**Scenery Robot: Robotic Path Planning for Theater Scenery Movement**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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## ABSTRACT

The Scenery Robot project aims to address the limitations of traditional winch and track systems for moving large set pieces on stage. The use of this system is labor-intensive, expensive, and lacks adaptability to changes. The solution is a scenery robot that can carry heavy objects around on stage, navigate any stage independently, and follow flexible paths of travel. To design and implement the solution, the team leveraged skills in front-end development using JavaScript, CSS, and HTML, version control framework Git, and creating resilient network communications using an API between the node JS server and the robot firmware in Python. The robot is powered by two independent gear motors and uses odometry algorithms and sensors for navigation. A custom-built web application is used to plan the desired path of travel, calculate critical points for the robot to follow, and communicate those points to the robot. The major outcome of this project is a more flexible and cost-effective way to move large set pieces on stage, allowing for greater creativity in theater productions. Future work toward use in a live show should involve programming pathing resets that allow for ease of use in rehearsals and adding functionality to break down a path into sections that align with lighting and sound cues used in productions.

## 1. INTRODUCTION

Moving heavy scenery on stage has been a challenge for theater productions since ancient times. In the early days, stagehands used brute force to push and pull scenery, a time-consuming and physically demanding process. Over time, stage technology has evolved to include more efficient and sophisticated methods.

One of the earliest solutions was the use of wheels. This allowed stagehands to move scenery more easily, but the wheels were noisy, prone to getting stuck or jammed, and required a smooth surface to move on, which limited the types of terrain that scenery could be moved across.

Another solution that was developed was the use of winches and tracks. Winches allowed for heavier scenery to be moved, and tracks provided a more stable platform for the scenery to move along. However, these systems were expensive to install and maintain—just the winch system can cost upwards of $25,000 (Pushstick), requiring specialized equipment and trained operators. They also required a significant amount of space and power, making them impractical for smaller productions.

Today, new technologies have emerged to address these challenges. Motorized systems have become more compact and affordable, allowing for more flexible use in smaller productions. Additionally, new materials and designs have been developed to improve the durability and reliability of these systems.

Despite these advances, there are still challenges to overcome. Motorized systems can be noisy and require maintenance to keep them running smoothly. They also require careful coordination with performers and other production elements to avoid accidents or mishaps.

## 2. RELATED WORK

Scenery robot work is something that has been relatively untouched by others, the intersection between those in the theater and engineers being relatively small. In another thesis, Sisney et al. (2019) utilized DMX to control scenic automation. While the physical model is similar, created by a rolling robot that goes across the stage, the path drawing process is very different from our work. In this method, a light board is used to manually move the robot across the stage. It does allow for small-scale automation, but does not allow for the robot to be specified directly to the stage. This does provide an important step in scenery technology, allowing for the integration of a robot into the arts to allow for the movement of larger set pieces.

More generally, work has been done to allow for robots to move around following a path. One of the most prominent examples of this was the work by Hassani et al. (2018), which sought to help robots to avoid obstacles in a known environment. This work worked to increase the ability of robots to move around obstacles in the path and is very relevant to the scenery design process that requires the robot to go around other set pieces and actors on the stage. Other notable works in robotic movement include Hong and Park (2011)'s work on turning point algorithms and Cherni et al. (2016)'s work on path planning of mobile robots.

## 3. PROJECT DESIGN

The first iteration of this project, as well as other schools' drama departments, have attempted to address the issue of scenery movement through the use of a remote control robot. However, this approach has significant limitations, with the most significant being human error due to the inconsistency and imprecision of human operation. In addition, it is challenging for the driver to have a clear and comprehensive view of the stage, making it difficult to control the robot effectively.

To overcome these limitations, we developed the Scenery Robot web app, which serves as a control panel for robot path planning, calculation, and communication. The app features a blank canvas with a grid by default, as well as a side panel with icons representing various screens, including home, grid, draw, stage map, save/upload, and robot communication.

### 3.1 Path Drawing

The path drawing feature allows directors to carefully plan the robot's path in advance. Users begin on the home page and can create a stage by specifying dimensions and a starting point for the robot. They can then click on the starting point and drag a path that the robot will follow. Our app also allows for importing a dxf file containing a stage map of all scenery objects on the set as an overlay on the drawing canvas, enabling directors to visually plan the robot's path against the set design. If users want to draw their path in segments, they can pick up their mouse and resume drawing by clicking and dragging from where they left off.

### 3.2 Critical Point Extraction

On the draw screen, users can click "get points" once they have finished drawing their path, and critical points will be extracted. The position values of the drawing are stored in an array, and every 20 pixels along the path, a new critical point is extracted and added to a new critical point array. This list of critical points is then displayed as ordered pairs, which reflect the position of the points on the screen, scaled with the user inputted dimensions of the stage.

### 3.3 Robot Communication and Motion

The robot communication feature allows users to send the path to the robot when they are ready for it to be loaded. The node.js server posts the points to an input endpoint using a POST request, which the Python-based firmware on the robot accesses on a loop with a GET request until the endpoint is updated. Once the robot has successfully loaded the path, the user can click the play button for the robot to follow the path relative to the robot as though it were in the designated starting position and users can play and pause the robot as it follows the path. The robot converts these critical points into movement using the pure pursuit algorithm to determine the proper amount and timing of rotations applied to its independent wheels, with one on each side.

## 4. RESULTS

The Scenery Robot project has undoubtedly been a success at creating a platform for users to plan a predetermined path for a scenery object to move across the stage. The application makes it easy to make changes to a path, and the option to overlay the stage map that every production already uses when designing the set allows the planning of the robot's path to be seamless within the production ecosystem.

Ultimately, there are a few quality of life problems that need solving before the project can achieve its overarching goal of being used in a live theater production. Once those changes are made and it can be incorporated into a show, further data on how to improve the robots use within a production will be revealed.

## 5. CONCLUSION

The Scenery Robot project's use of pre-drawn paths to control a robot holding scenery via our web application provides a viable solution to many of the challenges faced by other approaches to moving scenery, such as the remote controlled robot approach. Our approach offers greater precision and control over the movement of scenery, as well as reducing the need for specialized training and equipment. These advantages position our solution as a promising alternative to traditional methods of moving scenery in theatrical productions.

## 6. FUTURE WORK

A large barrier for this robot being used in productions is the lack of an easy way for the robot to revert to its prior position. This issue is mostly relevant in rehearsals due to the fact that the starting point could be a variety of places depending on the part of the scene being redone. Another improvement known as the 'cue system' that allows for more seamless integration with the standard lighting and sound cues by splitting up a path into sections and independent play pause buttons would also serve to address the aforementioned issue, as a user could select a particular place along the path for the robot to reset its position and later start from.

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