A Literature Survey on

Cleaning Robots Navigation Techniques

Chuqiao Shi(20444076), Zian Zhou(20454351) - August 10, 2015

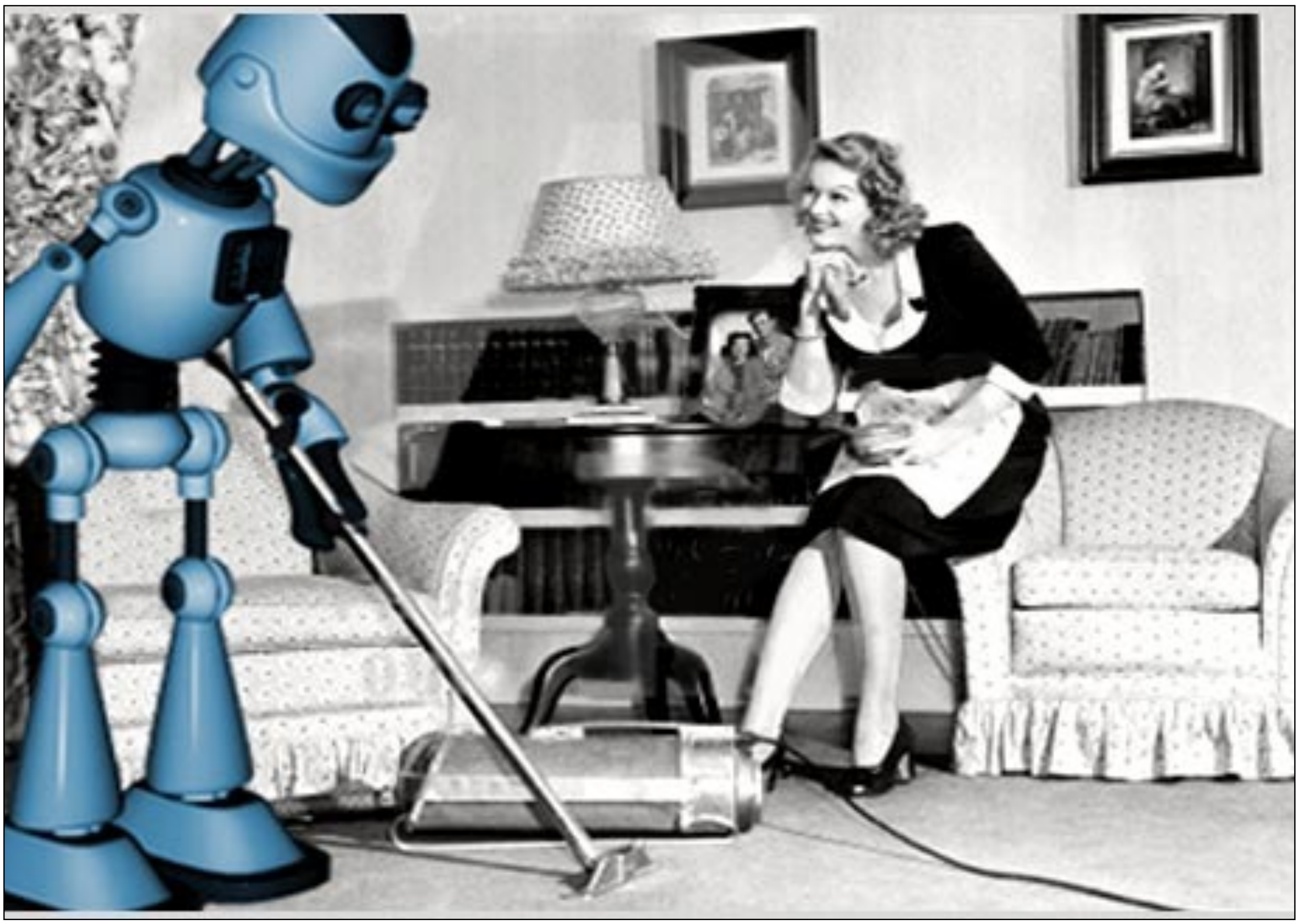

Table of contents

1 Introduction

The evolution of robotics and their application in diverse areas is becoming widespread nowadays. The uniformity of design plus the level of technology allows building robots with different features and suitable for a variety of tasks. Modern robots are utilized for replacing people in areas of human activity, like vacuum robots, firefighter robots and even military robots. Each kind of robots needs a way to navigate a necessary route in the area. Before robots are usually navigated by the human with the help of control units, but in past few years, there is a trend of robotic self-routing planning. People want robots to perform things without human interaction.

