Paper-Based Plasma Sterilization iRobot

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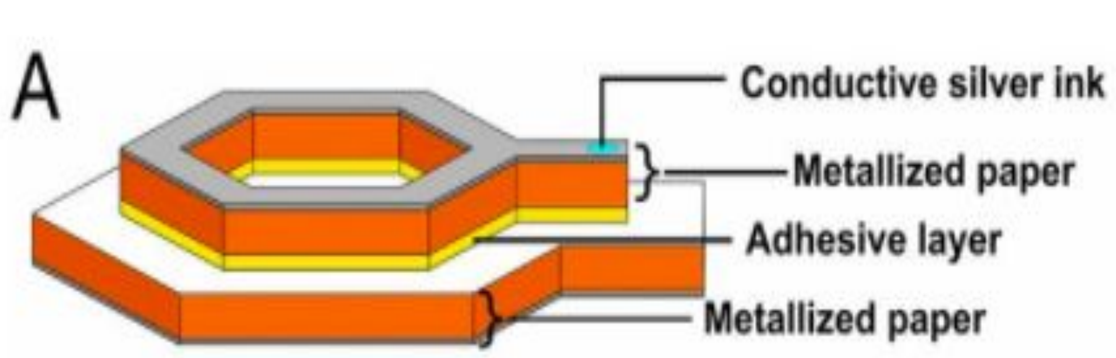
Abstract

Following the outbreak of COVID-19, there is a greater need for sterile work surfaces, particularly in areas with large numbers of people. Thus, the overarching goal is to develop a method for sanitizing large floors, counters, desks, and other surfaces, while not putting a human worker at risk of infection. This issue highlights how crucial it is to integrate mobile robotics in sanitization procedures in order to facilitate the establishment of sterile working environments. The following work describes the modification of an iRobot Create 2's hardware and software.
At less than two hundred dollars the iRobot is a Roomba 600 series mobile vacuum that provides the perfect chassis to reprogram and attach underneath thin paper-based plasma sanitizers. These sanitizers feature a metallic-like paper structure that enhances material flexibility and aids electrical discharge used for creating plasma. Both volume and surface plasma is created in the process, which has been used to eliminate *Saccharomyces cerevisiae*, *Escherichia coli* cells, and other harmful microorganisms. These plasma generators are also completely biodegradable, and thus helps provide an eco-friendly solution for sterilization processes. Before attaching these sanitizers to the iRobot, however, analyzing the mobility of the robot through a simulator is critical for receiving prolific insight into parameter accuracy and collision avoidance among other key metrics. Moreover, a simulation was developed using MATLAB software, which helped generate a rectangular target area and a solid iRobot model. Carefully programmed path-planning and trajectory functions allowed the model to trace the perimeter of the area by following a set of waypoints. This computationally-driven experiment shows promising results toward reprogramming the iRobot Create 2 and equipping it with plasma sanitizers to combat COVID-19 and other harmful microbes.

GETUP Research Thrust:
- Devices and energy management systems for energy generation, conversion and storage

Previous Lab Work



Paper is a versatile material with applications in advanced manufacturing techniques. The Rutgers lab for Machines, Manufacturing, and Mechatronics sought an advantageous approach to flexible electronics by using paper due to its bendable structure, environmental friendliness, and cost-efficiency, among other characteristics. This approach is what helped spark paper-based electronics and also led to enhanced applications in energy harvesting, acoustics, situational awareness sensors, energy-storing, displays [1], and plasma sanitization. As shown in figure A, plasma sanitizers feature a layered structure and a hexagonal pattern that is optimal for using a small amount of perimeter to completely cover a surface [2]. Moreover, the catalyst for the sterilization of harmful microbes is called dielectric barrier discharge or DBD. In previous lab work, these self-sustaining electrical discharges that are DBD create both volume and surface plasma through the separation of two electrodes by a permeable layer made up of cellulose fibers in the metalized paper.

