A Comprehensive Overview of AI and Visual Data Applications in Mobile Robotics

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ABSTRACT

Mobile robots are increasingly being suggested as solutions to various problems on their own, thanks to the significant progress in the field of mobile robotics in recent years. In recent years, advancements in computer vision hardware and algorithms have made visual sensors an integral part of mobile robots operations. It is worth noting that mobile robots has made great strides in using AI technologies to address a wide range of issues, with photos serving as the primary or secondary source of data, or in conjunction with other sensors like lasers or GPS. The scientific community is closely watching efforts to enhance the autonomy of mobile robots. There has been a wide range of methods developed as a result of the large number of planned works in recent years. Any mobile robot worth its salt needs to be able to map its surroundings, pinpoint its exact location inside the model (localization), and navigate itself from one spot to another. Keeping this in mind, the purpose of this review is to examine these issues, the ways in which academics have used AI tools and visual information to tackle them, and the ways in which these techniques have developed over the past decade. There are a lot of studies in the connected literature, and the topic is open at the moment. Consequently, it could be worthwhile to assess where things stand with the subject at the moment. Information retrieval from scenes, mapping, localization, and exploration are only a few of the mobile robotics jobs that have benefited greatly from AI, as this review has shown. Still, it's worthwhile to keep digging into this area of study in the hopes of uncovering more comprehensive answers to the navigation challenge, allowing mobile robots more independence in complicated, diverse, and expansive settings.

Introduction

Mobile robots have seen a meteoric rise in usage in recent years. These days, you can find them in all sorts of places, from homes to schools to hospitals, and they have a broad variety of uses. With regard to mobile autonomous robots, it is essential that they can do their intended mission while navigating an environment that is typically a priori unknown. Consequently, the robot has to be able to construct an environment model, use this model to estimate its present location and orientation inside the environment, and navigate to the target points [1-9]. Traditional challenges in mobile robotics include mapping, positioning, and navigating. These issues have garnered a lot of attention and are still a hotspot for researchers since finding solid solutions to them is crucial for making mobile robots more autonomous and finding new uses for them.

Giving the robot accurate environmental data is essential for it to carry out the mobile robotics duties. Robots can gather this kind of data because to the sensors they're outfitted with. After then, the robots must interpret the environmental data and turn it into information that they can utilize to do their jobs. Metric and topo-logical maps are the two most prominent frameworks mentioned in the relevant literature when discussing the mapping problem. Metric maps, on the one hand, are very accurate geometric representations of the surrounding landscape. In contrast, topological maps usually result in a graph representation, where the environment is depicted as a network of locations and the connections between them are represented by links. Regarding the localization challenge, it utilizes an environment model to attempt to estimate the robot's present position and orientation. The localization job cannot be executed without first modeling the environment. Therefore, this is how the robot does the mapping work; once the map is ready, it can then do the localization. However, a combination of the two tasks that may be created simultaneously has also been investigated in the relevant literature. The idea behind SLAM is to represent the world around the robot while it moves through it and estimate its location and orientation all at the same time.

In addition to mapping and localization, the mobile robotics challenges encompass a variety of additional activities. Among the tasks involved in navigation is the capacity of the robot to ascertain its location on the map, devise a through which the robot must go in order to reach a predetermined location, all the while dodging ever-changing obstacles. Therefore, the robot has to be able to read the environment's maps and understand the agents inside. As a robot navigates its surroundings, its primary goal is to avoid obstacles like walls, objects, and people, as well as harmful environments like those with radioactive materials or extremely high temperatures. showcase a special issue addressing the state of the art in mobile robot navigation frameworks and a range of methods pertaining to this assignment [10-28].

Combining mapping with navigation is something that the mobile robotics sector studies, which is similar to the idea of SLAM. Exploration describes this mix. Navigating a robot so that it covers the surroundings with its sensors is the main component of the exploration assignment. Several issues, including surface inspection mine sweeping and surveillance, can be addressed with exploration methods. In this study, we zero in on camera usage as one of the sensors offered to tackle the mobile robotics jobs. These types of sensors have found extensive usage in various applications. This manner, we may showcase a special issue highlighting the potential of vision systems, with an emphasis on their many configurations and innovative uses in domains such as object detection, scene reconstruction, and mapping for mobile robot navigation. It is possible that the data acquired by these sensors will be sufficient to address the majority of issues of mobile robots. Additionally, the senators show a "quantity of information - cost" relation that is really excellent. One drawback of these methods is how sensitive they are to changes in illumination. For instance, in some underground settings, the only way to see is through light sources placed on the robot or strategically placed around the room. This means that shadows can lead to errors [28-44].

