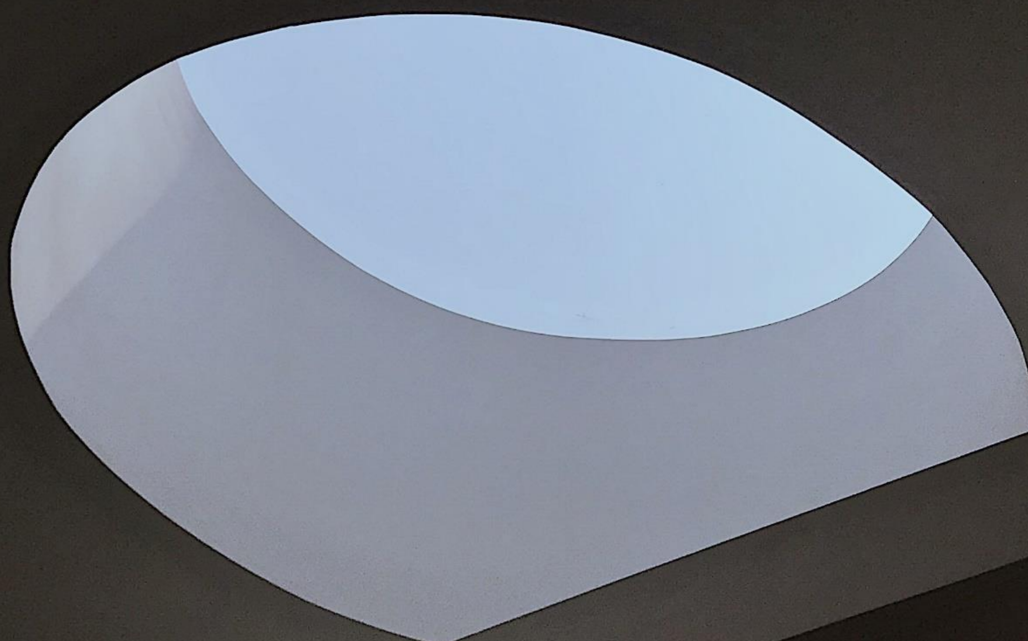
KUWAIT COLLEGE OF SCIENCE & TECHNOLOGY
كلية الكويت للعلوم والتكنولوجيا
Private University جامعة خاصة

An Autonomous Window cleaning robot

Client: households or small businesses

Advisers: Dr. Ismaeel Al Ridhawi **Team Number: 3**



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List of Definitions

AI: arterial intelligence

ML: machine learning

IoT: Internet of Things

QR: quick response code

Algorithm: instructions for solving a problem or accomplishing a task

LED: Light Emitting Diode
GPS: Global Position System

IEEE: The Institute of Electrical and Electronics Engineers

3D: Three-dimensional form

LAN: Local Area Network

ID: Identification data

SMS: Short Message Service

PDF: Portable Document Format

Ex: for example

Abstract

With the advancements in automation technology nowadays, the involvement of Artificial Intelligence (AI) and Machine Learning (ML) in everyday tasks is becoming a reality. The use of such advanced technologies leads to task fulfillment cost and time efficiency. As such, the use of robotic devices for automated task fulfillment is becoming a must nowadays. This project focuses on the design and implementation of an autonomous window cleaning robot. Such a robotic device will replace the way windows are traditionally cleaned with the aid of humans and make it more time and cost efficient to use the proposed robotic device, especially in high-rise building scenarios. The proposed robotic device uses ML algorithms that provide path planning mechanisms prior to initiation and while running. Obstacle avoidance methods are also incorporated to ensure that path routes are planned to avoid any known obstacles. Obstacles that are found in real-time would initiate the path planning algorithm to run iteratively to find more optimal paths in terms of time-efficiency. A plethora of sensors are used to support the robotic device in path detection and movement.

1 Introductory Material

1.1 Acknowledgement

we would like to convey our gratitude to everyone who made it possible for us to finish this report. Dr. Ismaeel AlRidhawi, our final year project advisor, whose stimulating suggestions and encouragement helped us to coordinate our project, particularly in writing this report. We also want to thank Dr. Ahmed AL Saleh for assisting us with the report and providing us with additional information about the robot.

1.2 Problem Statement

Other companies rely on the employee cleaning surfaces at high altitudes and other companies depend on installing the cleaning device through the wiring, but our project does not need any of these things only depends on the air pressure and thus avoid any material or human damage

1.3 Operating Environment

For safety of our customers and our end users, our products would made of plastic materials that would will be recyclable, and to be sure of the safety of our customers the propeller blade that we are going to use would be a plastic like a lot of the other parts and the reason for that, firstly is not use sharp meal object, secondly is to make our product weight less so if some reason our robot got dropped there would not be any reason because it can take the impact.

1.4 Intended Users and Intended Uses

First, our users would be mostly households so we made a robot that would not be interfering with their home security system, and there will also be no cameras instead of that we will be using “IRF” sensors and algorithms so our robot can be smart, fast, easy to use with the mobile phone application or with a remote control like any of the “IOT” devices that are currently in your house.

The use of our robot is to clean giant or small windows that are in households and are hard to reach/clean, but unlike other robots from other companies, who are unable to clean windows as efficiently as our robot, because we are using “ML” and algorithms, since that is our advantage, so we can compute, scan and map any large or small area to clean without leaving behind any stains or dirt but with a cheaper price.

1.5 Assumptions and Limitations

- ASSUMPTIONS:
  - Our robot can move several movements whether it's controlled by the phone application or by the remote control and that can be conceded manual and the other movement is automatic by the computer itself after its scans and apply the algorithm after calculating the most effecting way to do the cleaning.

  - Before the robot starts to cleaning the robot will do a scan/sweep to map and calculate the area with the senser that know if there is any obstacle and if any humans.

  - the robot can clean any window for a long period of time when its connected to a wire since there will be a wire and a battery version each one of them would have its use.

  - our end user would be able to read and know the progress that the robot has finished from the mobile phone app.

- LIMITATIONS:
  - The robot will only clean single glass panel at a time so it will not be able to jump from a window to a window in the house without a human interference.
  - The other limitation that our battery version will only work for 15-25 min because we are using small batteries so if something happens to our product (if it's dropped) the batteries would not be a safety concern.

1.6 Expected End Product and Other Deliverables

- The product is a window cleaning robot to that can help us clean windows with sensors that can avoid any obstacles without the concern of the low battery life because e there is a wire version that can work for long hours.