A primary issue of vacuum robotics is making a robot find efficient paths and navigate through the entire place without stuck on its way. This issue can be classified as a navigation and route planning problem. When planning a route, a robot faces plenty of issues that need to be managed to ensure effective navigation such as bypassing the barriers and sensing obstacles in the nearby environment. It is also critical for a vacuum robot to return to the charging base or perform a suitable action for an emergency like brush stuck, crashes or battery exhaustion. Furthermore, when using multiple vacuum robots together, each one should adapt to the environment or even build up to a same goal by cooperating with each other. It is crucial for each robot experiences a process of learning and adaptation to the dynamic context. Although, there is no one comprehensive answer for efficient robotic route planning, there are some algorithms can be utilized for this problem. This literature survey will discuss two major techniques used in cleaning robots route planning - **obstacle sensing** and **simultaneous localization and mapping (SLAM)**.

2 Navigation Techniques Survey

The two major navigation techniques used by cleaning robots are **obstacle sensing** and **simultaneous localization and mapping (SLAM)**. Robots using only obstacle sensing technique take random walk and change directions randomly when obstacles are detected on the way, while robots with SLAM algorithm generates a map of the area and therefore have clear paths to follow when cleaning.

2.1 Obstacle sensing

As the fundamental technology for mobile robots, obstacle sensing is widely used for autonomous cleaning robots navigation. A robot with obstacle sensing usually has sensors attached to its front bumper and two sides. It senses obstacles through collisions, changes direction upon collisions and eventually covers the whole area. Because robot with only obstacle sensing is not able to learn an efficient path, it's basic strategy is random navigation. The robot follows random walk using some predefined behaviour patterns: random walk, spiral, wall follow, and "S" shape pathway. A obstacle sensing robot usually has one or more of these predefined movement patterns to achieve efficient navigation and sufficient coverage.

2.2 Simultaneous localization and mapping (SLAM)

The simultaneous localization and mapping (SLAM) algorithm is for constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it. Cleaning robots using this algorithm usually have a laser scanner, which can scan in a full 360 degree circle to map the room for accurate navigation. With the mapping and the localization ability, the robot cleans the room by following the 'S' shape pathway and avoids collisions with objects. The short-range IR sensors on the sides of the robot also allow it to accurately follow walls.

2.3 Navigation Techniques Evaluation

2.3.1 Navigation Efficiency

A cleaning robot should find an efficient path to navigate through the room while minimizing collisions with objects. The mitigation of the effects from the robot impacting or colliding with objects is also closely related to users' wish regarding preservation of potentially fragile objects [4].

An obstacle sensing robot takes random walk and is therefore not able to navigate through the room as efficient as a SLAM-based robot. It also relies on collisions to detect obstacles, so it is not able to control its speed before colliding with an object. A SLAM-based robot, however, has a dense map of obstacles in the room so it is able to slow down when arriving near an obstacle. This is also reflected in the experiments conducted in research [4].

2.3.2 Cleaning Coverage

A cleaning robot should not only have efficient navigation algorithm, but should also effectively cover the area of importance. Because an obstacle sensing robot navigates based on collisions and follows random walk, it tends to miss places along the way. Although it can achieve a robust coverage eventually, it usually takes a long time.

In comparison, SLAM-based cleaning robot achieves larger coverage in shorter time since it has mapping of the room. It is also able to return to its base station faster after the coverage reaches a steady state. However, localization-less robots like obstacle sensing robots do not have a robust way to compute the achieved coverage and therefore often does not return to its station until an extended period of time.

2.3.3 Energy Consumption

Besides navigation and cleaning efficiency, low-power and energy consumption is another important criteria for a cleaning robot. The energy consumption for a cleaning robot are mainly energy required for moving and cleaning. With the same cleaning system, the SLAM-based robot that has a more efficient navigation system should consume less power compared to the obstacle sensing robot.

But the laser scanning of the SLAM-based robot adds additional power consumption, which increase the it's total energy cost. However, the additional cost of the SLAM laser scanner represents only a small part of the total energy consumption. The robot benefits from the mapping generated by laser scanning, accelerates in navigation, and turns out saves energy during the overall process.

Therefore, SLAM-based robots have lower power consumption than obstacle sensing robots; with the same amount of energy it provides larger coverage.

