Research Report for the Project

School year 2022-2023

"E-Gaïa, the flora regeneration gardener"

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SUMMARY

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 a response, for our third year project in the Robotic specialization, we chose to create the E-Gaïa robot which could plant in arid zones after a fire or in desertic areas.

Here is a major ecology initiative to which we would like to contribute.

In 2007, the African Union conceived a project to assist communities in mitigating and adapting to climate change, as well as improving food security. The Great Green Wall, as it is called, aims to tackle desertification by planting a wall of trees that stretches across the entire Sahel.

Why a robot ?

Despite being an unconventional approach, an autonomous robot could assist in resolving some of the current issues. With the ability to work for extended periods of time while traveling long distances, isolated zones would be easier to reach. Furthermore, because the robot would be self-sufficient, technicians would not be required.

We hope that by implementing this initiative, E-Gaïa will be able to prevent overheating and so improve wildlife habitat. Finding adequate locations, planting suitable seeds, and taking care of irrigation are some of the tasks that will be performed.

This innovative, constructive and useful project will allow us to discover all aspects of robotics. Plus, it also represents a technical and scientific challenge.

I. Design

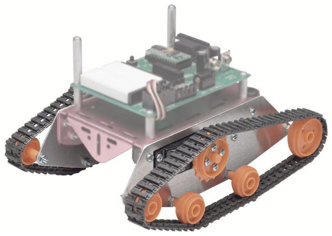
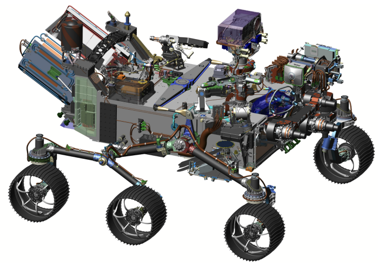
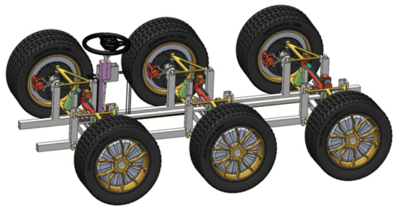
This section will cover the robot's structural specifications. We will discuss the dimensions, configuration, and materials to be used.

I.1. Technical specifications

Constrains:
- ➢ The robot must be designed to work on various types of terrain.
- ➢ In order to support the heavy load of seeds and water, the E-Gaïa structure must be as light as possible.
- ➢ Resistance to meteorological conditions (rain, sand, wind and heat)

I.2. Structure

3 types of structures were taken into consideration:

 **Image I.1** *Tank robot*	 **Image I.2** *Mars rover, NASA*	 **Image I.3** *Design of six aligned wheel steering*
Tank structure	Rocker-bogie	Six-wheel structure

Here are the specifications comparison :

Type of Structure	Positive aspects	Negative aspects
Tank structure	Excellent weight distribution Good adaptation to terrain	Expensive to repair Sand gets stuck in between gears
Rocker-bogie	Good weight distribution Excellent adaptation to terrain The choice of NASA for the Rovers	Difficult to build
Aligned six-wheel structure	Good weight distribution Easy to build Moves quickly through flat terrains	Not ideal for traversing obstacles

It is clear that an all-terrain robot would benefit greatly from a rocker-bogie design **[1] [2]**. The university has a rocker-bogie vehicle from a prior project, so we'll have some grounding for the machinery even if the mechanical engineering represents a high level of complexity. **[3]**

I.3. Configuration

As illustrated below **(I.4)**, the robot will be divided into four areas, each performing a different task.

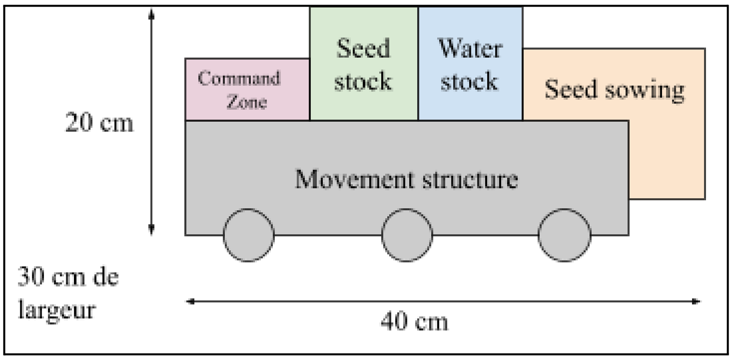


Image I.4 *Weight distribution for the different modules*

However, the dimensions are not precisely defined yet, we will set them once we start modeling the whole structure.

