University of Maryland College Park

Professional Master of Engineering

Robotics Engineering

ENPM808 - Independent Study

Coverage Path Planning for UV Sterilization Robot

Students:
Nupur Nimbekar (116894876)

Guide:
Reza Monfaredi,Ph.D.

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Introduction:

UV Sterilization technology can assist us in various fields such as, air disinfection, water disinfection, wastewater treatment, medicinal facilities, and laboratories. There are UV Sterilization robots tested and used in the field of horticulture serving the cultivation process. When exposed to UV light, the genetic material in cells is damaged as chemical bonds are severed within the DNA structure. Prolonged exposure to UV light inflicts more damage to the point where the DNA cannot be repaired, and cells die as a result. [1] Advancing technology has led to development of UV Sterilization Robots which can use this light and clean highly contaminated rooms while reducing human contact with the infected surfaces. [2] There is a huge unexplored potential for handling disinfection via a mobile robot solution with a UV light system that is designed specifically for disinfection of hospitals. [3]

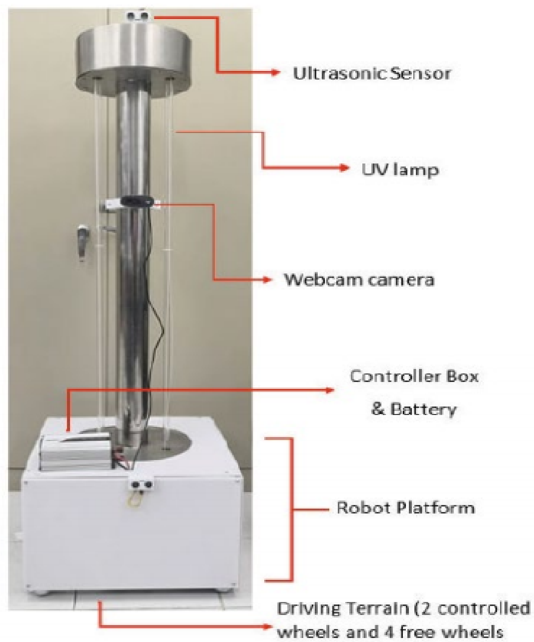

Figure 1: UV Sterilization Robot

To increase the efficiency of these robots, we can study the Coverage Path Planning (CPP) algorithms used in the UV Sterilization Robots and review the results of the comparative study the coverage path planning algorithms to understand the advantages and disadvantages for them.

The main idea behind path planning is connecting a destination and target point in the most optimum way possible. In the scope of this paper we will discuss two techniques to implement the path planning algorithm in an indoor area aiming at coverage of points in a specified area.

The two algorithms that will be discussed, compared and implemented as a part of the study are Standard geometric distribution based CPP and Voronoi Cell based CPP.

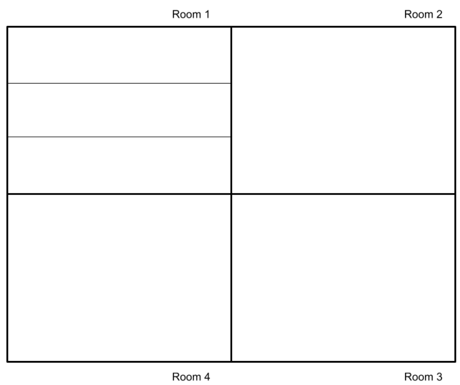

Figure 2: Standard CPP

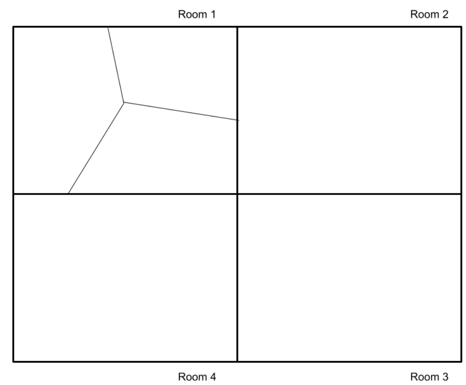

Figure 3: Voronoi CPP

Literature Survey :

Literature Survey will present us with basic idea of coverage path planning algorithms used and the result of comparative studies conducted so far.

