Final Report for the Project

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"E-Gaïa, the flora regeneration gardener"

Students:

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Introduction

For more than a decade, climate change has been a major issue which has greatly disrupted the world we live in. Intense drought, melting glaciers, rising sea levels, heat waves and warming oceans are some of the actual repercussions that don't appear to be slowing down.

More recently, the number of forest fires in France and around the world has increased. Aware of the risks nature is facing, our team decided to help preserve the wildlife at our own scale. As part of our third-year project in Robotics, we have developed the E-Gaïa robot, designed to restore and regenerate arid and desert areas affected by fires.

Our endeavor aligns with a significant ecological initiative initiated by the African Union back in 2007. The Great Green Wall project [1] aims to combat desertification by creating a vast stretch of trees across the Sahel region, contributing to climate change mitigation, adaptation, and improved food security.

Why a robot? This unconventional approach offers unique advantages in addressing the current challenges. An autonomous robot, capable of operating for extended periods and traversing long distances, can access isolated areas with ease. Moreover, the self-sufficiency of the robot eliminates the need for constant human presence. By implementing our initiative, E-Gaïa seeks to prevent overheating and enhance wildlife habitats. It will perform crucial tasks such as identifying suitable locations, planting appropriate seeds, and ensuring effective irrigation. This innovative project not only presents an opportunity to explore various aspects of robotics but also represents a significant technical and scientific challenge.

I. Mechanical structure

A. Rocker-bogie suspension

The mechanical structure of the robot is crucial for ensuring its mobility and the ability to navigate various terrains. While several solutions, such as the four-wheeled system used in NASA's K-10 Rover Red [2] or the tank tracks of the ECA Cameleon [3], exist, our research led us to the Rocker-bogie structure [4]. This design was initially developed in 1988 for NASA's Mars rover Sojourner [5] and has been utilized in subsequent rovers.

The "rocker" component of the suspension involves a larger linkage mounted on each side of the rover, which facilitates a rocking motion. These rockers are connected to each other and the vehicle chassis through a differential mechanism. The rockers rotate in opposite directions relative to the chassis, ensuring balanced wheel contact, while the chassis maintains the average pitch angle of the rockers. At one end of the rocker, there is a drive wheel, while the other end features a bogie.

The "bogie" element of the suspension refers to a smaller linkage that pivots to the middle of the rocker and is equipped with a drive wheel at each end.

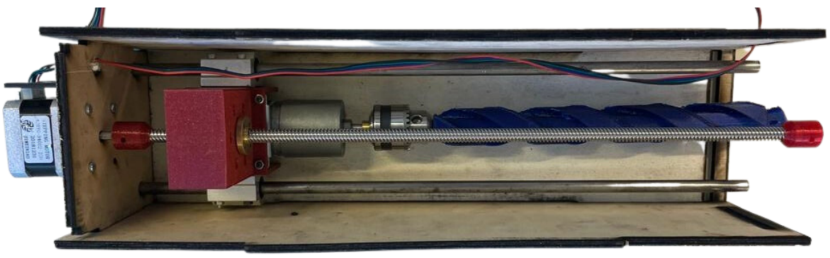
To address the challenges associated with the weight and complexity of a traditional car differential, we have implemented the differential used in the Perseverance rover [6], which efficiently connects the rocker components across the chassis. This updated differential design offers improved performance while overcoming the limitations of the previous system.

By adopting the Rocker-bogie structure with an advanced differential mechanism, our robot gains enhanced mobility, ensuring it can effectively maneuver and conquer a wide range of terrains encountered during its operations.

B. Drilling system

The drilling system plays an important role in the E-Gaïa robot, as it is essential for planting in arid zones. This system efficiently excavates the soil to prepare it for the planting process [7].

The drilling system comprises three key components: a mandrel, a 3D printed drill, and motorized mechanisms that allow its movement. Inspired from the vertical motion of a 3D printer, the system incorporates an endless screw which enables the drill to precisely operate vertically.



By employing this drilling system, E-Gaïa overcomes the challenges posed by arid environments, ensuring effective soil penetration and creating optimal conditions for successful planting.

II. Circuit diagram

The robot's electronic components are efficiently managed by an Arduino Mega board. Its integration with the Nvidia board would enable the delegation of basic tasks such as motor control and sensor data reception to the Arduino.

