ECE 445

SENIOR DESIGN LABORATORY

EARLY PROPOSAL

Early proposal for ECE445

Team #25

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1 Introduction

1.1 Problem

Modern air travel involves the constant movement of passengers within airport premises, often burdened with personal belongings and luggage. While airports strive to provide convenience, the process of moving from the check-in area to the departure gate can be challenging for passengers, especially those carrying heavier bags or many bags. This challenge is particularly relevant given the increasing trend of passengers bringing additional luggage, with weights ranging from 2 to 3 kilograms. Although the total weight might still in under the restriction of 50 lbs, the increased amount of bags will add difficulties for people to hold with two hands.

1.2 Solution

The proposed solution for this problem is the development of a leg-wheeled robotic system designed to accompany airport passengers with their luggage. The primary objective is to enhance the passenger experience by offering a reliable and autonomous companion capable of carrying bags weighing 2-3 kilograms. This robotic system will intelligently follow passengers with the help of camera and vision control algorithms as they traverse the airport, providing a hands-free and effortless solution to the burden of carrying personal items. In instances where passengers face challenges, such as staircases, the robot's unique legged design allows it to overcome obstacles that traditional wheeled robots cannot. This robustness ensures smooth navigation in a variety of airport environments.

1.3 Visual Aid

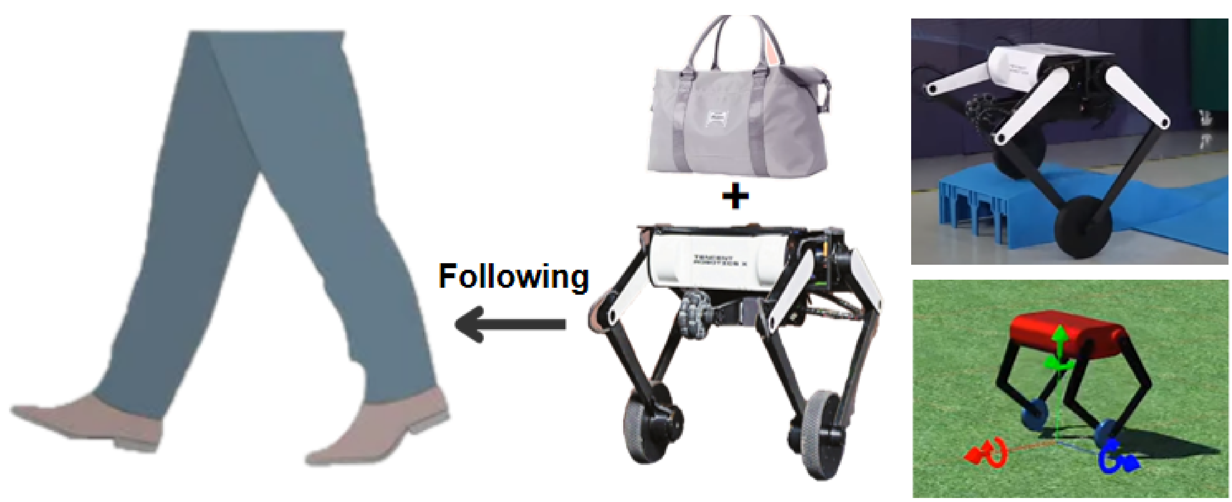

Figure 1: Overall Work Flow

1.4 High-level requirements list

1. The luggage weight must be around 2-3 kg.
2. the overall size of the robot needs to be around 500mm×500mm.
3. The distance between the legs and the robot should be within 1m throughout the whole process.

2 Design

As shown below, our design contains the following part: Power unit, the control unit, the planning unit, sensor unit and motor unit. The control unit is the central unit of our system, where the microcontroller receives the command and execute by sending signals to different motors. The power unit is responsible for converting the battery voltage from 24v to any voltage needed by different units. The motoe unit consists of four leg motors and two wheel motors.

