E-Gaïa, the autonomous gardener

Brice Mabille and Jaime Alba Pastor

***Abstract*— This article shall walk you through the important steps of the project that we've completed so far, as well as how they were achieved. E-Gaïa is an autonomous robot intended for replanting arid and post fire areas.**

***Index Terms* — Assembly, autonomy, design, ecology, exploration, motion, revegetation, robot, rover**

I. INTRODUCTION

FOR more than a decade, climate change has been a major issue which has greatly disrupted the world we live in. Aware of the risks nature is facing, our team decided to help preserve the wildlife at our own scale. For our third-year project, we chose to create the E-Gaïa robot which could plant in arid zones after a fire or in desertic areas.

Despite being an unconventional approach, an autonomous robot could assist in finding adequate locations, planting suitable seeds, and taking care of irrigation. We hope that this self-sufficient robot could help regenerating vegetation and by doing so, safeguarding the ecosystem.

II. MECHANICAL STRUCTURE

A. *Mobility and suspension*

The mobility and suspension structure must enable the robot to overcome any kind of terrain it may find. There are lots of solutions such as the four-wheels used in the NASA's K-10 Rover Red [1] or the tank tracks used by the ECA Cameleon [2]. However, we came across the Rocker-bogie structure, developed in 1988 for NASA's **Mars rover Sojourner** (Fig. 1) [3] and used in all the following rovers.

Fig. 1. NASA's Mars rover Sojourner using the first version of the rocker-bogie structure. The differential is located inside the chassis and is similar to the one found in a car. [4]

The "rocker" part of the suspension comes from the rocking aspect of the larger, body-mounted linkage on each side of the rover. A differential connects these rockers to one another and the vehicle chassis. The rockers will rotate in opposite directions relative to the chassis to ensure approximately equal wheel contact. The chassis maintains the average pitch angle of both rockers. A rocker has a drive wheel on one end and a bogie on the other.

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

The original differential employed was the one of a car [4], which is heavy and difficult to build. That is why we included the differential used in the **Perseverance rover** [5], which connects the rocker parts over the chassis (Fig. 2).

Fig. 2. The Rocker-bogie structure of the E-Gaïa robot, equipped with the Perseverance's differential design.

The six-wheel configuration structure will provide full-time wheel contact when climbing steep features as well as excellent mass distribution, making it ideal for unknown and wild areas.

B. *Drilling system*

For planting seeds, various technologies such as a tractor-like shovel or a small plough were considered. A drill, on the other hand, appears to be the most efficient way, being both swift and precise.

The drill is powered by a high torque DC motor, allowing it to dig even in hard soil. Once the seed has been placed, the drill reverses direction to refill the hole by supplying an opposite current.

For the robot to move around freely, the drill must be able to

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return inside the frame. As a result, the drill has a vertical movement powered by a stepper motor. This motor will rotate a threaded tube linked to a helicoidal nut, translating it vertically (Fig. 3).

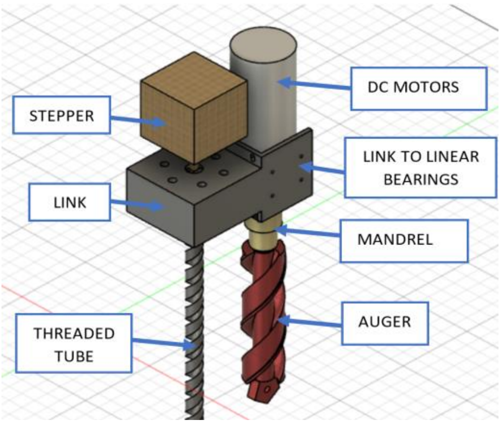

Fig. 3. 3D model of the drilling system equipped with vertical translation.

A wooden box was built to protect the drill inside the frame and attach the components allowing a fluid vertical movement (Fig. 4).

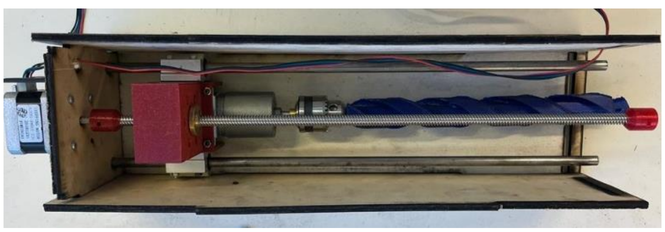

Fig. 4. The drill structure enclosed within the wooden frame.