Task partitioning technique has been proposed in the previous literature. The paper supporting this approach for coverage path planning, suggests that the target region should be divides using voronoi cell decomposition and then the target voronoi cells may be explored using Boustrophedon-decomposition-based coverage or Spanning tree coverage method. This paper explores different ways of Voronoi cell decomposition for global path planning (euclidean, Manhattan, geodesic, and geodesic-Manhattan) to divide the area in such a way that no unreachable section is formed. For local path planning, Boustrophedon-decomposition-based coverage (exact cell decomposition) and Spanning tree-based coverage (approximate cell decomposition) for coverage path planning [4]. From this paper, we observed that although a single robot can cover a region with CPP, partitioning and distributing regions drastically increases coverage performance.

Studies have been conducted where the voronoi cell decomposition was used to divide the region in n cells and the edges for cell were used to map the path from start to end. Although this gives us a path from charging station to the target region, A-start might provide us with a more optimal solution. Additionally, this would not cover the coverage path planning and we would still need either Boustrophedon-decomposition-based coverage or Spanning tree coverage to implement coverage planning.

Later we tried to understand the applications of spanning tree coverage (STC) planning. Spanning Tree Coverage ensures that every node of the graph is connected.The paper for on-line coverage for grid environments explores the comparison of Spiral-STC and Full-Scan-STC. If on-line coverage is used, it decreases the overlapping but that may affect the coverage rate of a region. The concept used for on-line coverage is based on dividing each cell into a 2-by-2 grid and use the central point for navigation. This makes the grid sized to be explored in reality 2 times larger in memory as compared to the actual map. Hence, the robots with low memory may have difficulty with the path or a multiagent systems may be used for coverage. [5]

Some paper have used DARP (Divide Areas based on Robots Initial Positions) algorithms with the help of multiagent systems to achieve high efficiency rate. The idea of equally distributing the space for n robots is highly affected by their initial positions. The DARP+STC is one of the most efficient approach used for coverage planning. [6]

The literature survey shows us how coverage path planning can be categorized on various basis, but we shall consider various algorithms and their study to understand their advantages and disadvantages.

Objectives :

Main aim of the project is to conduct a comparative study of Standard CPP and Voronoi CPP and to determine which is the most suitable approach for indoor navigation of UV Sterilization robot. The target region will be divides into sub-regions based on the region that can be covered by individual robot. Ideally, multiple robots would be deployed in each room based on the area of the room. But for experiment purposes, we will send one robot through all regions. The robot is capable of covering 64sq meter of area in each charge.

Secondly, we assume that once the agent has cleaned the designated room, it will be capable of navigating back to the charging station using Astar algorithm. Also, anytime the charge of robot reaches 20 percent, it will halt the disinfection process and navigate back to the charging station using a-star algorithm.

The main requirement of the accurate and optimal path planning is the accessibility of environmental and odometric information. This depends upon how accurate the environmental and odometric information is attained by the robot. In addition to a multiagent system, the robots will also be detecting contamination around them to ensure that the exposure time is efficient.

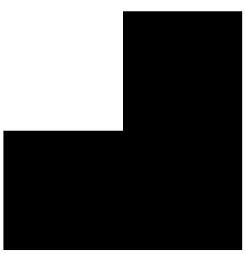

Figure 4: Room 1

Figure 5: Room 2

Figure 6: Room 3

Figure 7: Room 4

Figure 8: Black region indicates the invalid region or other rooms

Methodology :

Path planning is considered as one of the most important tasks for any kind of navigation-based robot. The attempt of the proposed algorithm would be to understand the applicability of Coverage path planning for disinfection tasks.

Coverage Path planning.

In an contaminated region, the ideal path would be the one covering maximum area while disinfection process along with continuous UV light exposure. The Spanning Tree coverage algorithm ensures that every node of the given region is covered.