- Our robot comes with a smart phone app that receives notification through the robot when the robot has finished the given job.

- There will be an included charging wire with the battery version of our robot and the version without the battery would have the option to get a longer wire.

- User manual will be contained with a “QR code“ that will help to describe how to use the robot, and how to connect it with the application, including warning you about what not to do, and how to charge it.

- The final product employs machine learning (ML) to compute, calculate, map and learn the best way to finish the job.

- The robot will also feature state of the art ML and algorithm that will help the robot for path planning.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

The idea of the project is simple, but the impact of its activities is very useful in our day-to-day life and specially in a country like Kuwait that suffers a lot of sandstorms ant hot weather, we will show the hardware and software component we used:

Hardware:

- Suction Motor: - The suction motor is one of the most important parts of a vacuum cleaner. It is this motor which takes the electrical power from the power source and converts it into mechanical power in the form of suction with air flow.

- Propeller Blade: - The propeller blades are shaped much like a wing of an aircraft, using the rotation power of an engine rotates the propeller blades produce suction power to keep the robot on the window.

- Wheels & Tires: - Tires and wheel which the other companies are using are not suitable for all surfaces and the reason why the do it to reduce the cost.

- Motors: - The other companies are using small electrical engines – motors – and the reason why they do it to have a higher torque and eco-friendly.

- Bluetooth Module: - Bluetooth module refers to the basic circuit set of the chip with integrated Bluetooth function, used for short-range 2.4G wireless communication module. (Bluetooth sensor).

- Switches: - a switch is an electrical component that can disconnect or connect the conducting path in an electrical circuit, interrupting the electric current or diverting it from one conductor to another.

Software:

- The most important task of the software is to always keep the user always connected.
- The second task of the software is to notify the user if there is an error or when the task starts and ends.
- Also, to update the user if there is an error or a new update on the map for ex: a new obstacle.
- The last benefit of the software is also to control the robot.

Service to be performed

The most important process is to wipe the area to be cleaned in the beginning we swap the area which need to be clean to decide the accurate path whether it's vertical or horizontal Controlling the scanning process by the application in the second step, we can control the path and the movement through application. Starting to function. The third step, the robot will start cleaning and if any obstacle found the chime will ring as a notification.

2.2 FUNCTIONAL REQUIREMENTS

2.2.1: Surface mapping:

Mapping: the robot will scan the area or the surface that will be cleaned, the robot will move vertical and horizontal to clean. and the robot will record the started point.

2.2.2: robot application:

Application: the robot is connected to the application that anyone can control with the movement, and the feature of the application is: if there are any error in the robot will send to me notification, and it will calculate the time that will take to clean the surface.

2.2.3: Avoiding obstacles /Objects:

Obstacles: if there any obstacles will be facing the robot like human or animal the robot will avoid them and move to the left, right, up or down. it will be avoided all the obstacles.

2.3 Constraints Considerations

Constraints:

1. Battery:

- The robot returns to the recharging itself.
- The second version comes with wire to charge the robot when it needs.

2. Safety:

- Up to the safety requirement.

3. Weight:

- The weight of the robot should be average.

4. Cost:

- The cost should be affordable for all people to cover their needs.

5. Time

- The time the robot would take should not exceed the recommended time that we will provide to the user which is for ex: the wired version should not exceed 1.5 hrs. and the battery version should not exceed 30 min

Non-Functional Requirements:

1. Security:

The robot and the app that will be used to control the robot will not need any access to your camera roll, contact, or any sensitive information on your device.

2. Usability:

The robot should include a remote control that can be easily navigated and the robot will be already fitted with 2-3 moods to clean windows.

3. Availability:

The app will be available 24/7 to use Furthermore any Explanations and requests would be responded by support team.

Engineering standards:

In our scenario we don't have any ethical problems or concerns but the only concern that we may face is the safety of our users mobile phone so we will try to keep our application up to the safety requirement that all the other mobile phone apps have.

Storage:

- There will be a memory for saving the map services area that the robot will scan it.

Wi-Fi:

- Wireless communication if you are using Wi-Fi, you should indicate that you will be using the IEEE 802.11.x standard.

2.4 Previous Work And Literature:

Starting with the most similar research was done by Young-Ho, Jae-Youl, Jong-Deuk, & Ka-Eun in the year 2012 talks about if its possible for small robots to clean windows [1], and the goal off the experiment at the time was to create the World's First Commercialized Window Cleaning Robot for Domestic Use, and the way the they wanted to archive their goal is by writing simple programing and relaying on math to clean windows.

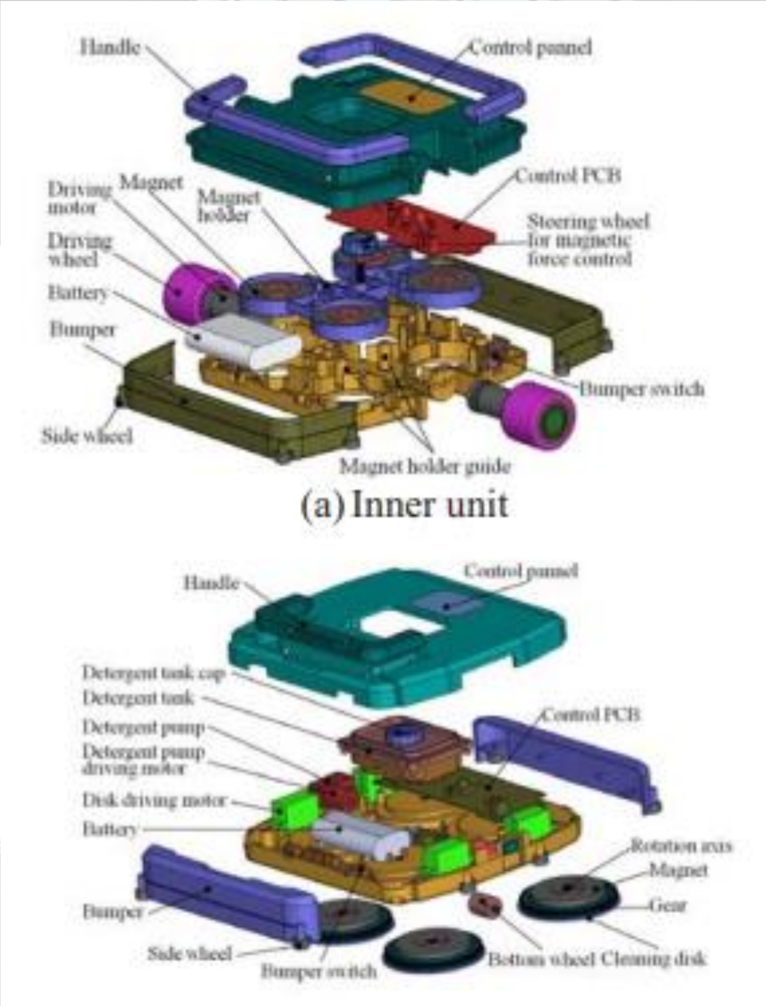


Figure 1This figure shows the original design that the researcher's team in used in 2011 that they later have modified