By employing this drilling system, E-Gaïa overcomes the challenges created by hostile environments, ensuring effective soil penetration, and creating optimal conditions for successful planting. But, because the reliability of this drilling mechanism is critical to the overall performance of the robot, it still needs to be improved and thoroughly tested.

C. *Lidar guidance system*

The robot should be aware of its surroundings in order to avoid obstacles. We considered three options: low-range ultrasound sensors, a camera, and the Lidar laser scanner. This last approach has the advantage of being very accurate and not requiring to compute the heavy images of a camera. This sensor determines how long it takes for light beams to hit an object and reflect back to the scanner. It also provides 360 degrees of vision when combined with a rotating structure [6] (Fig 5).

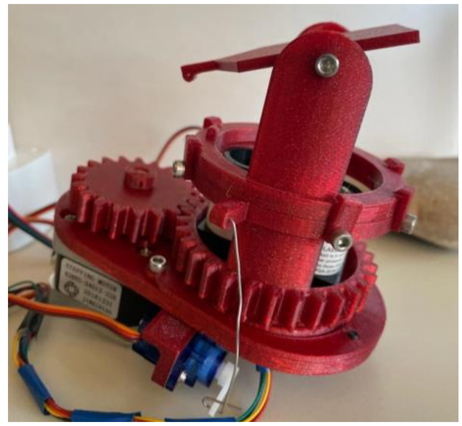

Fig. 5. 3D printed 360-scanner equipped with the Lidar sensor, a stepper motor and two servo motors.

This arrangement is made up of a stepper motor that rotates around the vertical axis. In addition, two servomotors control the angle of the mirror that reflects the laser.

Although this element isn't part of the current version, it shouldn't last to much longer to be incorporated.

III. Electronic structure

A. *Current structure*

The Arduino Mega board efficiently manages the electronic components of the robot. Integrating it with the Nvidia board allows for 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) (Fig. 6).

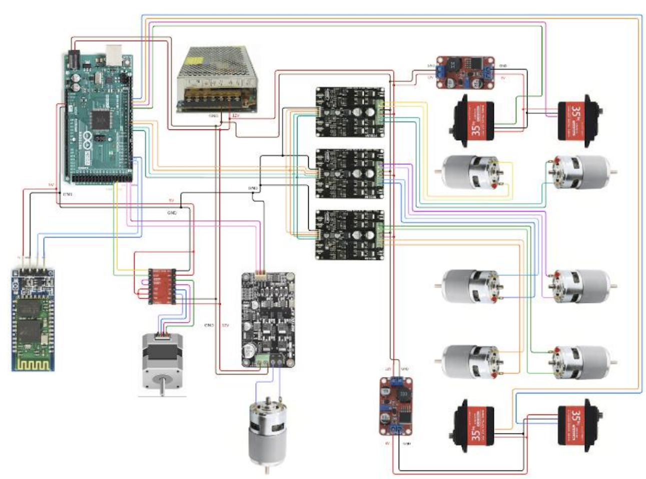

Fig. 6. Electronical flowchart describing the relationship between the control board, drivers, motors and power station.

The DC motors operate on a 12V power supply, which is supplemented with coupling capacitors. They are controlled through the MDD10A and MD10C motor drivers, utilizing

PWM signals to determine 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 exclusive TX1 and RX1 pins, which are available only on the Arduino Mega.

B. *Boards connectivity*

While the Arduino Uno R3 is used to control the robot's motions and actions that demand fast responses, the Jetson Nano will serve as the robot's brain, where data analysis and IA will later take place.

These two boards are linked via serial connection to exchange data (USB port). However, because mapping the surroundings requires rapid communication, the Lidar will have exclusive direct wiring with the Jetson Nano board.

IV. PROGRAMMING STRUCTURE

A. *Operating program*

The Arduino code implemented for our robot incorporates three classes that play a crucial role in controlling movement, the drill, and Bluetooth commands.

Each class contains essential functions that provide control over their respective components, with additional functions built upon them. This modular approach ensures that each function serves a specific purpose, enhancing the code's readability, performance, and memory efficiency.

Furthermore, thorough documentation is included within the code to facilitate comprehension for future programmers. This documentation proves valuable in delegating tasks from the Nvidia board to the Arduino by leveraging these useful functions effectively.