I.4. Weight estimation

In order to prevent irregularities, we rounded the numbers up.

Module	Element	Weight per unit (g)	Units	Estimated mass (g)
Structure	Movement structure	4000	1	4000
	Chassis	1500	1	1500
Transmission	Motor	50	6	300
	Torque gears	50	6	300
	Wheels	50	6	300
Drill	Auger	200	1	200
	Motor	380	1	380
Components	Arduino UNO	25	1	25
	Jetson Nano	61	1	61
	Battery	1000	1	1000
	Sensors	10	8	80
	Wires	0,5	40	20
			Total	8166

II. Mechanical movement

II.1. Technical specifications

Constrains:
- Be able to climb inclined planes
- Have enough mobility to avoid obstacles
- Carry heavy stocks of seeds and water

II.2. Wheels

Weight distribution is a critical factor to consider when purchasing an all-terrain vehicle. If the robot's weight distribution is insufficient, the wheels will become stuck in the sand or fail to pass over certain obstacles. **[4] [5]**

The wheels will perform this task. As a result, these ones must have a significant area of contact with the ground, which translates to a large width and radius **(II.1)**. Furthermore, if the tyres are slightly flattened, the area of contact will increase.

Image II.1 *Wide tyres for the 2022 Sand Sports Super Show*

II.3. Motors

For the robot to operate and perform his job, motors are unavoidably necessary, therefore we compared different motor types in the chart below: **[7]**

Type of motors	Positive aspects	Negative aspects
Servo motors	Easy to configure Cheap price Very precise	Can only rotate 180º Couple decrease with high speed Resonance issue
Stepper	Very precise	Not continuous (discrete steps) Current consuming
Direct Current	Robust Constant torque 85% of efficiency	Yield loss Power loss Brush
Brushless	Excellent efficiency Long lifetime Breakdown decreased More reliable	Blockage on an electronic defect Risk of failure while installing Higher price

Regarding the wheel motors, as seen in the chart above, Brushless motors are the more reliable and efficient ones. They would be a great alternative, but since we need six of them, the cost is out of the question. Using DC motors is a good alternative as their efficiency is still very acceptable (85%) and we can adjust their speed and torque with gearing.

We have counted how many motors we need for the Robot:

- 6 DC motors for the wheels to move forward and for the drill to plant the seeds.
- 1 DC motor for the drill to rotate *(V.3 Digging technique)*
- 1 Stepper to lift the drill *(V.3 Digging technique)*
- 1 Stepper for the Lidar 3D scanner *(IV Autonomous movement)*
- 1 Servo motor for the Lidar 3D scanner *(IV Autonomous movement)*
- 1 Servo motor for the seed distribution. *(V.4 Sow a seed)*
- 1 Stepper motor for the rake to bury the seed. *(V.4 Sow a seed)*

Finally we would need: 7 DC, 3 Stepper and 2 Servo motors.

II.4. Motors for the wheels

We simulated some of the factors that would guide our choice of the most suitable motor (**II.2**):

Image II.2 *Simulation of robot characteristics for the motor choice*

The torque of the motors is the most crucial factor because the robot's weight is quite consequential.

We discovered a geared motor with 1.4 Nm of torque that matches the specifications : link. **[6] [8]**
Also, to connect the motor to the wheel and main construction, we will need two more elements.. These are a hub **(II.3)** and a mounting bracket **(II.4)**.

Image II.3 *Hub for DC motor*

ImageII.4 *Mounting bracket for DC motor*

III. Power supply

III.1. Technical specifications

Constrains:
- ➢ Supply power to all the components (including six motors)
- ➢ Enough battery life to endure a few hours of work

III.2. Batteries

When it comes to the robot's battery, it is instantly clear that a powerful battery is required to provide the robot greater autonomy. The battery will supply enough electricity to allow movement, the planting of seeds, and the administration of water to assist in the growth of the plantation.

First, we just saw some battery types and we can observe what battery is the most adequate for our Robot. We did some research on other batteries and thanks to a website we can compare some batteries.

Construction Type	Plomb / Acide	LiCo (Litio Cobalt) / Li-ion	$LiFePO_4$ BC Lithium
Nominal Tension (V)	2,1	3,6 / 3,7	3,2
Energy Density (Wh/L)	Medium	High	High
Specific Energy	Medium	High	High
Max Discharge Current (C)	15	None	50
Security	Toxic Substances Presence	Low	Excellent (No Fire or Explosion Risk)
Lifetime (h)	>400	>500	>2000
Eco-compatible Product	NO	NO	YES

This chart demonstrates that a lithium battery is the best option for our robot because it is powerful, has good autonomy, and is the safest.