Contact sensor-based coverage of rectilinear environments:

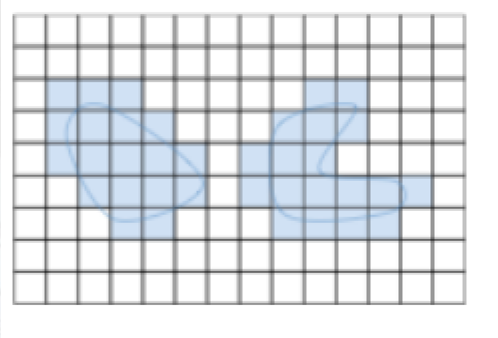


Figure 2 Contact sensor-based coverage of rectilinear environments

An algorithm known as CCR is proposed to decompose an environment into rectilinear regions. Its goal is to provide a coverage of the obstacles faced by robots in this region. Most grid-based methods are complete when they are computed according to the approximate representation of the environment. This is because the grid map can be represented as an array with the cell's associated values. On the other hand, grid maps are very simple to use since they can easily mark regions in a grid map. Due to their resolution, grid maps are commonly used for coverage algorithms. Due to the small size of the area covered by grid-based coverage methods, they are commonly used for indoor robot operations.

Grid-based Coverage using the Wavefront Algorithm:

presented the first grid- based method for coverage path planning. In their offline method, they use a grid representation and apply a complete coverage path planning algorithm to the grid. The method requires a start cell and a goal cell. A distance transform that propagates a wave front from goal to start is used to assign a specific number to each grid element

Graph-based coverage:

First, it considers that the prior map information provided as a graph might be incomplete. Second, it accounts for environmental constraints, such as restrictions in certain directions in the graph (corresponding to a one-way street, for example). Third, it provides strategies for on-line re-planning when changes in the graph are detected by the robot’s sensors when performing coverage. Finally, strategies for coverage using multiple robots are provided.

Grid-based methods:

Grid-based methods use a representation of the environment decomposed into a collection of uniform grid cells. This grid representation was first proposed by Moravec and Elfers to map an indoor environment using a sonar ring mounted on a mobile robot. In this representation, each grid cell has an associated value stating whether an obstacle is present or if it is rather free space. The value can be either binary or a probability. Typically, each grid cell is a square, but also different grid cell shapes can be used, such as triangles. As grid representations only approximate the shape. spanning tree until it reaches the end of the tree. At that point, the robot turns around to traverse the other side of the tree. It is worth noticing that, when coverage is completed, the robot returns to the start cell, facilitating its collection and storage. On the other hand, STC never visits any small cell twice and thus minimizes the cover time. Fig. 21(b) shows an example of a coverage path generated by the Spiral-STC algorithm. wall finding. Nonetheless, they introduce a map coordinate assignment scheme based on the history of sensor readings to improve the time-to-completion by reducing the number of turns on the generated path. The generated spiral paths are then linked by an in- verse distance transform they introduce. This proposal is validated in simulation and with real-world experiments conducted in- side a room with a mobile robot.

Grid mapping movement on a surface:

So starting with Acar and Chose whom proposed to plan the paths of their sensor based Morse decomposition approach by relying on the boundaries of each cell, so they can minimize the dead-reckoning error, but on the other hand Tully et al used a method that is combination of three robots that move together to minimize the localization error and that was accomplished by using two off the three robots a static robots and the third one as a beacon to communicate, and on top of that the three robot fleet that was also designed to so the roles can be interchangeable. But the problem was that they are so good on two dimensional suffuses but when it came to realty the obstacles was not consideration. So, despite what was said Using multiple robots in a CPP task still has a lot of advantages over using a single robot and some of them are that you can reduce the time it takes and improve robustness, and as failure of some members of the robot team can be compensated by other members. Most approaches extend single-robot ideas presented before to multiple robots by using a strategy to divide the workload, which can be achieved by Algorithms for the complete coverage path planning problem using a team of mobile robots on an unknown environment The algorithms use the same planar cellular decomposition as the Boustrophedon single robot coverage algorithm. In summary the article/research paper keep going over the fact that using a single robot can be good enough in a lot of scenarios with a good algorithm or with an algorithm that is specially designed for the task, but using a fleet of robot also an idea that you should consider if you are determent to be efficient In the work/task that you are trying to finish specially because using a fleet of robot also can use the same algorithms and methods that a single robot is using but on a bigger scale and can minimize the effort the time and also improve the communication between the user and the robot in some scenarios (if one of the robot was used as a beacon).

3D coverage:

Most coverage path planning methods, and in particular the methods reviewed so far in this article, assume that the environment can be modelled as a simple planar surface. However, some surfaces in nature are 3-dimensional, and 3-dimensional coverage path planning is required instead to cover these surfaces. This is the case of an autonomous underwater vehicle covering the seabed or a robot spray-painting vehicle parts, for instance. Next, we review several 3-dimensional coverage methods. Indeed, in 3-dimensional coverage, covering 2-dimensional surfaces embedded in 3-dimensional space such as the boundaries of automotive parts, the boundaries of buildings, the ocean floor, rugged agricultural fields or the boundaries of the in-water part of a ship hull are the main focus.

3D coverage using a planar coverage algorithm in successive horizontal planes:

3D coverage using a planar coverage algorithm in successive horizontal planes Hertel presented a 3D coverage algorithm that is based on a planar 2-dimensional terrain-covering algorithm. Their target application is an autonomous underwater vehicle imaging the sea bottom. Their solution applies to a 3D protectively planar environment by applying the planar terrain-covering algorithm in the successive horizontal planes laying at different depths. Artificial inlets are covered in the same way that real diversion inlets are. Therefore, aiming to make the robot navigate only in areas close to the surface, artificial obstacles (artificial islands) are introduced in the robot's map of the environment.

