Satellite Orbital Routes

ECE 445 Senior Design Project

Group members:

Zhihua Gong

Lunan Ke

Wenhan Jiang

Kuangji Chen

Advisor: Prof. Pavel Loskot

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1 Introduction

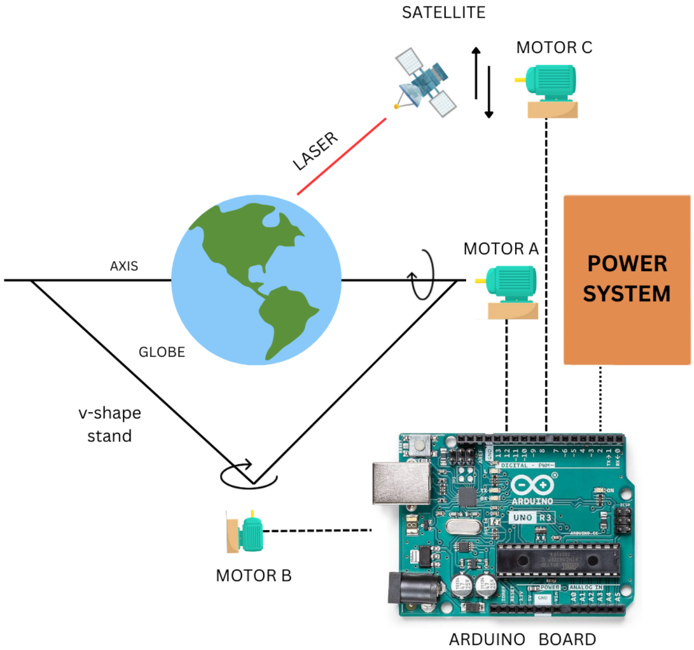
1.1 Problem

Educational institutions, aerospace enthusiasts, and researchers often struggle to visualize and demonstrate the dynamic interactions between satellites and the Earth in a tangible way. Traditional models and computer simulations exist but lack the physical interaction and direct observation components that enhance understanding and engagement. A hands-on, accurate representation of how satellites operate in relation to the Earth, including aspects like orbit altitude adjustments and the Earth's rotation, is needed to bridge this educational gap.

1.2 Solution

We propose to create a 3D hardware demonstrator that physically represents the interaction between a satellite and the Earth. This model will feature a stationary satellite with the capability to adjust its altitude along a one-dimensional axis. The Earth model, placed on a stand equipped with internal wheels, will rotate, simulating the planet's rotation. This setup aims to offer a more intuitive understanding of satellite positioning, Earth's rotation, and their interplay, enhancing educational outcomes and interest in aerospace and earth sciences.

1.3 Visual Aid



1.4 High-level requirements

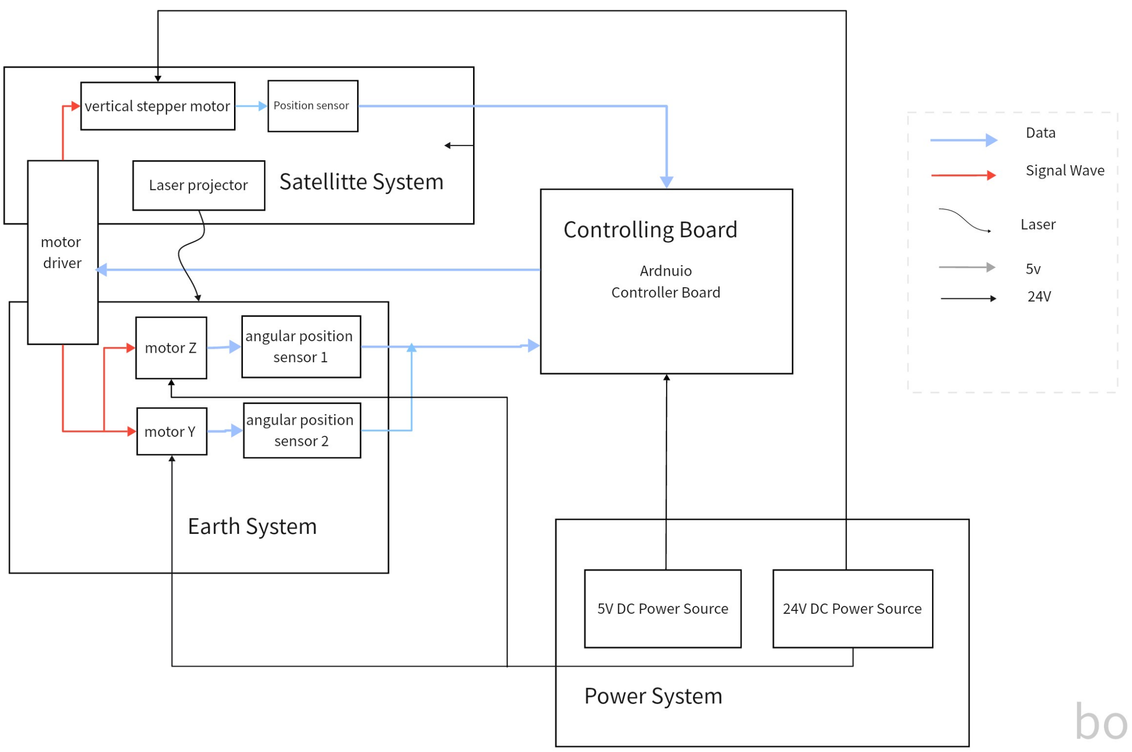
- The globe we use will be of proper size so that it will be too large for the motors to drive or too small for difficulty in visualization, we set the standard of the globe of 30 cm (about 11.81 in) in diameter.
- To ensure the safety and endurance of work, we will use low-power laser and make the whole device as light as possible (less than 500g) so that we can ensure its functions with relatively low power supply.
- The least accuracy of the position controlling of motors should be within 1.8 degrees, otherwise will result into a huge error in earth position.