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 it straightforward to modify them. In the current version, all motors operate at the same speed, and DC motors on the same side share the same direction. However, we have also implemented functions that enable individual control over each motor's speed and direction.

The *DrillController* class merges 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 that validates and executes every Bluetooth command. It coordinates the actions of the *DrillController* and *WheelsController* when triggered, ensuring cohesive functionality.

B. *Autonomous driving algorithm*

We developed the primary programming flowchart of an autonomous driving algorithm which enables the robot to analyze its surroundings and make informed decisions about its intended destination (Fig. 7).

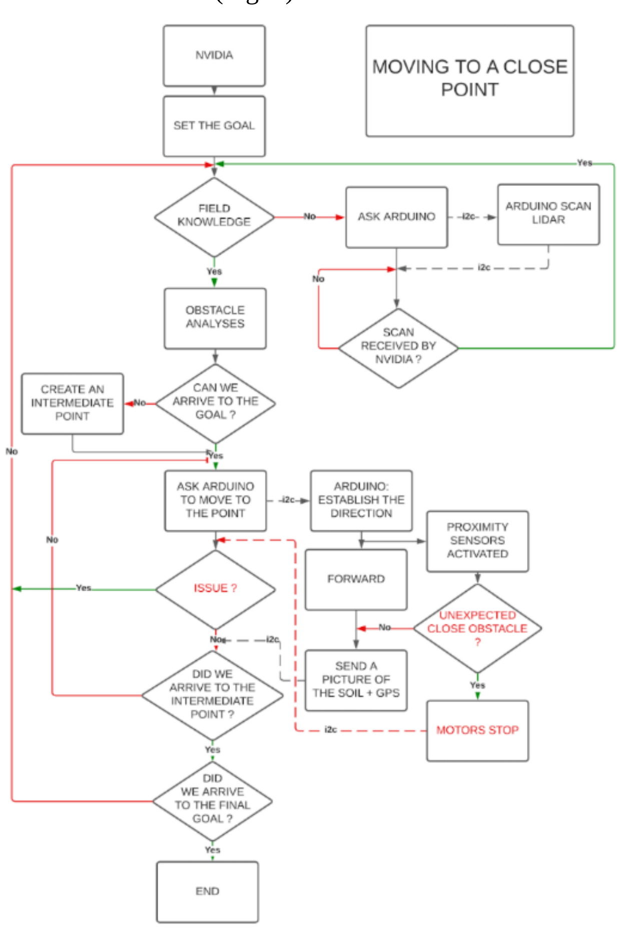

Fig. 7. Autonomous driving algorithm to be implemented between the Jetson Nano and Arduino boards.

The idea is to guide the robot to a specified location. If that location is beyond the Lidar's range, we shall navigate using the GPS tracker by establishing intermediate locations. If it is within that range, the sensors controlled by the Arduino board will activate in the event that unexpected obstacles, such as walking people or larger events, occur.

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

V. Conclusion

In conclusion, the initial phase of our autonomous robot project has been both challenging and rewarding. The meticulous design and implementation of the rocker bogie structure although time-consuming, will undoubtedly prove its worth by enabling the robot to navigate with flexibility and reliability in hostile environments (Fig. 8). Additionally, the mechanically regulated suspension system not only simplifies the writing of the program but also ensures smoother and more efficient operation.

While the chosen method for the drill is a promising starting point, further adjustments are required to enhance its performance. Exploring more compact solutions could potentially optimize its functionality and overall design.

From a coding perspective, our team has successfully developed Arduino code that optimally delegates tasks to the Jetson board. This approach has simplified and streamlined the control functions, leading to a more efficient and effective robotic system.

In summary, despite the challenges encountered, we have made significant progress in our autonomous robot project. We are excited about the prospects ahead and confident in the positive impact our work will have in pushing the boundaries of automation and innovation.

Fig. 8. Result of the 3rd year's robotic project: E-Gaïa.

Appendix

Our project is detailed on our GitHub repository:
https://github.com/jaimealbapastor/autonomous-gardener

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Jaime ALBA PASTOR completed an integrated preparation course in 2022 and is now enrolled in the Robotics and Autonomous Systems specialization at Polytech Nice Sophia. He is pursuing his passion while participating in fascinating projects whenever possible.

Brice MABILLE has completed a preparatory class for high schools and has incorporated the Robotics specialization from Polytech Nice-Sophia in 2022. He is developing his CAO passion through E-GAÏA, the autonomous gardener.