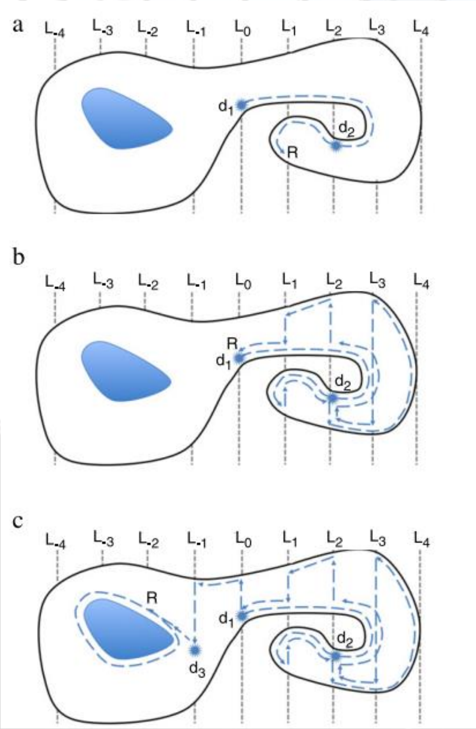
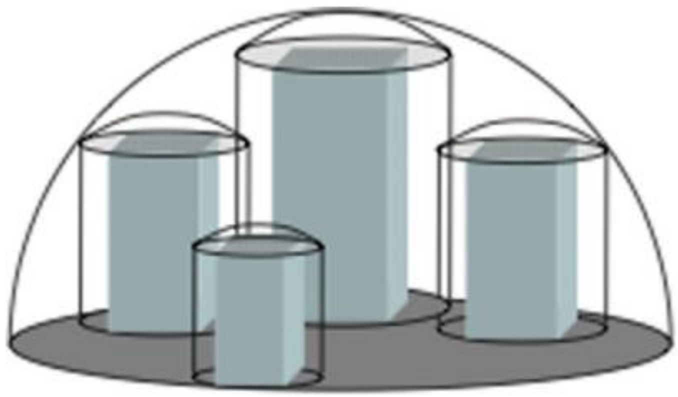


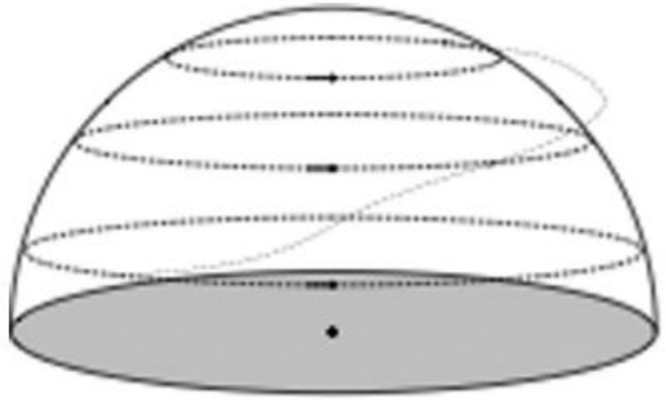
Figure 3: 3D coverage using a planar coverage algorithm in successive horizontal planes.

3D cellular decomposition

considered the problem of trajectory generation for spray-painting robots. In their early work, they proposed an on-line, 3-dimensional, on-line CPP method for closed, orientable surfaces embedded in R3. Addressing their spray-painting target application, the method does not plan a coverage path on the target surface, but the coverage path is rather planned in an offset surface from which the end effector will spray the target surface. However, if the surface is non-convex and includes elements such as a bifurcation, the planner will use the critical points occurring in such shape changes to divide the surface in cells that will be covered individually. As in the on-line Morse decomposition for planar spaces, a Reeb graph is used to encode the topology of the target surface.



(a) Simplified model of an urban environment.



(b) Illustration of a coverage path.

Figure 4 3D cellular decomposition

Random sampling-based coverage of complex 3D structures

To handle this family of problems, global path planning strategies, utilizing sampling-based planning have been applied to find feasible, collision-free, paths through confined areas and obtain full coverage of a 2-dimensional target structure. It should be noted that the generated paths cover cluttered spaces where complex structures such as shafts and rudders are present.

The approach is validated using sensor imagery of real vessels and with experiments conducted at sea. As discussed above, the approach by Englut and Hover first generates a set of view configurations that completely cover the target surface (by solving an instance of the art gallery problem) and then finds a path that connects them (by solving an instance of the traveling salesman problem). To tackle this problem, presented a random sampling-based algorithm that incrementally explores the robot's configuration space while constructing an inspection path until all points on the target surface are guaranteed to be covered.

optimal coverage

Work addressing the optimality of the generated coverage paths, in terms such as path length and time to completion, appears in the CPP literature. Huang presented an optimal line-sweep based method for cellular decomposition algorithms in planar spaces. This approach produces an optimal length coverage path by allowing different sweep directions in the lawnmower paths used to cover each cell. This is achieved by allowing a different sweep direction in each cell. Mandira and Realities proposed an algorithm based on the Boustrophedon cellular decomposition that achieves complete coverage of known spaces while minimizing the path of the robot.

Component description:

For the positioning part at the start we will begin with a sweep that will map the surface than will send it to our raspberry pi that calculate and create a map in its memory which is helpful for the robot when the movement part begins, when the movement stage starts the maps we have calculate and collect it will be applied to an algorithm that will divide the surface area into small parts (maps) that will also later get their own algorithm, applied to them and this part will be done by the raspberry pi in collaboration with the sensors that will be detecting all the edges, after we have calculated our algorithm a signal will be sent by the raspberry pi to dc motors and the sensors to initiate the movement from the position that it has stopped on, the dc motors and the sensor will now work combined to move the robot and detects all the edges and will later send the signal to the raspberry pi again to record the progress and send it via Wi-Fi or Bluetooth to the iPhone.

design alternatives:

KITEROBOTICS window cleaning robot [3], they do not use a path detection system it's just a mix between horizontal and vertical movements that are done by machines which pull from each corner and that can be operated by a control panel. And They also do not use an algorithm it's just pre-programmed route. There is no obstacle avoidance system, but cable system follows the contours of every surface and brush rotation direction cleans all corners and indentations.

The advantages are

• The robot can move faster than any robot that is designed to clean household windows.