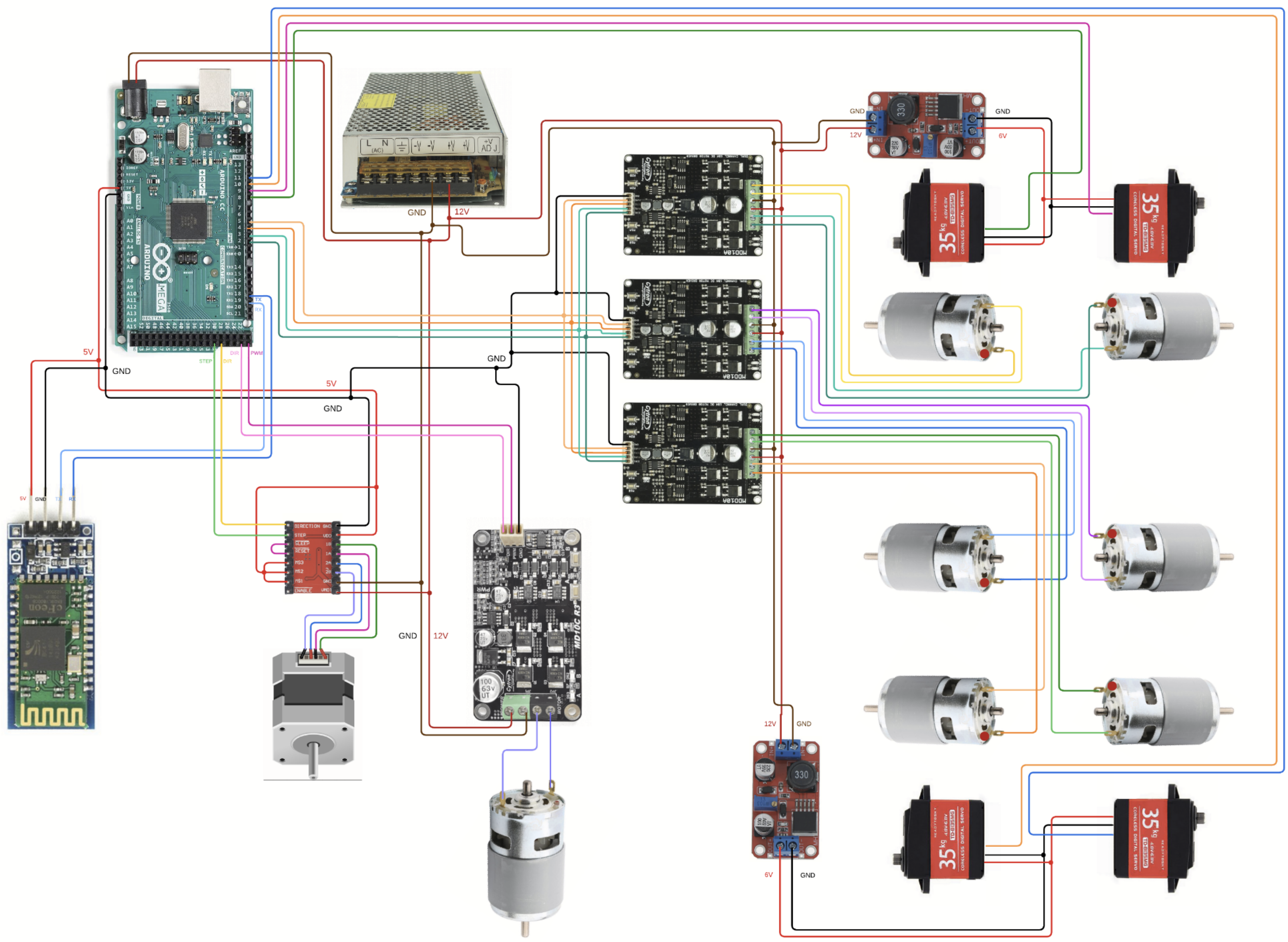
The Arduino board effectively controls four main types of components: 7 DC motors (MFA 970D7501), 4 servo motors (TD8135), a stepper motor (Nema17), and a Bluetooth module (HC-06).

The DC motors operate on a 12V power supply, supplemented with coupling capacitors. They are controlled through the MDD10A and MD10C motor drivers, which utilize PWM signals to determine the motor speed and digital inputs to specify the direction. The robot's movement relies on 6 of these motors, while the remaining motor is responsible for rotating the drill.

The stepper motor operates on a 12V power supply and is managed using an A4988 driver. Direction control is achieved through a digital input, while pulses are sent to the motor to facilitate stepping.

Each servo motor operates on 6V, obtained through a 12V to 6V converter (two servos per converter). These servos are controlled using PWM signals to indicate the desired angles, although their precision may be somewhat limited.

The Bluetooth module operates on a 5V power supply (typically 3.3V, but can handle 5V) and is controlled through the TX1 and RX1 pins, which are available exclusively on the Arduino Mega.



III. Operating Algorithm

The Arduino code for our robot incorporates three classes that enable control of movement, the drill, and Bluetooth commands.

