an interesting paper that could be improved, for instance, with the addition of a basic application example."*

- *Response: We appreciate your positive feedback and suggestion. W**e agree that including a basic application example would enhance the paper.** Unfortunately, due to page limitations, we couldn't integrate this in the current submission. However, **we plan to include a comprehensive example in a future paper,** demonstrating the integration of all modules from this framework in a real robot experiment. This will be accompanied by a GitHub repository to facilitate academic and practical learning for our readers.*

- *"Typos:*
  Page1.
  Sect I " … than can seamlessly BE INTEGRATED across.. "
  Sect II. "…the the analytical rigor …."
  " The objective WERE to …""

- *Response: Thanks for the observation, we have fixed the typos.*

Sincerely,

Marcus Vinícius Leal de Carvalho,
Roberto Simoni,
Leopoldo Rideki Yoshioka.