• The robot can clear gapes that are between windows because the robot is connect to wires instead of being connected to the window itself. The shortcomings are:

• The robot is only designed to skyscrapers that have a flat face that is covers with windows.

• There is no obstacle avoidance system, but cable system follows the contours of every surface and brush rotation direction cleans all corners and indentations

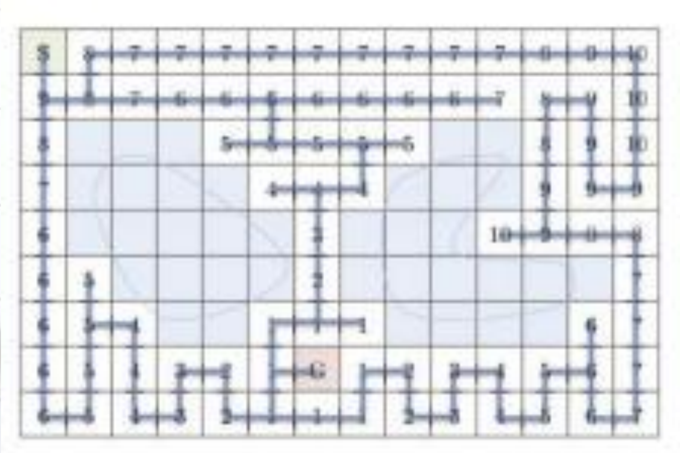


Figure 5 Grid-based Coverage using the Wavefront Algorithm

The advantages:

- Some of the most obvious advantages beside being the first to do it, is that that used simple programing that did the job that later will help them and other programmers and inventers to develop it better because the leaded the ground for others after them.

- They have focused on a different market that no body before them have though of which is house-holds and small company and apartment buildings which gave them the advantage because they are no competitors in their market.

The shortcomings:

- The experiment was done is a small lab with not a lot of working/experiment hours.

- The version that used only came with a battery so the work duration will not be so long compared to those whom are connected and powered by wires.

- The robot did not have a an algorithm that can handle wen the shape of window is different or with size of the window get scaled by a lot.

2.5 Proposed Design

In this report we have focused on the idea of cleaning windows, but now going in details the basic idea of the robot, so the controlling / circle of the robot can be divided into five stages the first one boing the input part which can be received via a remote control or the via the phone app, the second stage is the positing part which can be done by using the algorithms companied with the sensors that are connected to the device which can determine which side of the surfed you are on and whether the robot should move in certain direction instead of another, and at the end the moving and distant/area covered recording happen and all the data get sent to the rasppary pi that can coordinate with all the other part of the robot.

For the path detection the whole map is first covered by the mapping sweep and after that the robot generate smaller maps and select the easiest way to clean each part/segment, then for the movement algorithms we chose grid mapping (Wavefront Algorithm) because it was the most suitable for our application (uses), at last regarding the obstacle Avoidance our obstacle avoidance system is based on our algorithm witch first map the surface and that create smaller maps so our robot can avoid obstacles.

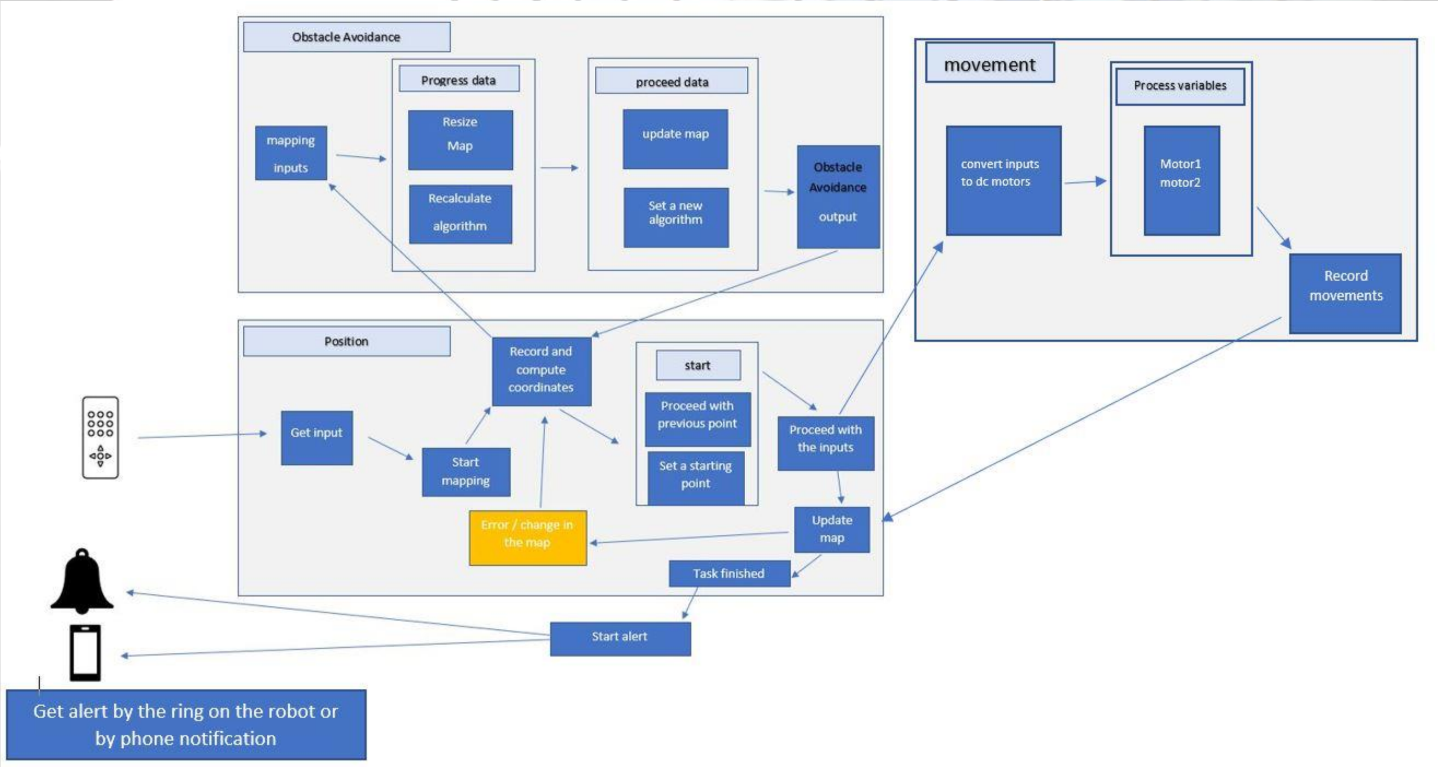


Figure 2

2.6 Technology Considerations

Starting with one of the most important strengths of our robot is that it can save water by just using small amount of water or cleaner while its moving in a certain direction, and the second one that it can be a huge help for people who do not have the time or don't have a lot of time to waste on simple day to day home tasks, and the third on is that using and "AI" and "ML' to make our houses more smart can be a huge step if you are trying to make your house a smart house.