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RISE at RUTGERS Research Intensive Summer Experience

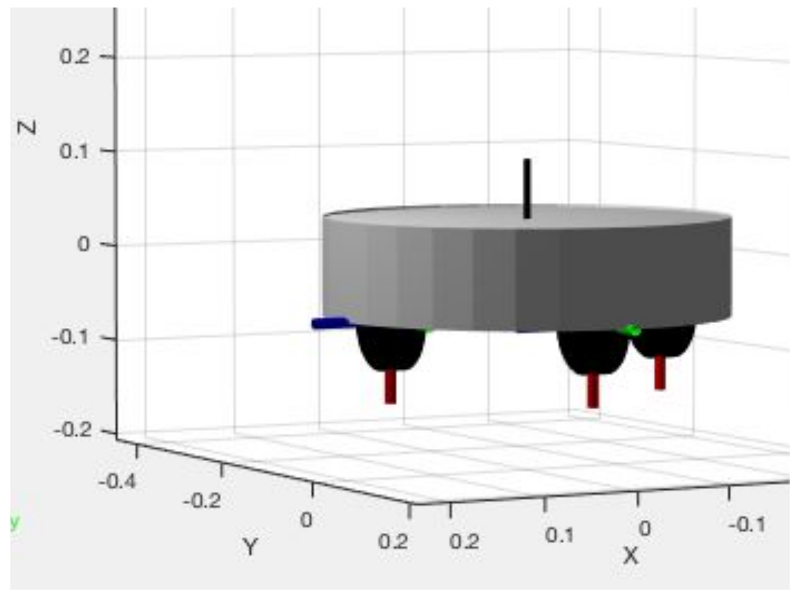
Methodology

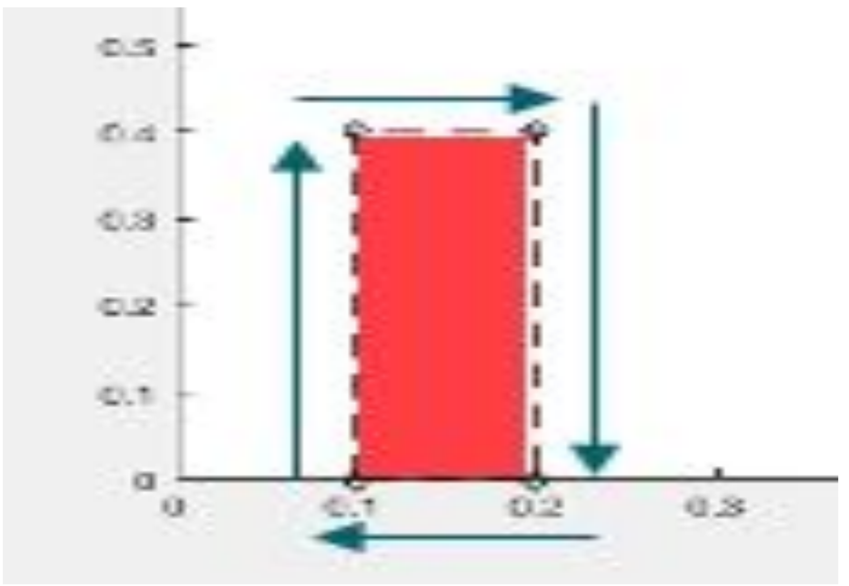
"Synthesize the functionality of paper-based plasma sanitization and mobile robotics to create a working package capable of vacuuming and sterilizing surfaces"

- The robotics system toolbox was used to visualize a simulation for observing robot mobility via MATLAb
- The simulation loaded a pre-designed target area and 3-D model of the iRobot to initialize perimeter tracing procedures
- During the simulation, it was observed that the robot was able to use look-ahead functions to closely follow the given parameters while avoiding any obstruction
- Once the simulation concluded, data was extracted and converted into a CSV file for numerical examination

Results

The figure on the right was created using a Unified Robotic Description Format or URDF. This method of formatting was useful in defining the robot's material by assigning a color to each component through what is called RGBA. The URDF also established links which are the pieces that make up the general structure of the robot model. These links include the base, right wheel, left wheel, and the navigator wheel; all to their appropriate dimensions. This format was also useful in creating joints that hold the robot links together. These joints were of revolute origin which features one degree of freedom along an axis and is bound by an upper and lower limit.





The figure on the left is the target region and represents an unsterilized working area such as a desk or countertop. This area was created using a conventional rectangular defining function that allowed inputs for face color, edge color, line width, line style, curvature, and an x limit as well as a y limit. The arrows indicate the direction for motion or "waypoints" that the iRobot will follow within the simulator.