Last but not least, the 12V Lithium rechargeable battery is required to power all six motors. It provides a significant amount of current. This ensures a simple beginning. It also maintains a healthy ecological balance. **[8 bis]**

We have found a good price 12V battery which suits our requirements: aliexpress link

III.3. Power board

We wouldn't require a separate power board since the Arduino board incorporates an inbuilt power board that converts 12V to 5V. However, if the motors look to require more voltage than 12V can provide, we would then adapt the entire power system, including the power board.

III.4. Refill station

An autonomous robot's primary purpose is to be self-sufficient, implying that no human involvement is required. If the robot ran out of battery in the midst of the field and a human intervention occurred, this principle wouldn't be verified. Two main solutions have been considered regarding this issue: a solar panel and a refill station.

If simply electric power was required, the solar panel would be a sufficient and viable solution. But E-Gaia also needs to be replenished with water and seeds. This wouldn't be sufficient unless seeds materialized out of thin air. A refill station is then the most realistic solution to this problem. The stockpiles of seeds, water and electricity could be replenished at the same time. The robot would just need to come back when needed **(III.1)**.

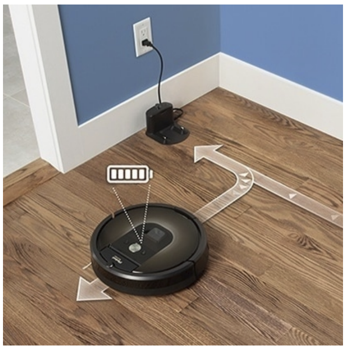


Image III.1 *Autonomous vacuum returning to its power supply*

IV. Autonomous movement

IV.1. Technical specifications

Constrains:
- ➢ Avoid or overcome obstacles
- ➢ Return to the refill station
- ➢ Water the seeds already planted (remember their location)

IV.2. Factors to consider

IV.2.1. Obstacle detection

The Lidar is a method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver. This approach, specifically the LIDAR-Lite V3, is what we'll employ for detecting obstacles.

However, this method would only allow us to determine the distance to a unique point in space. To fix this problem, the Lidar must fully rotate through the φ axis and through the θ axis **(IV.1)**. Two solutions are considered.

In the first **(IV.2)**, a stepper motor would rotate a flat gear through the φ axis on which the sensor would stand. Then it may rotate through the θ axis thanks to a servo motor attached to the Lidar.

The second is equipped with a spinning mirror over the sensor that enables him to inspect every point in space **(IV.3)**. Due to the mirror's lightweight and the fact that it will be the only rotating component, the movement will have a significantly lower momentum and will be much faster.

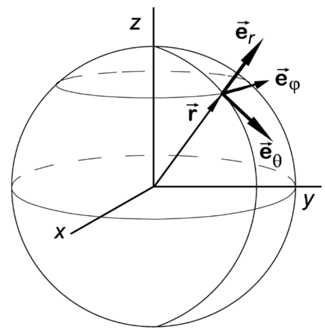


Image IV.1 *Representation of spherical coordinates*

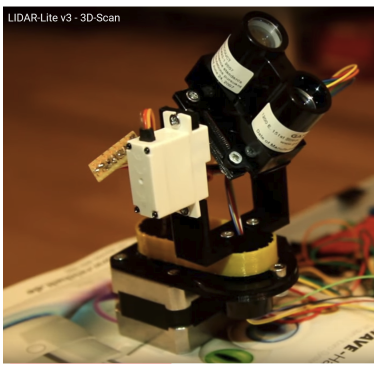


Image IV.2 *3D scanner with LIDAR-Lite V3*

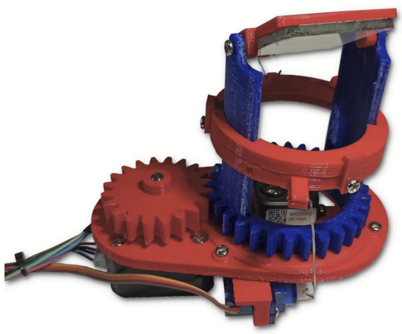


Image IV.3 *3D scanner with LIDAR-Lite V3 with mirror*

Given that the mirror's speed and precision are theoretically considerably greater, we opted to build the 3D scanner with the second structure **(IV.3)**. We will use the 3D printer to build the pieces. **[10] [11]**

IV.2.2. Slope level

We will use an accelerometer and gyroscope to compute the slope of the terrain and the power needed for the motors. We've picked the MPU6050 because it's simple to operate, accurate, and power-efficient. **[9]**

V. Method for planting

V.1. Technical specifications

Constrains:
- ➢ Have a seed stock
- ➢ Dig the terrain to plant
- ➢ Deposit the seed on the ground
- ➢ Bury the seed

V.2. Seed reservoir

The seed reservoir has to be large enough to ensure a higher lifetime. Indeed, the Robot must plant a lot of seeds before coming back to the base. We think the reservoir dimensions should be 7 x 4 x 16 cm.