On the other hand, there are some important weaknesses in our robot the most important one of them that the robot can not jump from a window to window so if the robot finishes cleaning a window you have to stop what you are doing and move the robot from a window to another, the second weakness is that if the robot is powered by batteries the duration of working time wouldn't be as long as if the robot was powered by a wire straight from the wall outlet.

Going over some of the important trade-offs that have been missed are using the robot to clean windows that have a walls or gaps between them without any human interference.

design alternatives:

KITEROBOTICS window cleaning robot [3], they do not use a path detection system it's just a mix between horizontal and vertical movements that are done by machines which pull from each corner and that can be operated by a control panel. And They also do not use an algorithm it's just pre-programmed route. There is no obstacle avoidance system but cable system follows the contours of every surface and brush rotation direction cleans all corners and indentations.

The advantages are:

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- The robot can clear gapes that are between windows because the robot is connect to wires instead of being connected to the window itself.

The shortcomings are:

- The robot is only designed to skyscrapers that have a flat face that is covers with windows.
- There is no obstacle avoidance system but cable system follows the contours of every surface and brush rotation direction cleans all corners and indentations.

2.7 Safety Considerations

Our robot may have some concerns that will be described below:

- our robot is safety because we will use the senser if they are any obstetrical or any object will face the robot its will chime sound and the robot will stop working so that our robot is safety.

- for larger windows we will recommend our customers to get the wire version so if the robot get dropped their will not be anu safety concerns.

- There will not be a huge amount of water on the robot and so if for some reason the robot gets dropped there will not be a safety concern.

2.8 Task Approach

Before we begin our project, we must first establish a plan to determine what we should do first. Following the creation of the plan, we will begin conducting the necessary research and finalizing concepts. Following our investigation and collection of ideas, we will begin work on the deliverables and final report. We will begin working on our project after the deliverables and final report are completed.

Second, we'll get the robot and any necessary parts, then install the software, set up the other robot parts, and begin programming and programming the robot. We shall begin the experiment and testing processes after programming it. We will begin revising, updating, and inspecting the final product after the experiment and testing phases are completed.

2.9 Possible Risks And Risk Management

Include any concerns or details that may slow or hinder your plan as it is now. These may include anything to do with costs, materials, equipment, knowledge of area, accuracy issues, etc.

- The power points to charge the robot might be weak/the battery might be weak, so the robot won't get enough power to get the job done.

- The programing phase may get some errors, so it takes a lot of time to solve the errors problem.

- The robot may slip and fall if it is not secured properly.

- We may face expensive costs in purchasing the necessary equipment's.

2.10 Project Proposed Milestones and Evaluation Criteria

The proposed project, constructed from four deliverables and an addition final report, shall be submitted to the university during this semester; this division helps the team track the progress of the project.

- deliverable (1): throughout the first week we have researched an alternatives idea that is similar to our project.

- deliverable (2): The team members will present the initial authentication system based on algorithms and some research papers we looked into using technology

- deliverable (3): Team members will introduce the second step of the authentication system that relies on ML (machine learning) technology and algorithms that we have looked into (waveform algorithm)

- deliverable (4): we have researched alternative proposed designs and we have looked into the advantages and disadvantages to compare them and see if they have met our standards.

- Final report: the entire project will be submitted with all the documentation.

2.11 PROJECT TRACKING PROCEDURES

Team members will send weekly reports from each member with a detailed description of the work they have done. All members will be assigned tasks of which issues and problems will be raised, new factors must be taken into consideration. Task completion is still a priority.

Progress Tracking Measures:

- Weekly meetings with our adviser. At these meetings the team members will come prepared for any clarifying questions, assumptions, or challenges to present to the adviser. Also ready for any good insight the adviser offers. These meetings provide social and intellectual communication.

Internal Peer Review:

- At the beginning of each week from February till April, the team members spent 1 hour to review and discuss the weekly report with our project adviser Dr. Ismail Al-Ridhawi to discuss the reports in order for improvement. Thus, it's leads to improvement of the team members and improvement in the project progress.

2.12 EXPECTED RESULTS AND VALIDATION

Before starting work, we must make testing for our system design:

The end goal is a robot that cleans windows either for high and difficult to reach or the normal height windows. This robot can speed up the process of cleaning. The robot will be fully functional and will be connected to a mobile application so the validation of the result will be divided into four parts moving testing: this testing will be test if there any obstacle and how the Chaim its work. Algorithm testing: this test will see if our raspberry pi can handle huge surfaces and can divided them to suitable parts that can be handle by the robot and based on the algorithm testing, we will determine if our robot can clean faster than human beings and other market alternative.

2.13 TEST PLAN

Before starting work, we must make testing for our system design:

