EPiC Series in Computing
Volume 82, 2022, Pages 11–20
Proceedings of 37th International Conference on Computers and Their Applications

Verifying and Assessing a Performance of an Automatic Vacuum Robot under Different Room Conditions

Thitivatr PatanasakPinyo, Natcha Chen, Natthikarn Singsornsri, and Nattapach Kanchanaporn

Faculty of Information and Communication Technology, Mahidol University
Salaya, Nakhon Pathom, 73170, Thailand
thitivatr.pat@mahidol.edu

Abstract

Artificial intelligence has become the mainstream technology. Automatic vacuum cleaners or robot vacuums change the field of vacuum cleaners with an involvement of an automation, which is a technology that makes people's daily life easier and more economical. Robot vacuums were invented by the Massachusetts Institute of Technology in 1990. Today, robot vacuums are successful and have many users all around the world. More than 2.5 million families live in 60 countries use them. However, a question that is still being asked about robot vacuum is the efficiency of room coverage and the ability to remember the redundant areas that have already been cleaned. The answers to these questions are unclear, as manufacturers do not reveal the algorithms that are learned by robots, or sometimes they just partially did, due to business reasons. This study was proposed in response to the above questions by using our mobile application for tracking and recording actual geolocations of the robot walking across various points of the room by extracting the real geolocation data from satellites consisting of a latitude and a longitude under multiple different room conditions. Once the robot has cleaned throughout the room, the application reported all areas that the robot has cleaned for analysis purpose. We presented the actual route map, the coverage area map, and the duplicate area map of the robot that potentially led the further understanding of robot vacuum's effectiveness.

1 Introduction

In this era, artificial intelligence has become the mainstream technology and a robot vacuum, which is one application of AI, changes the field of vacuum. There are several brands of manufacturers and distributors of robot vacuums in the market. Algorithms were placed in robot vacuums allow them to learn. It is advertised that robots could cover different layouts of a room. Because of trade secrets, the algorithms are not completely disclosed. Consumers could only be persuaded by a manufacturer's advertisement. For these reasons, we conducted this study to clarify our doubt about a coverage area and a redundant area of an robot vacuum. The first step of the study is to develop an Android application that is able to retrieve a real-time geolocation and log those geolocations. By placing a device that already has the application running on the robot, every single point (which is represented in a pair of a latitude and a longitude) of the room that the robot visited is tracked and recorded. However, the primary deliverable of our study is a result that we observed and an analysis on logged data to answer the research question that we raised rather than the application.

Let us repreat that the research question is that we doubted about the performance of a robot vacuum in term of room area that can actually be cleaned, i.e., if it really covers the actual area of the room as well as the efficiency of avoiding an area that has already been cleaned to save power. The answer to this problem is not obvious as a manufacturer cannot disclose sensitive business information and publicly presented only good points. A user will know only the advantages of a robot.

This article consists of six sections which are Introduction, Related Work, Methodology, Results and Discussions, Conclusion, and Acknowledgements. The first section introduces the foundation of the work including motivation, problem statement, objectives, scope and expected benefits of the study, and organization of the document. For the second section, it is to provide a background and related literature. The third section talks about how we designed and implemented the study. The results and analysis of results that we can gather from the experiment can be found in the section of Results and Discussions. The Conclusion section wraps up our study.

2 Related Work

Since we used iRobot (Roomba 2017) in our study, we did some research about a story of iRobot. We also talked about related applications and studies that involved location-based in order to solve a problem.

iRobot is an automatic robotic vacuum cleaner. An iRobot was invented in 1990 (USA). Before the engineer team created iRobot, they built and developed a robot that was used for the military. In 2002, iRobot company launched the first product in the market in the name of Roomba, a robot that helps us to sweep and scrub a floor. Roomba can productively clean the entirety floor, under and along walls. The initial plan included manual operation by mean of remote control and a "self-drive" mode which permitted the iRobot to clean autonomously without human control. A few designs utilize spinning brushes to reach tight corners, and some incorporate a number of cleaning features besides the vacuuming feature (mopping, UV sterilization, ETC. [1]) Roomba moves around your room with two colossal tractor-style wheels, each one autonomously driven by an apportioned electric motor and clean nearly any space it can drive into [1].

