Tilting Tiles: A 3 Degrees of Freedom Stewart Platform Array

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Abstract

Tilting Tiles, a research project focused on developing a kinetic art sculpture that merges modern manufacturing techniques with electronics design, consists of a series of interconnected triangular modules. Each Stewart platform module is capable of tilting in two axes and translating horizontally. These platforms, mounted to a wall, collectively form an interactive dynamic surface that displays preprogrammed animations or alternatively responds in real-time to inputs from sensors, cameras, or web-based systems.

The development of Tilting Tiles explores a plethora of manufacturing processes to ensure durable, scalable plastic components. Early prototypes use 3D printing for rapid iteration, while the final version relies on production-grade casting. Each module features custom electronics, including multiple printed circuit boards for power management and microcontroller functionality. The main control unit orchestrates animations through the modules wirelessly. The system is scalable, allowing for installations ranging from 24 tiles, as shown in Figure 3, to several hundred units, making it suitable for large-scale interactive displays in spaces like science museums, offices, or other institutional settings.

Tilting Tiles serves as a comprehensive investigation into the intersection of art, engineering, and technology, contributing new methodologies for kinetic sculptures and interactive installations.

Introduction

Each module within Tilting Tiles is designed to be semi-modular. They are designed not as individual products, but to be installed in groupings by a technician. This means that there are different enclosure designs depending on their position within the arrangement of tiles. In contrast, the power distribution and microcontrollers are completely scalable regardless of the arrangement of tiles. For groupings of more tiles, additional power supplies can be incorporated, and the new microcontrollers can be recognized by the central control unit seamlessly.

Continual improvements focus on new interaction methods. For example, cameras could track spectators to animate tiles in response, while LIDAR or distance sensors could trigger effects in larger installations. Alternatively, real-time internet data, such as tidal patterns, weather, or search trends, etc, could drive the system.

Figure 1. Servo Arm & Linkage Assembly

Figure 2. Single Platform with Accelerometer Mount

Mechanical Design

The Stewart platform mechanism traditionally operates as a 6-degree-of-freedom (DOF) parallel manipulator in a triangular configuration, providing full translational and rotational motion. In Tilting Tiles, however, the design is adapted for simplified motion: it retains tilt and height adjustment capabilities but excludes translational motion in the x and y directions. Instead of conventional linear actuators, Tilting Tiles employs rotor joints, where the rotor arms and linkages, as shown in Figure 1, provide controlled, precise adjustments in tilt and height.

The enclosure, illustrated in Figure 2, is optimized for either injection molding or urethane casting. It incorporates design features essential for molding, such as drafts, bosses, rounded radii, and tongue-and-groove joints, all to ensure structural integrity and moldability.

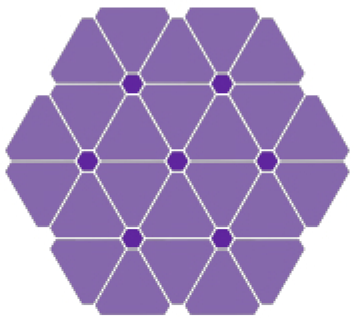

Figure 3. 24-Tile Arrangement

Electrical & Software Design

Each module contains two printed circuit boards (PCBs): one for the buck converter and the other for the microcontroller. Power is supplied to all modules from a centralized 36V, 600W power supply. The buck converters then step down the 36V input to 6V for the servos and 3.3V for the microcontrollers.

Each module uses an ESP32-C6 microcontroller, which is responsible for interpreting the received platform angles and generating the appropriate servo commands. The modules are designed as identical units, each with a unique ID, individual calibration data, and configurable registers. These registers allow the master module to control key parameters, such as interpolation type, speed, acceleration, and other settings for each platform.

The master control unit is a Raspberry Pi 5, equipped with an ESP32-C6 hat that interfaces with the ESP32 wireless network. The Raspberry Pi 5 provides native support for both static and dynamic animations, offering the processing power needed for the system.

Manufacturability & Production

A major component of this product's design is its required use of standard manufacturing techniques. This influences focus on material selection, ensuring that components can be made with readily available, cost-effective materials suited to typical manufacturing processes such as injection molding, additive manufacturing (3D Printing), and urethane casting. Additionally, each part is designed with an emphasis on Design for Manufacturability (DFM), which takes into account individual part costs, tolerance control, and ease of assembly. The design aims to simplify production, reduce manufacturing time, and minimize waste, while maintaining high quality and reliability. Considerations also include ease of maintenance and repair, ensuring that the design remains serviceable and adaptable to future improvements or modifications.

In addition to the platform design, jigs have been created to ensure consistent assembly of components. One jig aligns the servo arm to the servo head at a precise angle each time, while another jig helps press heat-set inserts into plastic parts consistently and vertically.

Conclusions & Next Steps

Tilting Tiles successfully combines innovative kinetic design with scalable electronics, offering a versatile interactive display solution. This project advances kinetic surface artworks, through a modular and adaptable Stewart platform mechanism, robust manufacturing practices, and seamless control systems. Tilting Tiles highlights the combination of art, engineering, and interactivity, creating a new medium for dynamic installations.

The goal is to complete a 6-Tile arrangement by January first, and to complete a 24-tile arrangement towards the end of the Spring semester.

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Acknowledgments

Hacer Varol - Capstone Professor & Advisor
Hector Ochoa - Electrical Engineering Advisor

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