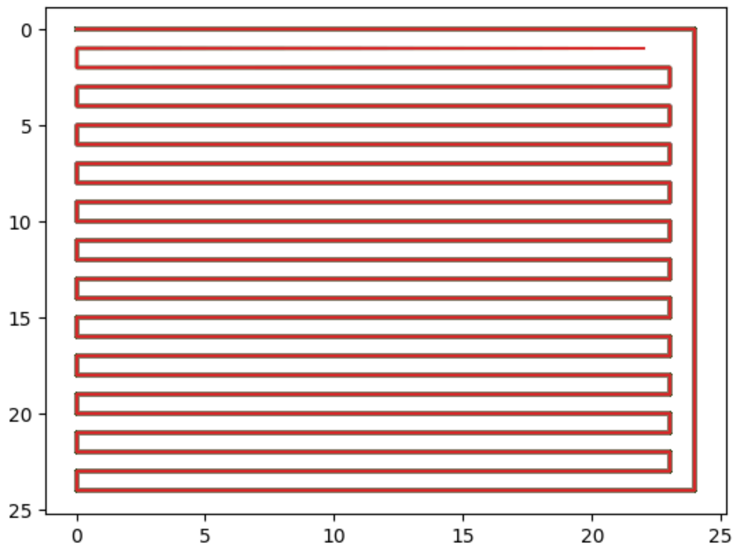

Figure 9: Spanning Tree coverage in a sample region of 25 by 25 m

Standard Partition CPP Vs Voronoi Partition CPP

The standard approach of division divides the target region geometrically in the sub-regions based on the number of robots required per room. This type of division is more effective when rooms are evenly spaced. Whereas, for Voronoi partition we use Voronoi Cell decomposition to divide the target region. Let say, we have P is a set of n points in a plane, then the voronoi algorithm lets use decompose the plane in n cells with a cell for each point. This decomposition is done such the convex sub-regions are generated around the point in P and every point in the convex region will be accounted for the generated point from P. A Standard Partitioning CPP distribution of n points in a d - dimensional space can have $O((nd) + d)$ vertices, whereas, a Voronoi Partitioning CPP distribution of n points in a d - dimensional space can have $O(n^{[d/2]})$ vertices. Hence the Standard approach will store less intricate data but the memory of robot will last longer as compared to the Voronoi approach.

Path planning Approach

1. A map of target space will be generated. Then based the user input a room will be selected.
2. The room will be divided into n number of sub-regions based on the type of division selected 'standard' or 'voronoi' and the agents required to disinfect the entire room.
3. Spanning tree coverage planning will be implemented to generate the path required to cover each sub-region.

Results :

The figure 10 demonstrates the path created for sub-regions created by Standard partitioning.

We can see the entire sub-region was covered but minute overlapping was observed in all cases. Time taken to calculate the nodes in the path for the agent was between 2-4 seconds with 100 percent coverage.