An advantage of utilizing robotic vacuum cleans is how quiet they are compared to a normal vacuum cleaner. Moreover, they are seen as more helpful to utilize since they can vacuum on their own. Automatic vacuum robot can be kept beneath work areas, while a standard vacuum cleaner requires a bigger amount of space [1].

As shown in Figure 1, an automatic vacuum robot calculates the ideal cleaning way because it cleans and chooses when to utilize its different cleaning behaviors:

- Spiraling: The automatic vacuum robot uses a spiral movement to clean a concentrated area.

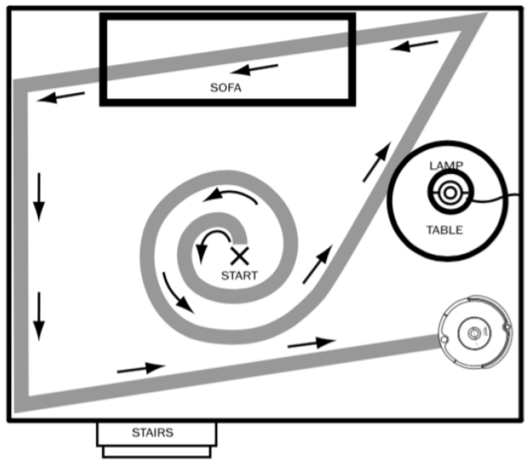

Figure 1: Cleaning Pattern from the Official Manual of iRobot.

- Wall Following: The automatic vacuum robot uses this method to clean the total of the room.
- Room Crossing: The automatic vacuum robot crisscrosses the room to guarantee full cleaning coverage.
- Dirt Detection: When the Automatic vacuum robot senses dirt, the Automatic vacuum robot cleans more intensely in that range.

iRobot algorithms are divided into iRobot movements and application operations. For the iRobot movements, Just touch of a button and begins its journey by mapping out its location and path. By using sensors on various sides of the iRobot, this allows the robot to map where it can and cannot go. For the application, when users first buy the iRobot, it allows them to control the iRobot directly from their phone. All users have to do is set up a free account with their information, link to their specific iRobot by putting in its individual number, and pressing finish. Once the app is downloaded and the user's phone is fully connected to their iRobot, all that is needed is for the user to press the "Clean" button within the app. Once pressed, the iRobot is turned on and begins to move away from the home base. Within the app, you also have the ability to set a specific time you want your iRobot to clean, and once set in the calendar, it will begin cleaning, and return home when the time scheduled is over. Users also have the ability to check how the iRobot is performing as well as any maintenance needs that will alert the user when the iRobot needs to be emptied or a filter needs to be changed [11].

The primary thing iRobot does when you press "Clean" is to compute the room size. iRobot is somewhat cloudy on how it does this, yet HowStuffWorks accepts that it conveys situated on its guard. When it sets up the size of the room, it realizes to what extent it ought to spend cleaning it [10].

iRobot starts cleaning in an outward-moving winding and afterward sets out toward the border. When it collides a deterrent, it trusts it has arrived at the border of the room. It at that point cleans along the "edge" until it hits another deterrent, so, all things considered, it cleans around it, find a make way and continues to cross the room between items like dividers and furniture until the apportioned tidying time is up [10].

While iRobot is cleaning, it stays away from steps utilizing four infrared sensors on the front underside of the unit. These precipice sensors always convey infrared signs, and iRobot anticipates that they should promptly ricochet back. This is the manner by which iRobot knows to head the other way. At the point when iRobot thumps into something, its guard withdraws, actuating mechanical article sensors that reveal to iRobot, it has experienced a snag. It at that point performs (and rehashes) the successive activities of sponsorship up, turning and pushing ahead until it finds a make way.

In summary, the approach for the iRobot is to spiral until it finds a wall/obstacle, and after that endeavor to clear back and forward. Spiraling is an efficient way to cover ground once you don't know how huge space is, and it too implies the iRobot will discover the closest wall first.

For location-based studies, a pair of latitude and longitude is a coordinate that could tell exactly where a location of any object on the earth is. This pair can be reliably retrieved by a GPS sensor on most mobile devices such as smartphones or tablets comparing to another metric like altitude that, sometimes, retrieved with errors [3, 4]. Multiple studies also used this concept to conduct experiments that related to a location-based application. One example was the series of studies of using an adaptive version of location-based application to verify addresses [2, 5, 6, 7, 8, 9].

