Self-Balancing Food Tray

ECE 445 Project Proposal

Team 31

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1. Introduction

1.1 Problem

Even for waiters and waitresses with experience, it may be a struggle to carry out and balance trays of food and beverages at restaurants while navigating around customers and rows of tables, especially with heavier and unevenly loaded trays. This is especially true when going to lower the tray down onto a nearby table or onto a folding servers table as the transition in height introduces potential dangers in stability.

With the recent growing popularity of robotic and automated waiters, the need for a self-stabilizing platform or tray could prove valuable to this emerging technology. Modern day waiter robots are slow, boxy, and require the user to ultimately still take the food off of the robot's carrying trays. With a small stabilizing platform, robots can be built to move faster with less risk and can actually serve food to a table like an actual waiter would.

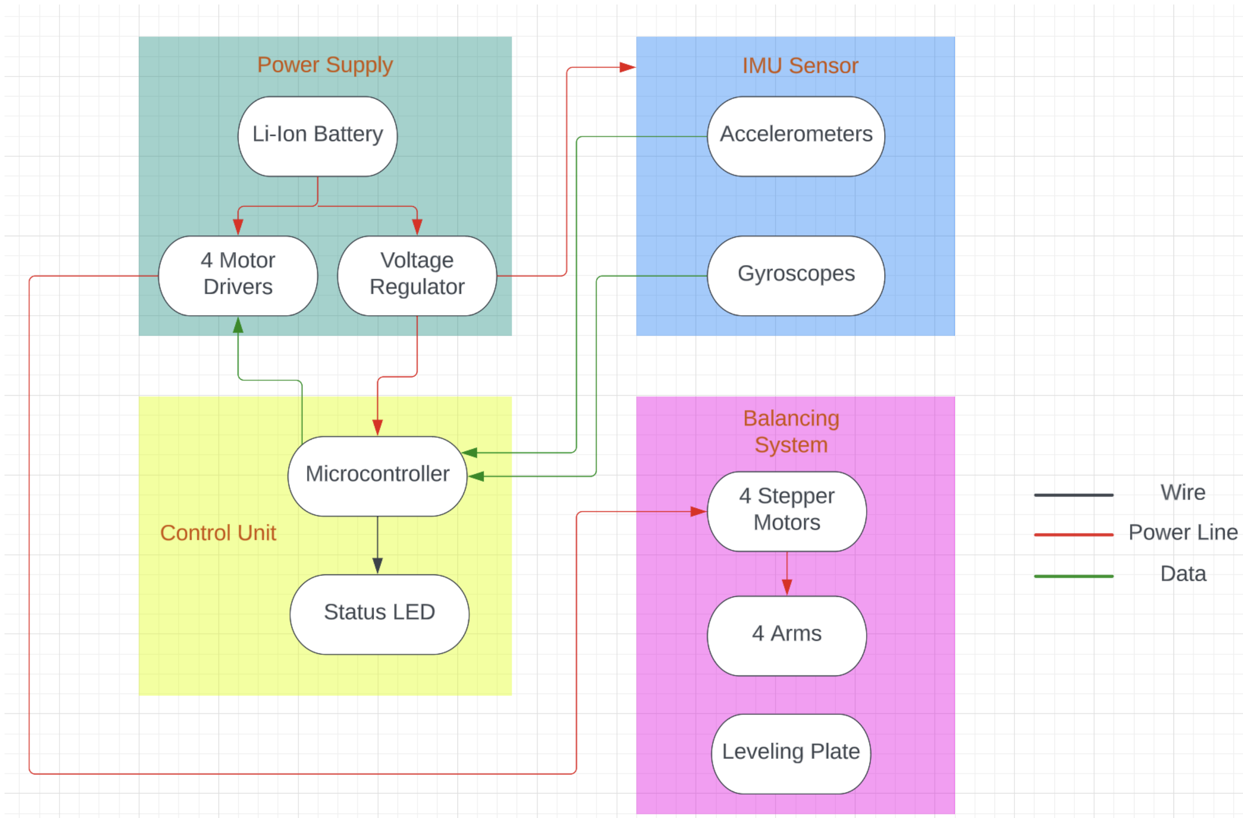
1.2 Solution

Our solution is to make a small, easy to carry electronic multi-axis gimbal stabilizing system to be inserted/carried between the server's hand and tray that will stabilize the serving tray in real time. This would ensure that no drinks or food tip over while serving customers when encountering smaller/slower impacts and disturbances, allowing the restaurant to save costs on lost food, drinks, and dishware while preventing dangers such as hot food being spilled on the nearby patrons.