1. Moving testing: this testing will be test if there any obstacle and how Chaim its work.

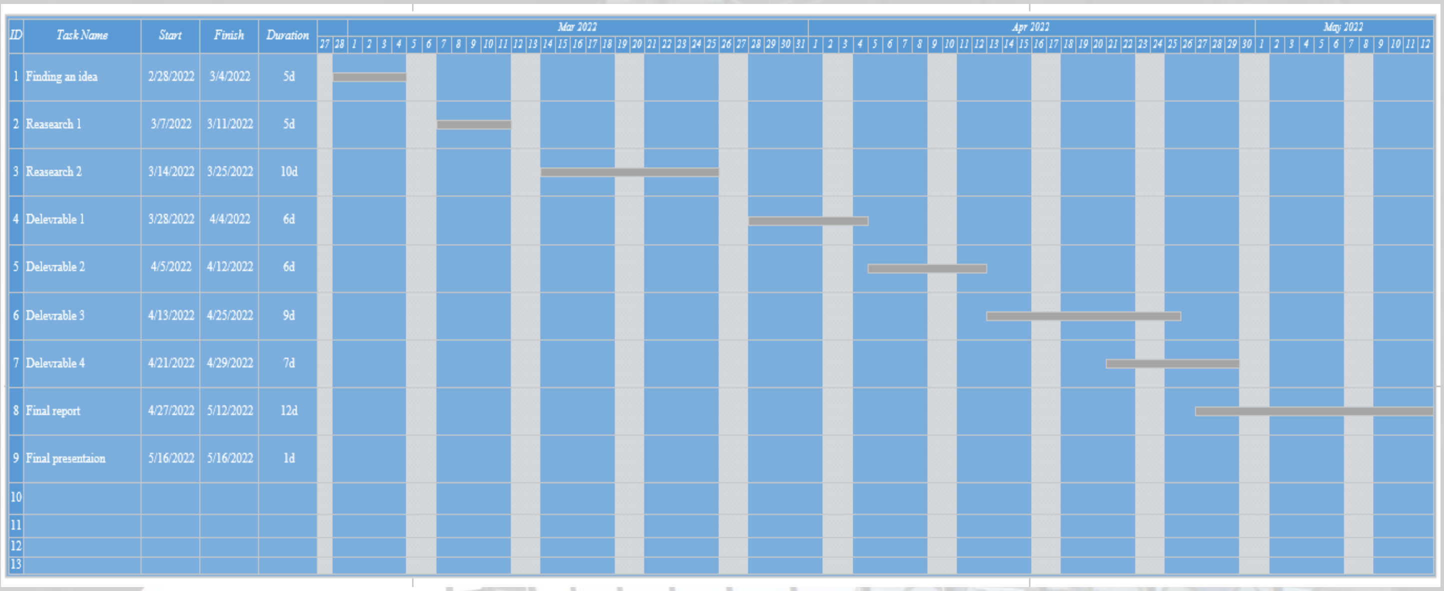
2. Algorithm testing: this test will see if our raspberry pi can handle huge surfaces and can divided them to suitable parts that can be handle by the robot.

3. Application test: the test will cove all the parts off our off our application like the connectivity and if the app have any bug or errors.

4. Sensor: the sensor test will cover and check if the sensors do in fact work when pumping into stuff.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline



ID	Task Name	Start	Finish	Duration
1	Finding an idea	2/28/2022	3/4/2022	5d
2	Reasearch 1	3/7/2022	3/11/2022	5d
3	Reasearch 2	3/14/2022	3/25/2022	10d
4	Delevrable 1	3/28/2022	4/4/2022	6d
5	Delevrable 2	4/5/2022	4/12/2022	6d
6	Delevrable 3	4/13/2022	4/25/2022	9d
7	Delevrable 4	4/21/2022	4/29/2022	7d
8	Final report	4/27/2022	5/12/2022	12d
9	Final presentaion	5/16/2022	5/16/2022	1d
10				
11				
12				
13				

3.2 Feasibility Assessment

The window clean robot provides an application for the iPhone to control it remotely, this will have an impact in the social feasibility in terms of ease of use for all ages especially elder people. The second one is the market feasibility, here with our product we are targeting Kuwait and The GCC Market because of the dusty weather conditions in particular the targeted people and those who have a lot of windows or glass surfaces which is risky to clean it and needs an effort to do it, therefore we are solving this issue by selling (window clean robot), for sure there are competitors however our aim is to sweep the market by selling our product with an affordable price, safe home usage, light weighted and high efficiency.

3.3 PERSONNEL EFFORT REQUIREMENTS

Major tasks:

Task	Description	Estimated time
Thinking in useful project	Discussing with the group member Ideas	2 weeks
Starting to do research about several Ideas	Dividing the task on each Of us	1 week
Deciding the final project	After a lot of researches and ideas we share we choose the window clean robot	48 hours
Searching for the accurate path	The team started to search about robot path algorithm in general and in our project in particular	3 weeks
Comparing the solutions	Group members were finding the difference between each path	1 week
SOFTWARE/HARDWARE	searching about the software and hardware	2 week
Designing	Our team start to design the project	2 week
Finalizing	Documenting all the researches about the component, the mapping path algorithm the software codes and the project designing	3 weeks

3.4 OTHER RESOURCE REQUIREMENTS

There are some hardware/software resources that will not be included in the total cost of

the project which are:

The hardware resources that are not included in the total cost:

- Switch, using for turning on and off the robot.
- Chime, used to start and to end the working period also to notify if any obstacle found.
- Bluetooth, to the robot connected to the mobile phone.
- Wi-fi, as a group we already have a wi-fi devices with internet connected.
- A computer, to program all the codes needed for the project.
- Object, to do the test for avoiding obstacles/objects feature we can use any object.
- Plastic, using it in case body for the device.

The software resources that are not included in the total cost:

- Using C++ programming language
- C#
- Python

PROJECT PROPOSED MILESTONES AND EVALUATION CREITERIA			
lestones	2 Comparisons		ALUATION CRITERIA
Boards	Arduino Uno	Raspberry PI	
Operating system	None	Some flavor of Linux	
Memory	2 kb	1 GB	Both have different features, but we focused on the features we need for our project, so our best choice is Raspberry PI.
GPU	None	Built in	
Networking	None	Ethernet, Wi-fi, Bluetooth	
USB ports	1	4	
Programming language	Python	C/C++	Both are strong programs, but we prefer python. The reason is that Operating System Raspbian comes preloaded with Python, the Raspberry Pi's official programming language. It also has a lot of the libraries provided by various organizations (Ex- OpenCV for image processing).
Software and algorithm complexity	High	Medium	

3.5 Financial Requirements

We have financial requirements that we need it in our robot windows cleaner. And to know how much it cost

Component name	Number of parts needed	Price
Arduino Uno	1	30$
Raspberry pi	1	150$
LED	1	8$
Wires box	1	7$
Distance sensor 4 pcs	1	-
chime	1	34$
The total price		unknow

4 Closure Materials

4.1 Conclusion:

Reduce the amount of water wasted Improve home cleaning technology using ML (machine learning) & AI (Artificial intelligence) Help older people to easily clean their own homes safely Overall the main goal is to make the life easier and invent a helpful product like our window clean robot. And hopefully in future we are trying to make our robot eco-friendlier so all the parts of the robots can be recycled.