3 Methodology

3.1 Study Designs

In this section, we divided an experiment to see the result in 5 room conditions. Each different condition was based on a level of obstacles (furniture) in the room. Those conditions are: 0 percent obstacles, 20 percent obstacles, 40 percent obstacles, 50 percent obstacles, and 80 percent obstacles. The experiment was in the room we selected, which located on the fourth floor of the Faculty of Information and Communication Technology building, Mahidol University, Thailand. The reason we chose this room because the size of the room was appropriate. It was neither too big nor too small and importantly, we could receive a value of latitude and longitude from that room better than other rooms on the other floors. The obstacles that we brought in this room were boxes, chairs, and tables. The experiment was conducted to see the working of iRobot when the room came to several obstacles. We developed an application to collect a list of both a latitude and a longitude corresponding to the robot's location, which we used for analysis, visualization, simulating the robot path of cleaning and working area, and summarizing redundant areas that the automatic vacuuming robot cleaned the same area more than once, including the number of times the robot repeatedly cleaned. Figure 2 shows the floor plans of different room conditions: (a) 0% obstacles (b) 20% obstacles and (c) 40% obstacles. Figure 3(d) shows the floor plan of 50% obstacles condition and Figure 3(e) shows the floor plan of 80% obstacles condition. Figure 4 shows the actual environment of the room with 20% obstacles.

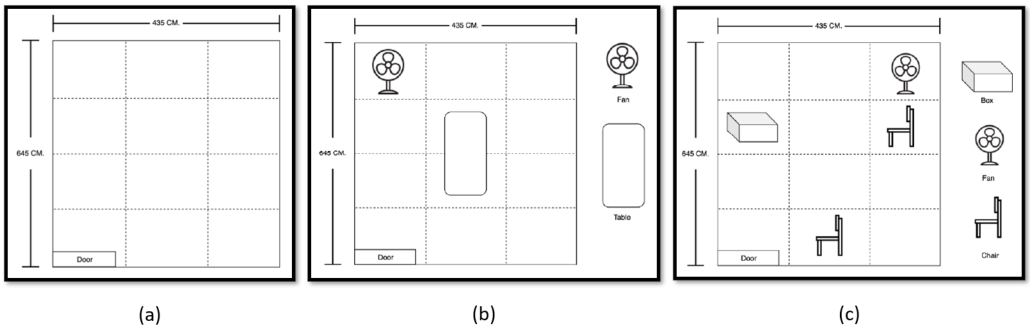

Figure 2: Floor Plans of Different Room Conditions.

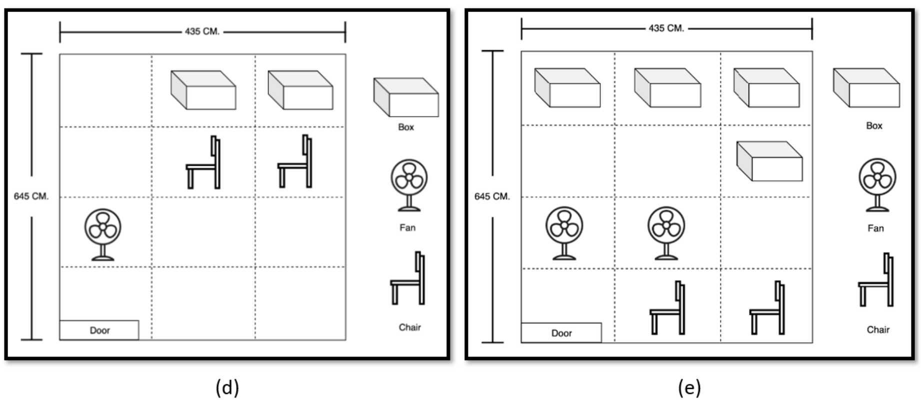

Figure 3: Floor Plans of Different Room Conditions.

Figure 4: Actual Environment of a Room with 20% Obstacles.

3.2 Study Procedures

Figure 5 illustrates an experimental process to verify the outcome of iRobot, starting from where we developed an application for retrieving the coordinate values that we wanted to use for analysis. After that, we selected a room and designed a layout to make that room diverse according to all conditions. Next, we ran iRobot to do an experiment. We repeated the experiment up to all conditions as mentioned previously. For each run, we placed a device that has the application launched on top of iRobot while the robot functioned. Once we have finished the field experiment, we analyzed using logged data to observe the performance of iRobot whether there were effective or not.