1.3 Visual Aid

2. Design and Requirement

2.1 Block Diagram



2.2 Overview of Subsystems and Requirements

2.2.1 IMU

The inertial measurement unit (IMU) will be our primary form of detecting the state of the tray and determining whether it is considered balanced for our system. The IMU will contain gyroscopic and acceleration data, both of which we will leverage as part of our PID algorithm.

Requirement 1: Deliver gyroscope and accelerometer data with accuracy of within 0.1 degrees and 0.01 meters per second per second.
Requirement 2: No noticeable drift large enough to affect data accuracy and PID algorithm.

2.2.2 Power Supply

All four stepper motors will be each powered by a driver board. The driver must be capable of delivering enough current and voltage to drive the motor it is assigned to while also being capable of handling the same or higher number of microsteps as the motor. This power driver will in turn be connected to a rechargeable battery.

Requirement 1: Able to deliver proper voltage, current, and microsteps to stepper motor
Requirement 2: Battery is portable with the entire balancing system and easily replaceable.

2.2.3 Control Unit

The microcontroller will take the IMU's gyroscope and accelerometer data to measure angular tilt and velocity. This data will be used to make the necessary adjustments as it is fed into the PID algorithm running onboard the microcontroller, which sends the adjustments in angle as PWM signals to the Balancing System.

Requirement 1: PID algorithm must be robust enough to handle sudden increases in weight of up to 1 lb on outer edges of tray
Requirement 2: Microcontroller buses must be able to send quick and frequent data to all 4 motors while running

2.2.4 Balancing System

The balancing system will consist of the aforementioned four stepper motors. These motors will control the distance the four arms will bend or extend. These arms will consist of three solid pieces: one piece connected to the tray, another connected to the motor shaft, and lastly a linkage piece between the two. The three pieces will be connected via two revolute joints which will allow the arm to freely rotate in one degree of freedom (up and down)

Requirement 1: Create four arms of the almost identical specifications with little to no friction for smoothest possible movement
Requirement 2: Use stepper motors which are rated at high enough holding torque to fulfill our high level requirement.

2.3 High Level Requirements

- 2.3.1 Manipulate motor as with at least 200 Mhz PWM, resulting in smoothest movements possible and less than 0.5 second latency per adjustment
- 2.3.2 Able to balance at least 5 open-top cups or containers of water while moving at normal walking pace
- 2.3.3 Handle a weight of at least 5 pounds while constantly achieving active leveling

Tolerance Analysis: The most critical part of the successful completion of our gimbal stabilizing food tray lies in the fine tuning of the microcontrollers leveling system. Controlling each of the four motorized arms independently in order to successfully balance a regular sized food tray will require us to have a quick and accurate leveling algorithm. We will need to run real world tests with a loaded up food tray to test and dial in the leveling system and make adjustments as necessary. Once we get it dialed in we will be able to run a leveling simulation to see the maximum angle the tray gets off-level while the system is and the user is actively walking.

3. Ethics and Safety

Ethics

Code I.1 of the IEEE ethics code states, “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment”. Our gimbal system will strive to provide a safe experience, in accordance with code number one of the IEEE code of ethics, to both the user and customers who may be at the receiving end of the product's capabilities.

Code II.5 of the IEEE ethics code states, “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others”. We will provide credit to sources we received inspiration from and or received pertinent information from in the construction of our project in accordance with the code of ethics.

Safety

[1] There will be no exposed wiring to prevent liquids or other debris from potentially shocking the user.

[2] The motorized arms will not move in a motion too quickly where the user or surrounding people could be injured

[3] If the weight limit of the system is exceeded the system should handle it in a way that the stabilizer system is overridden and the product essentially turns off to prevent possible stress to the motor system as well as unpredictable behavior from the leveling system.

References

Visual Aid Images

[1] (n.d.). "Female Hand Holding Something." Depositphotos.
https://depositphotos.com/77620065/stock-photo-female-hand-holding-something.html

[2] Kuhn. (2021). "The Octo-Bouncer: Advanced Bouncing Patterns." YouTube. https://www.youtube.com/watch?v=lYyAMDYzJQM

[3] Food Tray: (n.d.). "Oval Restaurant Serving Trays NSF Certified Non-Skid Food Service Hotel Bar Tray." Overstock. https://www.overstock.com/Home-Garden/Oval-Restaurant-Serving-Trays-NSF-Certified-Non-Skid-Food-Service-Hotel-Bar-Tray/30827966/product.html

[4] “IEEE code of ethics,” IEEE, Jun-2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 6-Feb-2023].