Various configurations have been suggested, each based on the number of cameras and the field of vision. Certain writers, like, have made use of singular arrangements. While some advocated for monocular or even trinocular cameras, others put out alternative designs, such as. Multiple pictures are needed to get the whole picture of the environment. Omnidirectional cameras are a great substitute for this kind of camera. With a 360-degree field of vision, they can supply a great deal of data. in their immediate vicinity, and its price is quite modest when compared to other types of sensors. Additionally, there are additional benefits to using omnidirectional vision systems. You can estimate the robot's location and orientation using the picture characteristics, which are also more stable (since they remain for a longer period of time while the robot travels). Multiple writers have successfully utilized omni-directional cameras for mapping and localization purposes.

Many methods for processing data collected by the senses have evolved with this goal in mind. Consequently, several approaches including sensory data and processing methods have been put forward. The capacity of various AI-based tools and methodologies to address a wide range of issues through in-depth data treatment has also been demonstrated in recent years. It is worthwhile to explore the primary uses of these approaches to address mapping and localization problems, as their use has grown popular among mobile robotics works. One branch of artificial intelligence is known as machine learning (ML), and its algorithms make an effort to get better on their own [45–66]. In particular, these algorithms try to make predictions or judgments without explicit programming by constructing a mathematical model from sample data. In recent years, ML has garnered a lot of attention because to its ability to properly handle a wide range of complicated issues. There is a wide variety of machine learning algorithms available, each tailored to a certain issue type, data type input, and data type output. In contrast, supervised learning techniques include making a mathematical model out of a dataset that includes both the inputs and the outputs that are sought. In order to learn how to anticipate outcomes from fresh inputs, these algorithms tackle iterative optimization of an objective function. In contrast, unsupervised learning algorithms rely solely on input data. In the training data, these algorithms look for patterns like clustering or grouping.

Many recent machine learning efforts have shifted their focus to deep learning. In the same way that ML uses sample data to construct mathematical models, deep learning algorithms use an artificial neural network design with numerous hidden layers to make predictions and judgments without being specifically trained to do so. The goal of these methods is to build high-level data models automatically by combining a starting data matrix with structures that enable various, iterative, linear, and non-linear transformations. Some of the many recent applications of these systems include computer vision, bioinformatics, machine translation, social network filtering, speech recognition, natural language processing, and many more. The results it has produced are on par with, and often even better than, those of human experts [67–88].

Recent years have seen tremendous development in computer vision and mobile robots. Having said that, there are still a few things that want fixing to make mobile robots more capable of moving and doing duties independently in complicated environments, as they would in actual operation, by making them more robustly clad. The ever-increasing storage and processing power of computers has also contributed to the widespread use of various AI techniques. Accordingly, it is instructive to be aware of how AI has impacted computer vision and mobile robots, as well as the research gaps, possibilities, and solutions that are advancing these areas.

In mobile robots, a few scholars have offered summaries of relevant literature. formulates a survey into the approaches employed in distributed mobile robots to resolve challenges. present an overview of SLAM techniques that use visual data. pay attention to methods that address the topological mapping issue. In addition, we will show you the cutting edge of localization methods as they pertain to autonomous vehicles. Finally, revise the existing literature on omnidirectional vision mapping and localization methods. In light of these earlier assessments and the rapid advancement of AI methods and their applications in mobile robots, our current effort centers on these methods. We cover the most important artificial intelligence (AI) tools for mobile robots, how to utilize them to solve issues in mobile robotics, and how to extract useful information from scenarios [89-102].

In conclusion, this study aims to showcase the most pertinent works carried out in the domain of artificial intelligence (AI) mapping, localization, navigation, simultaneous localization and mapping (SLAM), and exploration, with a focus on advancements grounded on visual information. What follows is the outline for the rest of the paper. First, the primary artificial intelligence technologies utilized in robotics are introduced in section 2. The primary approaches of describing the data are then laid out in section 3. Then, in section 4, we see the many AI methods that have been suggested for using visual data to tackle mobile robotics problems. Section 5 concludes with a review of the current methods.