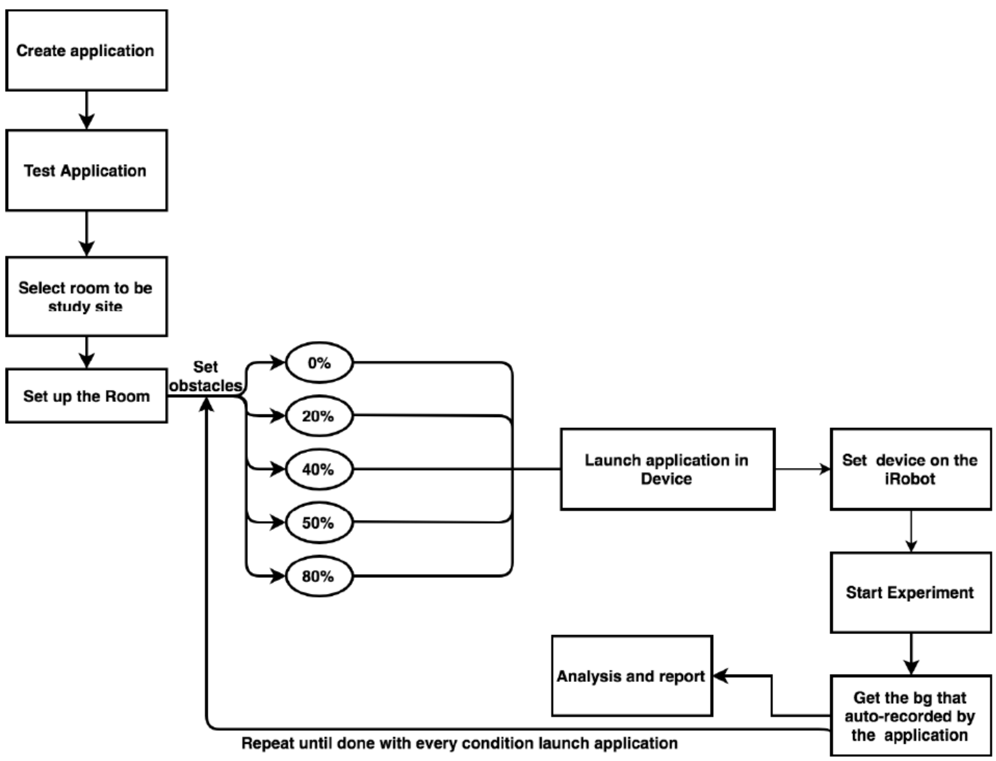

Figure 5: Study Procedures.

3.3 Study Tools

We wrote the Android application using Android Studio. For the purpose of visualization and analysis, we used Java 2D Graphics to draw a path of iRobot for each run. In order to convert each pair of latitude and longitude to a pixel on the canvas, we implemented the concept of world file where we created the world file corresponding to the image of the room floor plan.

3.4 Implementation

This project is divided into three parts. The first is retrieving GPS location. Second is tracking and logging essential data for analysis. And the last one is managing database. After we finished each run, we got a log file that recorded all pairs of latitude and longitude that the robot passed. Figure 6 shows an example of a log file generated by our application. For each room condition, we ran iRobot three rounds to reduce bias when we calculated the coverage and redundant areas.

	Timestamp	Latitude	Longitude
1	23:10:00	0.0	0.0
2	23:10:02	0.0	0.0
3	23:10:04	0.0	0.0
4	23:10:06	13.731865	100.36659499999999
5	23:10:08	13.731788333333334	100.36657333333332
6	23:10:10	13.731786666666668	100.36636333333333
7	23:10:12	13.73179	100.36640333333335
8	23:10:14	13.731784999999999	100.36641499999999
9	23:10:16	13.731796666666666	100.36642666666667
10	23:10:18	13.731773333333335	100.36648500000001
11	23:10:20	13.731773333333335	100.366495
12	23:10:22	13.73177	100.36650999999999
13	23:10:24	13.731763333333333	100.366525
14	23:10:26	13.731756666666667	100.36653
15	23:10:28	13.731756666666667	100.36653
16	23:10:30	13.731731666666667	100.36654666666666
17	23:10:32	13.731728333333335	100.366555
18	23:10:34	13.731728333333335	100.366555
19	23:10:36	13.731728333333335	100.366555
20	23:10:38	13.731728333333335	100.366555
21	23:10:40	13.731728333333335	100.366555

Figure 6: Example of Log File.

