Team Project Proposal for a self-balancing bicycle

High-Level Description

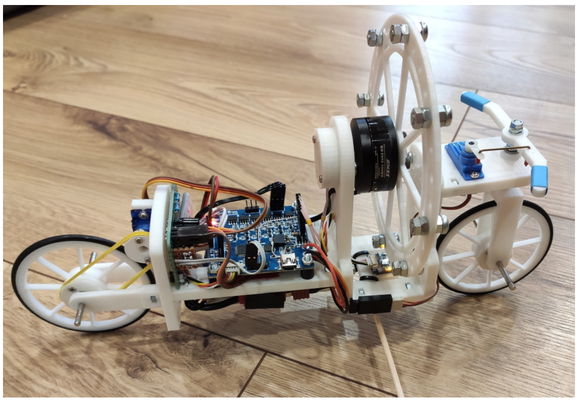
The goal of this project is to design and build a small-scale self-balancing bicycle. The initial idea of my project was to build a full scale self balancing bicycle. This was however deemed dangerous as the fast spinning reaction wheel can cause some serious damage. Instead, this project will focus on a scaled-down bike with a reaction wheel, motors and controls, allowing it to balance and move autonomously.

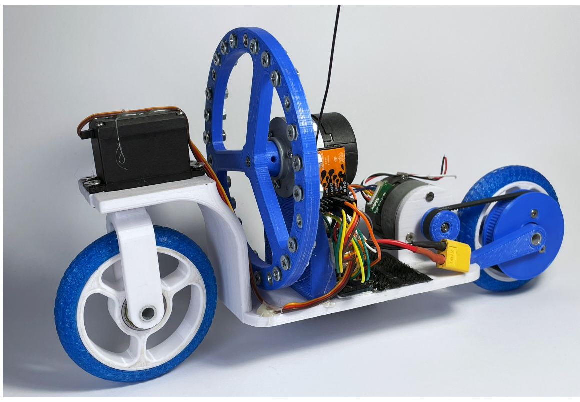
The project will be developed in multiple stages depending on the team's progress.

Stage 1 - Gyroscopic Balancing
The first stage focuses on the ability for the bike to balance on its own while stationary. In this stage the main objective is to design and implement the balancing system using a reaction wheel. An Accelerometer and gyroscope (MPU-6050) will be used to measure the bike's tilt. The microcontroller will then make adjustments by accelerating the flywheel in the right direction to correct any imbalances. Field-Oriented Control (FOC) will be used to control the brushless motor with the required precision. We will thus need two types of microcontrollers, a "core" and an FOC one. They will need to be programmed to talk to each other.

Stage 2 - Propulsion and Steering
The second stage will introduce propulsion and steering controls. Together with the first stage these implementations will enable the bike to move around while maintaining stability. The bike will be equipped with a propulsion motor and a servo motor for steering. In this stage the team will need to program a control interface that allows for remote operations of the bike. The challenge will be to maintain balance while the bicycle is in motion, which will require further tuning of the balancing system. The microcontroller will need to support wifi to be able to send the commands remotely.

Optional Stage - Autonomy with Vision and AI
Optionally, vision and AI would be implemented to allow the bike to move autonomously. This stage is quite ambitious and probably not attainable in the given time frame but would make for a very cool show piece. This stage would require cameras and distance sensors such that the bike could detect and navigate through its environment while avoiding obstacles. This phase would also not be able to run purely on microcontrollers. It would need to interact with a computer that would be in charge of the advanced computations needed for vision and machine learning. The AIThinker ESP32-CAM with antenna could therefore be a suitable option as a microcontroller. The extended wifi range would allow the system to transmit the video feed from a greater distance to a more powerful computer that can handle the computations for autonomous driving.





Breaking the project into multiple stage is a significant advantage. It ensures that even if time doesn't allow completing all milestones, there will still be a functional project to demonstrate.

Internet Research

A youtube channel called "ReM-RC" is dedicated to making self balancing objects. On his GitHub page, he provides plans for some of his projects (https://github.com/remrc). These can be useful for inspiration and can give some direction on what type of components we can use for such an object at this scale.

SimpleFOC is an open source initiative which provides a library that can be used for projects that need Field Oriented Control (https://simplefoc.com/#simplefoc_library). Their website also gives examples of projects that use their library and what hardware was used in these projects. This can again be a great starting point on what components we can choose for the project. Thus increasing the chance of a successful project.

I found a full scale self-balancing bicycle project that was developed by an employee from Huawei and posted his results on youtube (https://youtu.be/w5GwWftlLNI?si=psEJF2wL2qCtKrqQ). This shows that such a project would have been possible with some more experience. Maybe something for the winter break.

Their exists an app called RemoteXY (https://remotexy.com/en/) that we could use to control our bike remotely using the ESP32.

User Stories

This project could inspire future generations to pursue a career in engineering or computer science by demonstrating how real-world problems can be solved using sensors, motors and control systems.

Student Engagement :
The bike can be used as an interactive show piece to motivate high school students. It would have motivated me to study at EPFL, if students would have showcased a similar project at my school when I was younger.

In stationary mode, students will be able to see how the flywheel counteract any tilting of the bike, showing important physical phenomena.

Students would also be able to interact with the bike by using the remote control interface, allowing them to observe how it maintains balance even while in movement.

Physics Demonstration:
Additionally, physics professors at EPFL can use it as a teaching tool, as it provides a clear example of fundamental physics principles.

Product Management

Their is an after-life for this project. After completion it can still be used for multiple applications.

Educational Tool:
The self-balancing bicycle could be used by EPFL for demos at public events.

Further Development:
Future CS-358 students can build upon this project by applying the self balancing system to other use cases for example.

Commercial Potential:
This type of bike would make for a great children's remote control toy, provided that all components are designed with safety in mind. Ensuring that the system is robust, user-friendly, and safe would be key to its success as a consumer product.

Price breakdown

ITEM	AMOUNT	PRICE (PER UNIT)	PRICE (TOTAL)
Microcontroller (AIThinker ESP32-CAM w. Antenna)	1	CHF 13.00	CHF 13.00
Gyroscope + Accelerometer (MPU-6050)	1	CHF 3.00	CHF 3.00
Flywheel/Propulsion Motor	2	CHF 20.00	CHF 40.00
Motor Driver (Flywheel)	1	CHF 20.00	CHF 20.00
Motor Driver (Propulsion)	1	CHF 6.00	CHF 6.00
USB Isolator	1	CHF 15.00	CHF 15.00
Position sensors	2	CHF 3.00	CHF 6.00
FOC controller (STM32 B-G431B-ESC1)	1	CHF 20.00	CHF 20.00
Battery	1	CHF 17.00	CHF 17.00
Battery charger	1	CHF 7.50	CHF 7.50
Servo motor (steering)	1	CHF 5.00	CHF 5.00
Laser distance sensor (TOF400H)	1	CHF 6.00	CHF 6.00
TOTAL			CHF 152.50