3 Analysis

Currently obstacle sensing using infrared(IR) sensors is the fundamental navigation technology used on cleaning robots in the market. However, the use of laser scanner have made the simultaneous localization and mapping (SLAM) affordable for the mass market. There are several autonomous robotic vacuum cleaners available on the market that has intelligent navigation system. Two most widely known brands are Roomba and Neato; both of them produce wide range of models with different features.

iRobot Roomba uses obstacle sensing technique and is a random-walking robot. Roomba has IR sensors on the front bumper to detect obstacles through collisions and has sensors on two sides to sense walls. It takes random movements but it has predefined routing patterns including random walk, spiral and wall follow. No obvious claim can be made regarding the better performance of Roomba robot when using the obstacle sensing routing technology. Roomba robot relies primarily on the proximity sensors for obstacle avoidance, so it maintains the original speed instead of reduces its speed when approaching an obstacle and senses through collisions. The resulting routes Roomba takes are random and less logical comparing to localization-enabled robots.

In comparison, Neato uses the SLAM algorithm and navigates through area more efficiently. It has a laser scanner to scan the room to build a map and simultaneously locate itself in the area. It follows the "S" shape pattern when cleaning, and the simultaneous localization and mapping algorithm allows it to take a clear 'S' path which produces sufficient coverage while minimizes collisions with objects at the same time. Neato therefore has a more efficient navigation system comparing to obstacle sensing robots on the market.

Overall, robots with mapping and localization have efficient route plans while robots with only obstacle sensing navigates by random walk. Therefore robots with mapping and localization perform better than obstacle sensing robots.

4 Conclusion

This literature survey compared and analyzed the two major navigation techniques used by autonomous cleaning robots: obstacle sensing and simultaneous localization and mapping (SLAM). While robots using either technique can achieve sufficient cleaning coverage, SLAM-based robots like Neato has higher navigation efficiency comparing to obstacle sensing robots. The SLAM-based solution facilitates the minimization of overall power consumption by advancing the finish time, so robots using SLAM algorithm also has lower power consumption.

There are various possible improvements intended to satisfy the user's requirements and increase the robot's capabilities. One is that if the system can classify the contact surfaces by their roughness, the robot can use lower power on flat surfaces and reduce the noise level. Another possible improvement is that the robot could learn dirty spots over several runs and increase cleaning frequency. This can improve the cleaning efficiency.

Another improvement is that the system could integrated with user input for better-refined cleaning schedules and habits. Each user has different cleaning habits and these habits can be input into robots. For example, there are areas less practical and sentimental important than others. Those places do not expect frequent sweeping. SLAM robots under supervised learning could achieve a higher level of habits and adaptations.

Further more, by building a dense map of current environments, the robot could also be improved to generate the estimated task time, unfinished task map and the places it frequently confronts problems and needs human interaction. Cleaning robot could embed some medium to display the generated results, for example, could be a display screen on the top of the robot, a mobile app or even connecting to an artificial intelligence assistant like Siri.

These additions will be at the core of the future vacuum robot industry to provide more practical robots for everyday life. Furthermore, studying robot routing planning allows us to identify pivotal parameters to decrease the energy waste of household robots. By leveraging this information, robots could be made to function automatically at home without being an electricity monster. This development continues towards the expectations and needs of users.

The unconventional purpose of optimization pushes researchers to discard the techniques of direct search. A new evolutionary search algorithm is needed as another way of optimization. There are few has been chosen already; specifically, ancestral algorithms working together with the neural network. New models of these algorithms are under development and new methods of generating output populations are starting to implement. This advance also implies the necessity of new models of vacuum robots.

5 Reference

1. Pandey, A., Kaushik, A., Jha, A., & Kapse, G. (2014, April). A Technological Survey on Autonomous Home Cleaning Robots. Retrieved June 29, 2015.

2. Ja-Young Sung, Lan Guo, Rebecca E. Grinter, and Henrik I. Christensen. "My Roomba Is Rambo": Intimate Home Appliances. Retrieved June 29, 2015.

3. Liu, Kuotsan (2013, September). A Technical Analysis of Autonomous Floor Cleaning Robots Based on US Granted Patents. Retrieved June 29, 2015.

4. F. Vaussarda, J. Finkb, V. Bauwensb, P. Retornaz, D. Hamela, P. Dillenbourg, F. Mondada. (2014, April 1). Lessons Learned from Robotic Vacuum Cleaners Entering in the Home Ecosystem. Retrieved June 29, 2015.

5. Lawrence H. Erickson, Joseph Knuth, Jason M. O'Kane, Steven M. LaValle. Probabilistic localization with a blind robot. Retrieved June 29, 2015.

6. Chanak, P., Banerjee, I., Wang, J. and Sherratt, S. (2014) Obstacle avoidance routing scheme through optimal sink movement for home monitoring and mobile robotic consumer devices. IEEE Transactions on Consumer Electronics, 60 (4).

7. Rostyslav Kryvyy, Serhiy Tkachenko (2013). Planning Navigation Routes for Mobile Robots. Retrieved June 29, 2015.