4 Results and Discussion

This section reports the results and a discussion of our analysis of data that we gathered from the studies. This also includes a visualization of a path of the robot.

4.1 Results

After we ran couple experiments for each room condition, we drew a path of iRobot based on the list of latitude and longitude that logged by the application to observe in general the coverage area of iRobot. Figure 7 shows an example of a path of one run with 20% obstacles condition.

4.2 Analysis and Discussion

We separate the part of analysis into 2 topics: coverage and redundant.

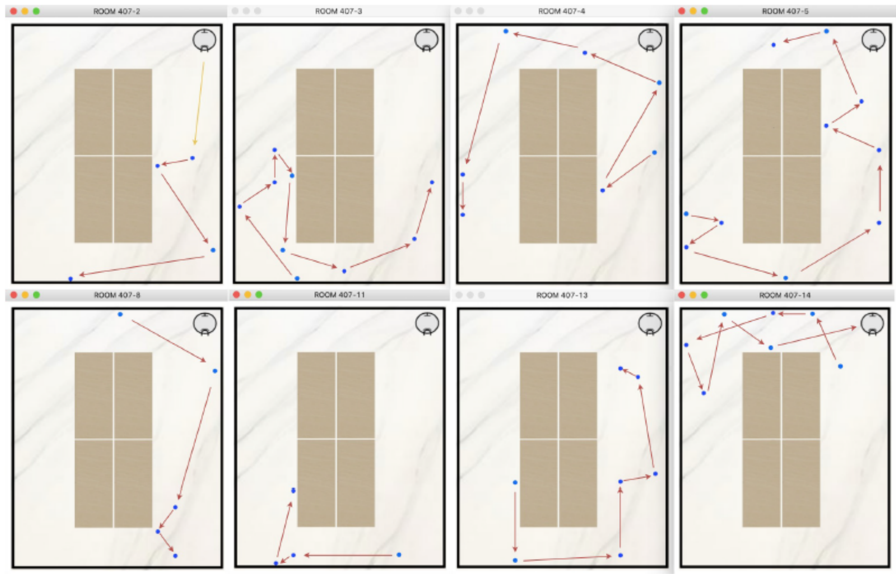

Figure 7: A Path of iRobot When It Ran under 20% Obstacles Condition.

4.2.1 Coverage

For this topic, we will clarify how much area the iRobot actually covered. We have a coverage of cases 0% are 77, 68, and 0 percent. A coverage of case 20% are 0, 90, 75, and 0 percent. A coverage of case 40% is 65, 0, and 72 percent. A coverage of case 50% is 30, 0, 90, and 20 percent. And coverage of case 80% are 0, 0, and 0 percent, in which the estimate is based on the map of the movement of the iRobot. However, it might not be 100% perfect because of the environment in the room. The orientation and placement location of the furniture was found to affect the way iRobot cleaned because they had more increased collisions with the furniture. Moreover, it resulted in an uncleaned floor area. All of the above results were caused by the robot traveled in a straight line until it detected something in its path. For now, we can clearly conclude that the iRobot that moved around the room is not efficient enough to thoroughly clean.

4.2.2 Redundant

For this topic, we clarify how iRobot working in the same area in each experiment and how redundant related to the cases that we study. We have a redundant work area and percent of redundant in each case to see which case is the best case that had less redundant when working by using total area work of iRobot to calculate the percent and value for each case, then conducting statistic tests to verify its significance. However, the redundant area in each case in which iRobot working, we found that the iRobot was spending too much power. We confirm this significance using R Studio to see the difference of statistical significance to calculating the p-value and drawing a box plot to see the difference between each case. We can conclude that the automatic vacuum robot is working within the same area in all cases. So it was using too much energy to working at one time. Moreover, we can conclude that case 0% which did not have any obstacle in the room is the worst case because it has the most redundant area. This can be seen from the result of the statistic test with other cases. So we found that the iRobot is hardworking when the room does not have any obstacle.