Software for Artificial Intelligence

This section provides an overview of artificial intelligence (AI) and the ways in which this science has been widely used in robotics in recent years. The most relevant methods are also detailed. Several robotics-related uses are defined in Section 2.1; several applications that enhance mobile robot autonomy are detailed in Section 2.2; and the challenges of mapping and localization, as well as the AI techniques employed to solve them.

"a field of study that seeks to explain and emu-late intelligent behavior in terms of computational process" is what definitional AI says. When applied specifically to robotics, artificial intelligence (AI) may be defined as a body of knowledge that, when applied to computer programming, yields solutions to problems whose complexity necessitates an elevated level of intellect. Many historians believe that the genius scientist Alan Turing developed AI when he was attempting to decipher the 'Enigma' code, which the Germans used to transmit secret communications during World War II. The Bombe machine, developed by Alan Turing and colleagues, was instrumental in deciphering the Enigma signals. The Enigma and Bombe machines are both thought to have laid the groundwork for AI.

Many fields have made extensive use of artificial intelligence. We may classify them into two groups based on the modification kind. To start with, there's physical manipulation, which encompasses domains like control systems, robotics, and computer vision. To identify or describe anomalies in digital images, for instance, have employed computer vision in conjunction with AI in macrography with great success. As a result, radiologists are better able to spot abnormalities, which in turn leads to a significant decrease in mammography interpretation mistakes. We have another example of computer vision and AI in the form of a proposal for a system that uses genetic algorithms, fuzzy logic, and artificial neural networks to recognize hand gestures during human-computer interaction. Concerning the use of AI to robotics, suggest a neural network to optimize the routes and times of mobile robots. Distances to obstacles relative to robot position and target angle are the inputs to the suggested neural controller. The neural network calculates the steering angle as its output. suggest a backpropagation technique for network training in the healthcare industry. The purpose of this robotic system is to aid surgeons by providing them with data that can be assimilated by the system, diagnostic images, and a variety of on-field sensors, all under the supervision of an intelligent high-level controller (HLC). Finally, think of a new way to optimize and model control systems for tuning an engine's steady-state and transient performance while it's idling. When it comes to electric control, the best setting is automatically obtained by applying a genetic algorithm and particle swarm optimization. provide a comparison of four AI-based speed controller design strategies; two of these strategies rely on tuning traditional PI (Proportional-Integral) controllers, one uses fuzzy logic, and the other is based on hybrid fuzzy sliding mode control theory [103-114]. Fields like Pattern Recognition, Automatic Learning, Neural Networks, Data Mining, and Natural Language Processing fall within this discipline of cognitive science. They are also the subject of a large body of literature. Give data mining jobs that make use of decision-tree discovery as examples.

Uses of AI

Some definitions and examples of their usage in different domains were provided in subsection 2.1. Recent years have seen significant advancements in artificial intelligence (AI) and its primary applications, many of which are directly or indirectly linked to mobile robots.

Automated Driving Directions

A vehicle may do its own route planning and execution with the help of self-driving navigation systems. The information gathered from the vehicle's sensors and, on occasion, its remote navigation aids are used to accomplish this duty. Not only does this function often in vehicles like automobiles and lorries, but it is also used by many types of ground, underwater, and aerial robots. The goal of creating a fully autonomous car, which would primarily serve to lessen traffic accidents caused by humans, has boosted interest in such applications in recent years. A mobile platform with a suite of sensors is the basic building block of such systems. The information about the surroundings is provided by the data gathered by the sensors. In order to navigate the surroundings with little human intervention, AI systems can digest this data and tackle the path-planning problem. Along with move-on-route, obstacle recognition and avoidance, and leader/follower capabilities, autonomous navigation also considers these tasks [114–124].