2 Design

2.1 Design overview

In order to project a trajectory over a globe. We decide to fix the relative position of the satellite from the globe, while the globe itself can rotate in two dimensions to achieve the smooth movement of the satellite. Meanwhile, we will alter the distance between the satellite and the center of the globe to represent the change in altitude of the satellite trajectory. With an initial starting coordinate and a given trajectory, our circuit can turn it into a signal of motion to the motors to correctly represent the trajectory.

2.2 Block Diagram



2.3 Subsystem

2.3.1 Earth System

To achieve the 2-dimensional motion of the globe surface, we adopt the designs shown below to manage it with two motors. In this case, two stepper motors, motor Z and motor Y can realize two canonical angular movements of the globe and further control the latitude and longitude change of the trajectory. Besides, we use two angular position sensors to detect the current state of the globe for accurate controlling. The stepper motors should be 42 stepper motors with 24 V DC power source and controlling by the LN298 motor drivers. The LN298 should be controlled by the Arduino. The least accuracy of the position controlling of motors should be within 1.8 degrees. Within such error, there will not be much differences between the one projected and the real one.

2.3.2 Controlling Board System

Our control circuit will accept the initial coordinate and trajectory function as input. We will use an Arduino board to achieve the control system of the globe. For example, our circuit should turn the coordinate changes in the orbit into the angular movement of the motors. Controlling signal will be sent to the motor driver and then control the movement of the motors. The platform we choose here is Arduino as it can run C scripts, which can be quite beneficial for us to make programming. With this we can deal with the mathematical input correctly and effectively.

2.3.3 Satellite System

In our design, two dimensions of the satellite itself is fixed (its relative position to the globe center) and the only changing dimension is its altitude. We achieve this by adopting a vertical stepper motor and a position sensor. Given the changes in altitude from the given trajectory, the stepper motor can receive controlling signal from the control board and control the vertical movement of the satellite. Besides, we will use a laser to mark the movement of trajectory over the globe surface. The stepper motors should be 42 stepper motors with 24 V DC power source and controlling by the LN298 motor drivers. The LN298 should be controlled by the Arduino. The laser here we use should be a low-power one. Laser with higher power may lead to physical injury in our eyes. Besides, the weight of satellite system should be less than 500g to ensure the motor can successfully control the movement of the satellite. Otherwise, there will be a high errors in the vertical movement of the satellite. Besides, a overweight structure may lead to instability in the system and cause other systemic problems.

2.3.4 Power System

We use one 5V DC power source to supply controlling board and one 24V DC power source to supply the motors. 5V and 24V is the standard input requirement of the Arduino board and motors. Any power source providing different voltage supplies may lead to malfunction of the system.

3 Ethics and Safety

In the development and implementation of our 3D hardware demonstrator for visualizing satellite-Earth interactions, ethical and safety considerations are paramount. Adhering to the IEEE Code of Ethics and ACM Code of Ethics, we commit to prioritizing the safety, health, and welfare of the public in our project activities. Specifically, we will ensure that our demonstrator does not pose physical risks to users, such as electrical hazards or moving parts that could cause injury. To prevent accidental or intentional misuse, we will implement safety features like enclosed moving parts and secure electrical connections and provide comprehensive user guidelines.

Ethically, we recognize the importance of presenting accurate and unbiased educational content, thereby upholding the integrity and respect for intellectual property stipulated in the IEEE and ACM codes. Our project will incorporate measures to ensure the educational materials and software used are freely and ethically sourced or developed in-house, with proper attribution and licensing where applicable.

Regarding safety and regulatory standards, our project will comply with relevant state and federal regulations, industry standards, and campus policies. This includes adhering to electrical safety standards (e.g., UL standards), mechanical safety standards (e.g., ANSI standards), and any specific regulations regarding educational tools and devices. We will review and follow the guidelines set by the Consumer Product Safety Commission (CPSC) and the Occupational Safety and Health Administration (OSHA) to ensure our project meets all required safety criteria.

Potential safety concerns include electrical safety (risk of shock or fire), mechanical safety (risk of pinching or other injuries from moving parts), and laser safety (if applicable, ensuring the laser used for satellite positioning does not pose a risk to eyesight). To mitigate these risks, our design will include protective casings for electrical components, safety guards around moving parts, and the use of low-power, eye-safe lasers, compliant with the International Electrotechnical Commission (IEC) standards for laser safety.

By consciously integrating these ethical and safety considerations into our project design and execution, we aim to provide an educational tool that is not only innovative and engaging but also safe and respectful of ethical standards.