5 Conclusion

We studied the efficiency of the robot vacuum which made to facilitate housework. However, the question that is still being asked about the robot vacuum is the efficiency of the robot. Although many companies say that robots are effective, we cannot really know how effective they are because they don't have an open algorithm on how robots move. That is why this study was proposed in response to the above questions. We reported all areas that the robot has cleaned. We reported the robot's route map, the coverage area map, and the duplicate area. This also leads to implicit guidance to users to use the iRobot more efficiently under the conditions of the room that is different for each user. Although vacuum cleaning may seem to be an easy task, in reality, it is quite challenging, as the robot will face a diversity of surfaces and the material to collect. When we started our experiment, working the process was the most important because if we did not follow the process, it may cause errors that we have to solve later. In addition, we learned to develop an application on the Android platform and we learned to utilize algorithms and mathematical formulas in our implementation. Moreover, we are able to easily overcome technical challenges due to the experience and knowledge of team members. The problem that we encountered is that sometimes the GPS is not precise enough to cause a slight discrepancy.

6 Acknowledgements

We would like to express our special thanks to the faculty of Information and Communication Technology, Mahidol University for their support throughout the whole study.

References

[1] Evan Ackerman and Erico Guizzo. irobot brings visual mapping and navigation to the roomba 980. *URL: https://spectrum. ieee. org/automaton/robotics/home-robots/irobot-brings-visual-mapping-and-navigation-to-the-roomba-980*, 2015.

[2] Thitivatr PatanasakPinyo. *Flattening methods for adaptive location-based software to user abilities*. Graduate Theses and Dissertations, Iowa State University, 2017.

[3] Thitivatr Patanasakpinyo. Ameliorating accuracy of a map navigation when dealing with different altitude traffics that share exact geolocation. In Alex Redei, Rui Wu, and Frederick Harris, editors, *SEDE 2020. 29th International Conference on Software Engineering and Data Engineering*, volume 76 of *EPiC Series in Computing*, pages 95–104. EasyChair, 2021.

[4] Thitivatr PatanasakPinyo. Exploiting a real-time non-geolocation data to classify a road type with different altitudes for strengthening accuracy in navigation. *International Journal of Computers and Their Applications*, 28(1):55–64, 2021.

[5] Thitivatr PatanasakPinyo, Georgi Batinov, Kofi Whitney, and Les Miller. Methods that flatten the user space for individual differences in location-based surveys on portable devices. In *31st International Conference on Computers and Their Applications (CATA 2016)*, pages 65–70, Las Vegas, Nevada, 2016. International Society for Computers and their Applications (ISCA).

[6] Thitivatr Patanasakpinyo, Georgi Batinov, Kofi Whitney, Adel Sulaiman, and Les Miller. Object-indexing: A solution to grant accessibility to a traditional raster map in location-based application

to accomplish a location-based task. *International Journal of Computing, Communication and Instrumentation Engineering (IJCCIE)*, 5(1), 2018.

[7] Thitivatr Patanasakpinyo, Georgi Batinov, Kofi Whitney, Adel Sulaiman, and Les Miller. Enhanced prediction models for predicting spatial visualization (vz) in address verification task. In Gordon Lee and Ying Jin, editors, *Proceedings of 34th International Conference on Computers and Their Applications*, volume 58 of *EPiC Series in Computing*, pages 247–256. EasyChair, 2019.

[8] Thitivatr PatanasakPinyo, Georgi Batinov, Kofi Whitney, Adel Sulaiman, Les Miller, and Stephen Gilbert. Extracting useful features for users with different levels of spatial visualization. In *33rd International Conference on Computers and Their Applications (CATA 2018)*, pages 86–91, Las Vegas, Nevada, 2018. International Society for Computers and their Applications (ISCA).

[9] Thitivatr Patanasakpinyo and Les Miller. Ui error reduction for high spatial visualization users when using adaptive software to verify addresses. In Gordon Lee and Ying Jin, editors, *Proceedings of 35th International Conference on Computers and Their Applications*, volume 69 of *EPiC Series in Computing*, pages 22–31. EasyChair, 2020.

[10] Daniel Paul Romero-Martí, José Ignacio Núnez-Varela, Carlos Soubervielle-Montalvo, and Alfredo Orozco-de-la Paz. Navigation and path planning using reinforcement learning for a roomba robot. In *2016 XVIII Congreso Mexicano de Robotica*, pages 1–5. IEEE, 2016.

[11] Ben Tribelhorn and Zachary Dodds. Evaluating the roomba: A low-cost, ubiquitous platform for robotics research and education. In *Proceedings 2007 IEEE International Conference on Robotics and Automation*, pages 1393–1399. IEEE, 2007.