4.2 REFERENCES

[1] Young-Ho, c., & Kwang-Mok, J. (2011). *Windoro: The world's first commercialized window cleaning robot for domestic use.* International Conference on Ubiquitous Robots and Ambient Intelligence (URAI). Retrieved 5 1, 2022, from https://ieeexplore.ieee.org/document/6145947

[2] Young-Ho, c., Jae-Youl, L., Jong-Deuk, L., & Ka-Eun, L. (2012). *SMART WINDORO V1.0: Smart window cleaning robot.* International Conference on Ubiquitous Robots and Ambient Intelligence (URAI). Retrieved 5 1, 2022, from https://ieeexplore.ieee.org/document/6462948

[3] kiterobotics. (22). *Revolutionary facade cleaning robot for high buildings*. Retrieved from meet kiterobotics: https://www.kiterobotics.com/en/

[4] Ontario Professional Engineers Act. (n.d.). Retrieved May 11, 2022, from https://engineerscanada.ca/sites/default/files/Ontario/Ontario_Professional_Engineers_Act.pd

[5] Professional engineers act - R.R.O. 1990, reg. 941. (n.d.). Retrieved May 11, 2022, from https://engineerscanada.ca/sites/default/files/Ontario/Ontario_Reg_941.pd

[6] Code of ethics. Professional Engineers Ontario. (n.d.). Retrieved May 11, 2022, from https://peo.on.ca/licence-holders/code-ethics

[7] Improvement, H., & Outlets? S. (2022). Should You Use 12 or 14-Gauge Wire for Outlets? | Pepper's Home & Garden. Retrieved 10 May 2022, from https://peppershomeandgarden.com/12-or-14-gauge-wire-outlets/

[8] Best arduino RC cars (including Bluetooth RC cars). All3DP. (2021, September 17). Retrieved May 11, 2022, from https://all3dp.com/2/arduino-rc-car-bluetooth-project

[9] Home. KITE Robotics - Veilig en accuraat glas en gevel reinigen op grote hoogte. (n.d.). Retrieved May 11, 2022, from https://www.kiterobotics.com/en/

[10] Skyline Robotics: The future of automated window cleaning. (n.d.). Retrieved May 11, 2022, from https://www.skylinerobotics.com/

[11]Miao, X., Lee, J., & Kang, B. (2018). Scalable Coverage Path Planning for Cleaning Robots Using Rectangular Map Decomposition on Large Environments. *IEEE Access*, *6*, 38200-38215. doi: 10.1109/access.2018.2853146

[12]Galceran, E., & Carreras, M. (2013). A survey on coverage path planning for robotics. *Robotics And Autonomous Systems*, *61*(12), 1258-1276. doi: 10.1016/j.robot.2013.09.004

[13]Ajeil, F., Ibraheem, I., Azar, A., & Humaidi, A. (2020). Grid-Based Mobile Robot Path Planning Using Aging-Based Ant Colony Optimization Algorithm in Static and Dynamic Environments. *Sensors*, *20*(7), 1880. doi: 10.3390/s20071880

[14]Almadhoun, R., Taha, T., Seneviratne, L., & Zweiri, Y. (2019). A survey on multi-robot coverage path planning for model reconstruction and mapping. *SN Applied Sciences*, *1*(8). doi: 10.1007/s42452-019-0872-y

[15]Ajeil, F., Ibraheem, I., Azar, A., & Humaidi, A. (2020). Grid-Based Mobile Robot Path Planning Using Aging-Based Ant Colony Optimization Algorithm in Static and Dynamic Environments. *Sensors*, *20*(7), 1880. doi: 10.3390/s20071880

[16]Matt. (2022, May 6). *Embrace lazy, why you need window cleaning robot*. Little Robot Shop. Retrieved May 10, 2022, from https://littlerobotshop.com/are-robot-window-cleaners-any-good/

[17]Connaughton, N., says:, R. V., says:, N. C., & says:, H. J. L. (2016, March 9). *Roomba algorithms and visualization*. Code and a glass of wine. Retrieved May 10, 2022, from https://blog.niallconnaughton.com/2016/01/25/roomba-algorithms-and-visualization/

[18]Do robot window cleaners work? Robot Chores. (2021, October 4). Retrieved May 10, 2022, from https://www.robotchores.com/do-robot-window-cleaners-work/

[19]irobot. (2016, August 4). *Clean Floors with the press of a button | roomba® 900 series | iRobot®*. YouTube. Retrieved May 10, 2022, from https://www.youtube.com/watch?v=XIPzSmwClJ8

[20]YouTube. (2020, March 1). *IRobot vacuum cleaner review in 2020: It's almost perfect! (iRobot Roomba E6 review)*. YouTube. Retrieved May 10, 2022, from https://www.youtube.com/watch?v=84wHv36s7tU&t=485s

4.3 Appendices

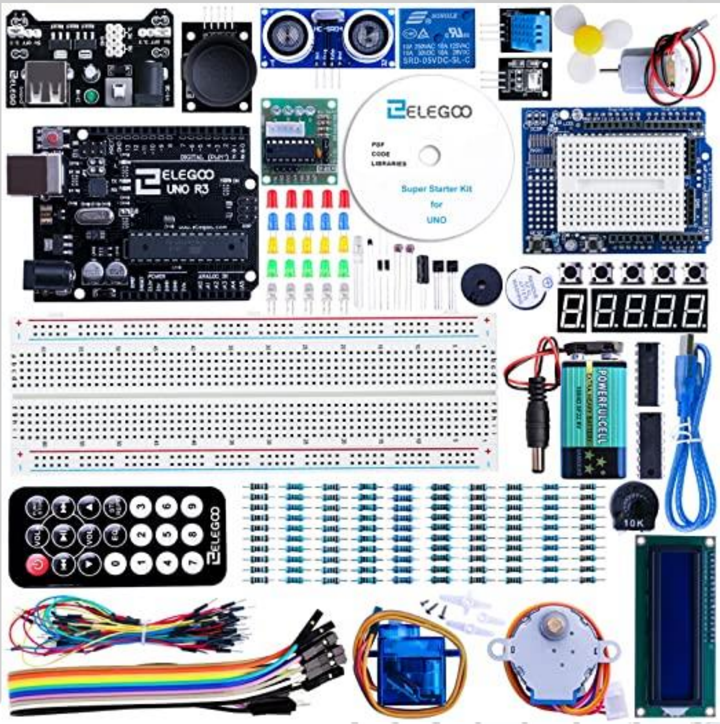


Figure3: Chime system

Figure 4: sensor

Figure 5: switch (on/ off)

Figure 6 : raspberry pi 3