There has been a substantial amount of literature published on the topic of applying AI to this domain in the last several years. In their 2017 publication, Li et al. present a smart microvehicle navigation system that is completely autonomous. The system includes a magnetic field generator, an artificial intelligence planner, and a microscope-coupled chargecoupled device camera. The three functional modules that make up the AI planner are as follows: a computer vision module that detects obstacles in the microvehicle's environment and tracks it; a motion planner that finds the best path between the starting point and the destination, avoiding obstacles; and a magnetic motion controller that controls the microvehicle's movement along a predesigned path. put forward strategies for autonomous UAV route planning and collision detection that make use of evolutionary algorithms and artificial neural networks. fill out using artificial intelligence to protect the wireless communications of connected vehicles, which allows for the transmission of safety signals to help self-driving cars avoid collisions. The artificial intelligence system improves its capacity to detect and identify its environment through learning. In their review of the current status of self-driving car research, Badue et al. (2019) look at publications covering the topic from the beginning of the Defense Advanced Research Projects Agency (DARPA) challenges. The perception and decision-making systems that rely on AI-based technologies are the main subjects of this survey.

Identifying and Recognizing Faces

Identifying faces in photographs is the primary goal of face detection, the first stage of face recognition. Robotics issues like home service robots and surveillance have benefited greatly from these kinds of jobs. The two-step process for solving the face detection problem is outlined by:

Detecting the Presence or Absence of a Face in a Picture.

Find the Face's Location if it Appears in the Picture.

There are a lot of books and articles about this topic in the linked literature. provide a face detector that uses a Support Vector Machine (SVM) to ascertain if an observation window contains a face by running the window at all potential locations. suggest using Haar feature-based cascade classifiers to develop face recognition and Local Binary Patterns (LBP) to recognize the face's ROI (Region Of Interest) inside the picture. However, the introduction of a real-time face detector—capable of accurately detecting faces in real-time—strikes a revolutionary chord in this endeavor. Three main contributions form the basis of this study. A novel picture representation that enables fast calculations is the first. The second contribution is an effective and straightforward classifier that uses the AdaBoost learning technique to narrow down a huge set of potential visual characteristics to a manageable amount. A third contribution is a cascade-based approach to classifier combination, which allows for faster rejection of background areas and increased computational investment in potential face-like regions.

It is usual practice to suggest face detection frameworks for use in smartphone cameras, such as explain, in order to recognize several faces. Facial recognition is now standard in almost every database and social media platform. Social media platforms like Facebook, Google, and others are starting to use facial detection in user-uploaded photos. Secondly, a face recognition system takes a user-supplied photo of their face and compares it to a database of previously-identified people in order to determine which of many possible identities is most closely associated with that user. The problem of automatically processing digital images has piqued a lot of attention since it might have many potential uses.

Object Identification and Classification

These activities have been crucial in robotics for creating environment-based object models and manipulating things. Classifying an individual object (such a cup of tea) is what object categorization is all about, whereas object recognition is all about identifying instances of objects. In order to train a Convolutional Neural Network (CNN) to recognize and classify common items in an autonomous vehicle environment, such as other automobiles, bicycles, pedestrians, and trucks, one may, for example, suggest an object classification approach that uses RGB-D data. deploy a convolutional neural network (CNN) for the purpose of traffic sign detection and classification. In addition, you can find a number of publications that employ this program to do a pose estimate on the identified items. classify objects in multi-view photos and provide a location estimate using a convolutional neural network (CNN). built a full-stack Mask-CNN model that prioritizes deep convolutional descriptors for enhanced object identification accuracy. We offer a convolutional hypercube pyramid (HP-CNN)-based multi-scale feature representation for viewpoint-invariant semantic object and scene classification.

The Manipulation of Objects

A similar job to motion planning is object manipulation or manipulation planning, which focuses on the items to be manipulated rather than the robot's movement. Moving and reorienting an item (or group of objects) while avoiding obstacles and collisions is the main objective of this assignment.

In recent decades, there has been a surge in interest in this application as a potential replacement for human workers in demanding or hazardous activities, particularly in industrial, healthcare, and household settings (Smith et al., 2012).

Conclusion

There are a lot of articles in the bibliography that discuss manipulations and planning and are supported by AI technologies. One example is the robot system introduced by Boularias et al. (2015) that uses depth images to grab things in cluttered environments. The robot accomplishes this by solving a reinforcement learning-based decision-making problem, which essentially amounts to trial-and-error learning how to manage the objects. Y. Using two convolutional neural networks (CNNs), Yang et al. (2015) present a system that can learn manipulation actions from online videos. One CNN can categorize the type of hand grip, while the other can recognize objects. To address the challenge of controlling deformable objects, Matas et al. (2018) provide a blend of cutting-edge deep reinforcement learning methods.

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