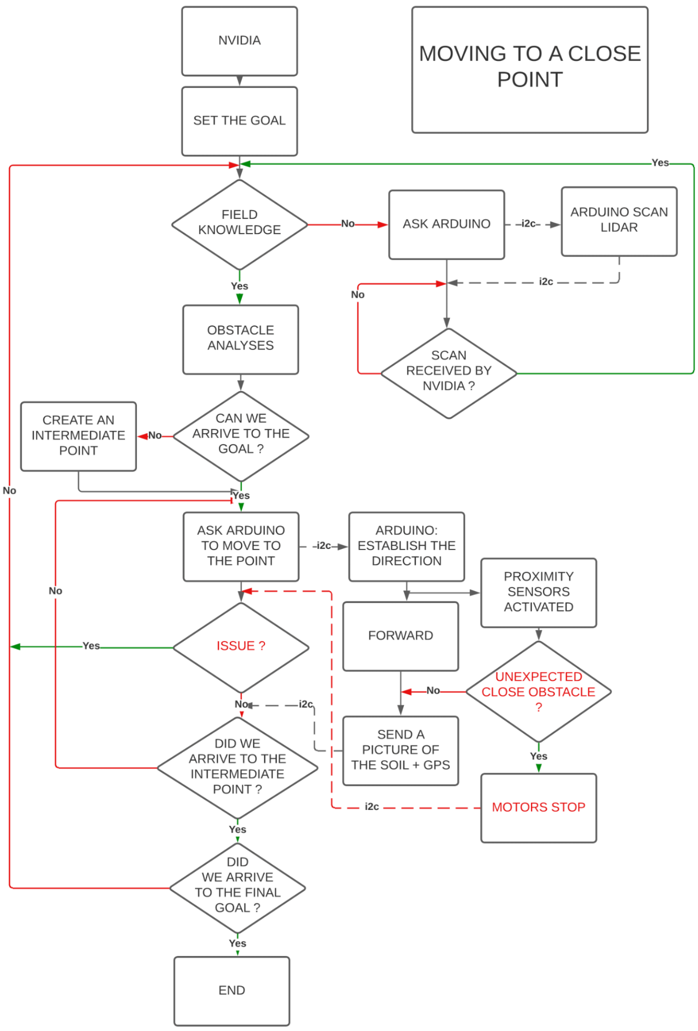
Each class contains essential functions that provide basic control for each component, with additional functions built upon them. This modular approach ensures that each function serves a specific purpose, enhancing readability, performance, and memory efficiency. Furthermore, thorough documentation is provided within the code to facilitate comprehension for future programmers. This allows a great delegation of tasks from the Nvidia board to the Arduino, utilizing these useful functions.

The WheelsController class combines the control of DC and servo motors to achieve smooth movement. All pins and settings are defined as constants within the source code, making modifications straightforward. In the current version, all motors have the same speed, and DC motors on the same side have the same direction. However, we have also implemented functions that allow individual control of each motor's speed and direction.

The DrillController class combines the control of a single DC motor and a stepper motor to enable the drill's rotation and vertical movement. This integration allows us to create a single function that activates the drilling process only when the robot is stationary.

Lastly, the BTController class provides a unified function for validating and executing every Bluetooth command. It coordinates the actions of the DrillController and WheelsController when triggered.

IV. Autonomy Algorithm



On the left, you'll find the algorithm that outlines how the robot will function in order to collect data and respond accordingly (not implemented yet).

The purpose of this algorithm is to enable the robot to analyze its surroundings and determine the appropriate destination. The NVIDIA card will gather data from both the Lidar and the camera, while the Arduino card will control mechanical movement.

Currently, the robot is not using the NVIDIA card as it requires a higher level of technological expertise. However, the robot can still be controlled using a Bluetooth remote. Through the Bluetooth interface, we have control over the direction, speed, wheel angle, and drill elevation for soil excavation.

V. Fabrication and engineering cost

After completing extensive study on the individual pricing of each component, we concluded that the robot's true cost is roughly 690€ and will be close to 800€ when completed.

Furthermore, we have estimated an engineering cost of €4,156.25 based on an assumed rate of €38,000 for 1,600 hours of work.

VI. Conclusion

In conclusion, the E-Gaïa robot has been specifically designed to restore vegetation in areas affected by fires or facing arid conditions. Its Rocker-bogie structure ensures effective navigation through various obstacles, while the carefully selected motors and wheels offer the capacity to transport heavy payloads steadily.

The robot can be conveniently controlled via a Bluetooth connection and is capable of executing basic drilling operations. However, with the incorporation of sensors, E-Gaïa will be ready to achieve full autonomy and enhance its capabilities.

In our future perspective, the robot will utilize a Lidar 3D scanner, GPS, accelerometer, gyroscope, temperature, light, and humidity sensors, along with the Arduino and Jetson boards. These sensors will play a crucial role in gathering and analyzing data. By leveraging this comprehensive set of sensors, E-Gaïa will be able to autonomously identify the most fertile locations for reforestation, ensuring optimal planting and restoration efforts.

While there is still work to be done, the E-Gaïa robot represents an innovative and impactful solution for ecological restoration, combining advanced technology and intelligent analysis to contribute to the preservation of our environment.

VII. Bibliography

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