Acknowlegements

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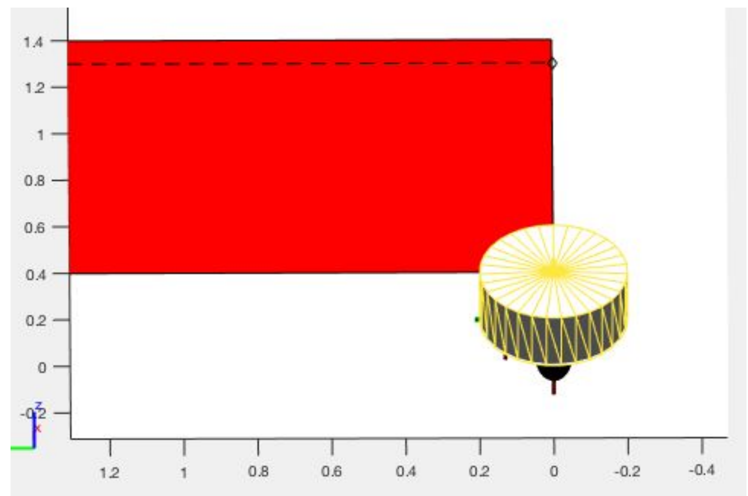
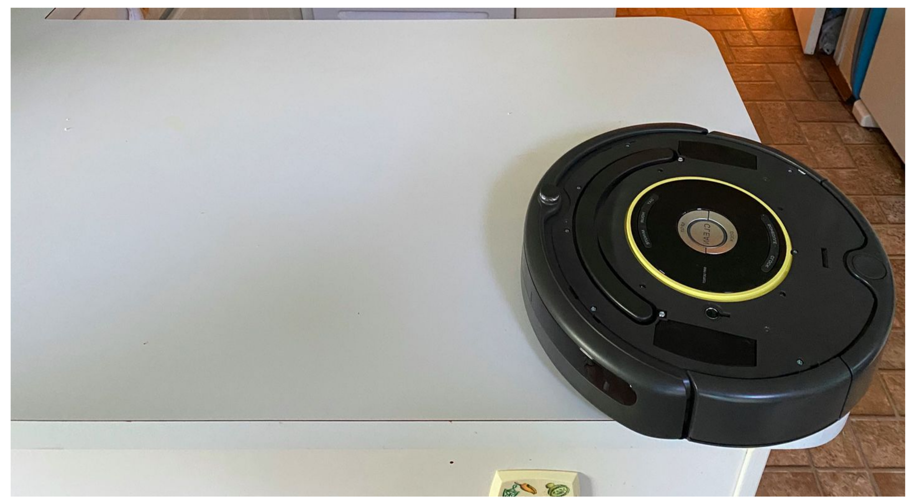
More Results





The figure above represents the simulation, which shows the iRobot at the bottom left origin of the rectangular target area, ready to begin tracing the edges along the perimeter. The iRobot was given a path planning function which defined 4 points along the perimeter that it needed to remain within. The heart of the simulation was powered by a trajectory planning function called Pure Pursuit Controller which defined the waypoints and told the iRobot to navigate from every corner to its original pose. After every run, the algorithm exported a spreadsheet which gave a numerical depiction of how precise the iRobot was in following the perimeter during sterilization. Any inconsistencies in this data implied a collision and required reprogramming of the iRobot's navigation functions.

Conclusions and Future Work

- The path planning and trajectory functions that were developed presented simple tracing motion, however, they will lay the foundation for more complex mobility algorithms for sterilizing a variety of areas.
- As represented by the simulator, the algorithm is complete and is ready to begin stage 2 which is uploading the program to the physical iRobot for further experimentation. This examination includes visualizing how efficiently the Roomba can trace a real rectangular table or countertop.
- These steps lead to stage 3, which includes mounting the paper-based plasma sterilization technology onto the chassis of the iRobot to begin sterilization procedures. Data will then be extracted from the iRobot's sensors to determine the appropriate amount of passes needed to sterilize an area to decrease unnecessary energy output.
- The concepts of paper-based plasma sanitization and mobile robotics can also apply to window bots and drones. The results from this research show that we may begin to see paper-based electronic devices more frequently in the workplace; to positively impact the future of sterilization processes.

References

- [1] "A flexible future for paper-based electronics" Liang Liang, Tongfen & Zou, Xiyue & Mazzeo, Aaron
- [2] "Paper-based plasma sanitizers"
Jingjin Xie, Qiang Chen, Poornima Suresh, Subrata Roy, James F. White, Aaron D. Mazzeo

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