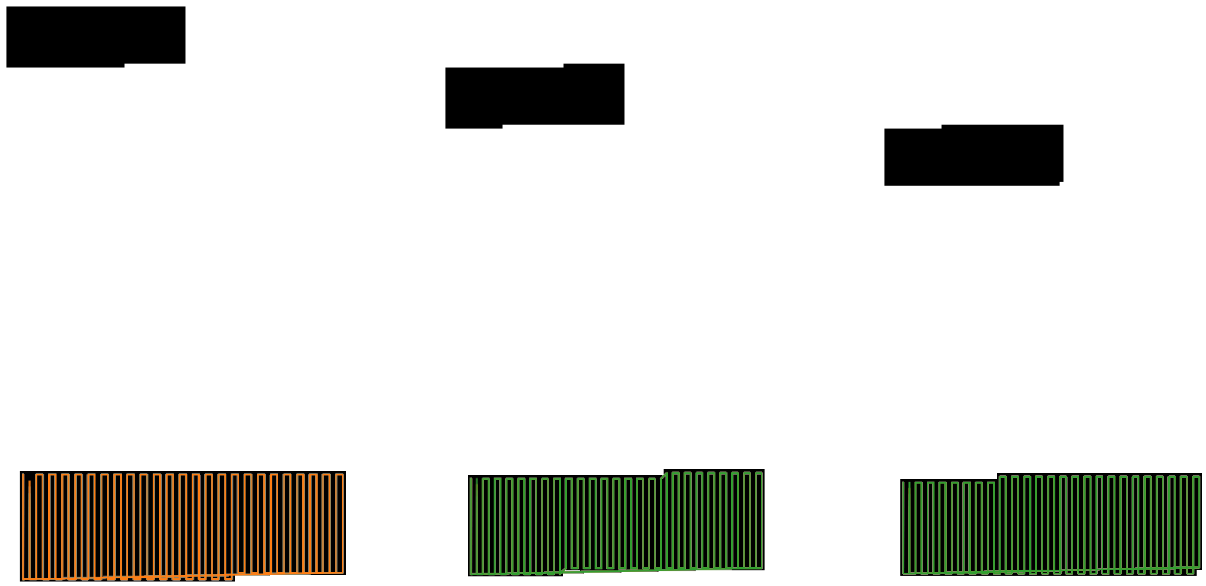

Figure 10: Path for sub-regions created by Standard Partition.

The figure 11 demonstrates the sub-regions created by Voronoi partitioning and figure 12 demonstrates the path coverage of each sub-region. Time taken to calculate the nodes in the path for the agent was between 4-7 seconds with 100 percent coverage.

Figure 11: Voronoi partition for Room 4

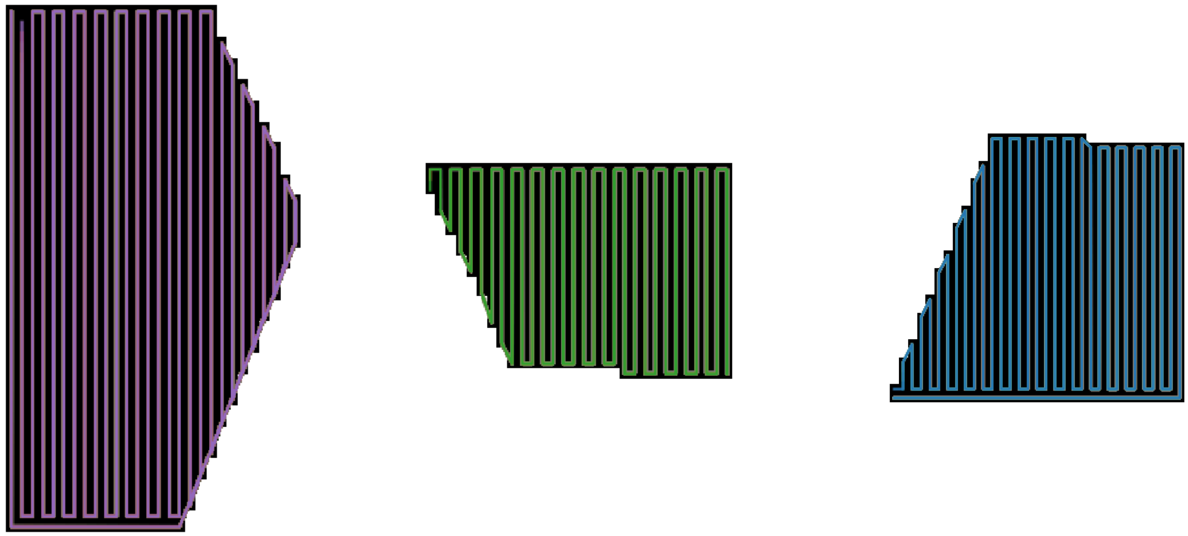

Figure 12: Path for sub-regions created by Voronoi Partition.

Table 1: Performance comparison

Room	Standard CPP	Voronoi CPP
1	12.67	21.08
2	14.64	11.15
3	11.61	14.42
4	13.00	22.31
Total	**52.27**	**68.96**
Efficiency Percent	**131.93%**	**100.00%**

Conclusion:

The Standard Partition CPP covers the target region is less time as compared to Voronoi Partition CPP. The observed efficiency increased by 31.93 % as stated in Table [1]. A slight overlapping was observed in terms of covered nodes near the edges. It was also observed that while using Voronoi Partition the sub-regions were not distributed equally and were different in terms of area covered. This can be improved if iterative algorithm like Lloyds is integrated with the Voronoi Partition or if Centroidal voronoi Decomposition is used. Although the efficiency rate of Standard Partitioning is higher than voronoi partitioning, Voronoi Partitioning will be more effective for regions with uneven boundary conditions.

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Thank you