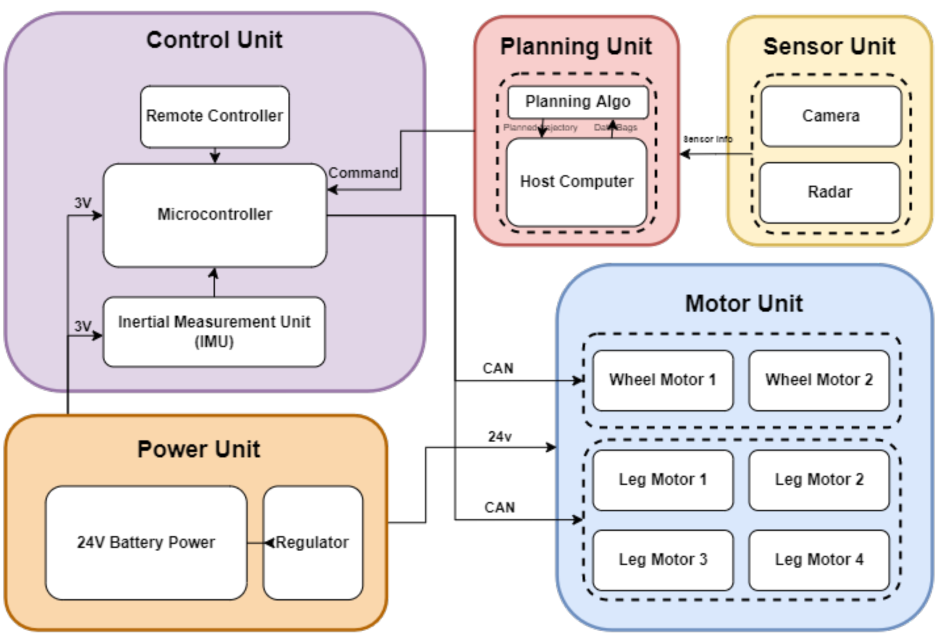

Figure 2: Top Level

2.1 Mechanical Structure

For the design of the balancing robot, we mainly consider aspects such as size and stability. We determined that the overall size of the robot needs to be around 500mm×500mm, so it can carry a normal-sized handbag. In terms of stability, we mainly focus on the leg joints. We found that many wheeled leg robots exhibit a splaying of the feet, which is due to gaps in their leg joints causing the robot's lower legs to bend outward under high torque. Our solution is to increase the diameter of the cylindrical shaft of the leg joint to suppress the splaying phenomenon.

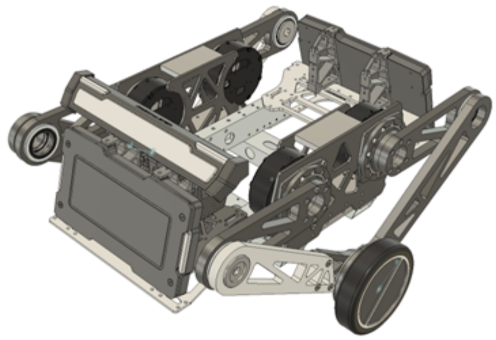

Figure 3: Overview for prototype 1

2.2 Mechanical System

We assume the weight of our balance robot is 20kg. At the hip joint, we use Unitree Technology's A1 joint motor, which has a peak torque of 33.5 Nm, meeting our requirements for joint motors.

At the leg joints, we use CNC machined aluminum parts and bowl group bearings for joint fixation. This method of fixation, compared to using screws, allows for a larger joint shaft diameter, effectively reducing the wobble in the leg joints. It also minimizes the parts number we need.

At the wheel joints, we use Xiaomi's Cyber Gear motors, along with KP035 robot joint bearings to share the load of the wheel motors.

In terms of materials, our final robot uses carbon fiber materials because they have a smaller mass compared to other materials at the same strength. We also adopt topology analysis to reduce as much weight as possible.

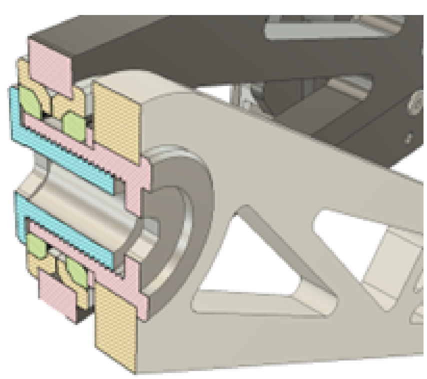

Figure 4: Leg joint cross-section view

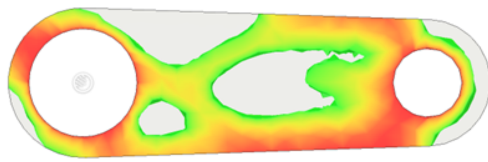

Figure 5: Upper leg topology result

2.3 Electrical System

2.3.1 Micro-controller Board

We are using STM32F407IGH6 for our microconrtoller board. This is a new product developed by ST in 2011 following the ARM Cortex-M4 architecture. Compared with the previous products, the STM32F4's new integrated FPU unit and DSP instructions greatly enrich the functions of the STM32 chip, and at the same time, the STM32F4's main frequency has also been improved. The main frequency can reach up to 168Mhz (can have 210DMIPS running speed), making the STM32F4 in floating point computing or DSP processing ability greatly improved, with a very wide range of application prospects.

2.4 Embedded Software

To communicate with the peripherals, we using the standard API and the API from HAL. What's more, we decided to use Real-time operating system to support multi-threads process.

2.5 Control System

As for the control system, since our robot controlling strategy is mainly consist of two parts: the wheel part and the leg part. We plan to use the Linear quadratic regulator (LQR) algorithm for both of them and see what performance looks like. And this process will be tested on matlab simulink for simulation and latter on moved to real robot.

2.6 Host System Trajectory Planning Module

For this part, we plan to move all the computation work to the host computer since we are afraid of the computing power of the microcomputer. Of course, if we latter proved the microcomputer can cater to this work, we will abandon this unit. Till now, we still want to use the ROS operating system to let the robot pass rosbags to the host system, which contains all the pos and vel infomation of the robot. What's more, the camera and radar unit will also catch the corresponding information. Then we will use an open source following algorithm to plan the trajectory and give specific command for robot to execute.(e.g: move forward, backward ....)

2.7 Sensor fusion Unit

In this unit, we want to integrate the camera and radar information to collect the road event. This unit will pass necessary information to the planning unit.

3 Ethics and Safety

3.1 Ethical concern

Our design does not interfere with any life-related experiment or social problem. However, military use of robots or any other misuse of our design that intends to turn the helper robot into a killer is against the IEEE Code of Ethics[1]. Therefore, we promise that we will not open-source the Control System and the Sensor Unit.

3.2 Safety concern

To prevent injuries resulting from collisions with the human body and to address potential experimental accidents during the assembly process, we will implement a collision detection mechanism for the robot. Additionally, an external emergency shutdown button will be installed to prevent any potential hazards.

References

[1] IEEE. ""IEEE Code of Ethics"." (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 02/08/2020).