V.3. Digging technique

Our Robot can't plant a seed without digging the ground, consequently we thought about a drill. The drill will be on the front of the Robot and will go down when the Robot detects the place to plant.
We must select a tiny drill which is powerful enough to dig the majority of the terrain the Robot will encounter. We discovered on the net an Auger piece which will help to dig the ground and the drill tip to maintain the Auger. This dig combination will be perfect to plant the seed in the ground.

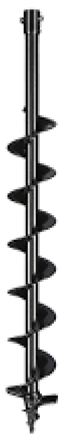


Image V.1 *Auger digger*

Image V.2 *The drill tip*

V.4. Sow a seed

To sow a seed in the hole the Robot dug, we thought about an ingenious seed distributor. We imagine a pipe connecting to the seed reservoir where the seed will fall in. At the bottom of the pipe, a distributor like a clapper will instantly move to put seed in the hole.
Moreover, to bury the seed, we thought about a rake on the back of the Robot e-Gaïa which could push dirt into the whole. **[12]**

V.5. Components required

Components	Units	Purchase Link
Drill Tip	1	Link Aliexpress
Auger	1	Link Amazon
Rake	1	Link Aliexpress
Seed Reservoir	1	Own production
Clapper	1	Own production
Pipe	1	Link Aliexpress

VI. Locate suitable places

VI.1. Technical specifications

Constrains:
- ➢ Humidity zone detection
- ➢ Temperature and Light detection
- ➢ Adequate seeds for the ground

VI.2. Analyze data

The Robot e-Gaia must determine if the soil is dry or wet. It needs to know the temperature and amount of light available. All of this information will allow us to select the best plants to sow in order to boost their growth. **[13] [14] [15]**

VI.3. Which seed to sow

The Robot's job requires him to sow seeds in the dirt, but which kind of seed should we plant? We conducted some research on the African Great Green Wall's plant species. The Fabaceae species that we consider to be the best are listed in the chart below. **[16] [17]**

Plant type	Growing Time	Water consumption	Light exposure	Soil benefits	Dryness Resistance
Senegalia senegal	Slow	Year precipitations	Acceptable	Soil fertility and crop growth	1 year
Faidherbia albida	Fast	River zone	Acceptable	Litter improve soils	Durable
Vachellia tortilis	Slow	Year precipitations	Acceptable	Improve soil fertility	Durable
Vachellia nilotica	Slow	River zone	Acceptable	Soil fertility and crop growth	Durable
Balanites aegyptiaca	Slow	Every zone	Acceptable	Excellent pasture	Durable
Boscia Senegalensis	Slow	Every zone	Acceptable	Soil protection	Durable
Pinus Pinea	Fast	Dry zone and grow in nutritionally poor soil	Acceptable	Improve soil fertility	Less Durable

We included the Pinus Pinea because we observed that it is a plant that grows quickly and doesn't require much water to develop. The problem with that plant is the fire risk; just one spark might start a massive wildfire in the area. This problem has been noticed in France this summer. However, we believe that this plant could be our testing seed due to its low price and availability.

Additionally, we found out that the diversity of trees within a forest offers superior fire protection. Therefore, we would like to sow a variety of seeds in our future forest.

Conclusion

To sum up, E-Gaïa will be an autonomous robot designed to reforest the burned or arid areas. It will have a Rocker-bogie structure capable of navigating through most of the obstacles, plus the motors and wheels have been selected for their capacity to carry a heavy package slowly but steadily.

It will be able to travel and identify the most fertile locations with the help of a Lidar 3D scanner, a GPS, an accelerometer, a gyroscope, a temperature, light, and humidity sensor, as well as the Arduino and Jetson boards that will be in charge of analyzing all the data.

Finally, the refill station will allow the robot to continue working continuously without a technician's assistance.

Personal thought towards the project

Although this project will take a considerable amount of time and represent a significant engineering challenge for us, it will undoubtedly benefit us greatly in terms of experience and knowledge. Following Aseedbot's inspiration, our team is enthusiastic and motivated to develop E-Gaïa, the autonomous gardener for burned and arid terrain. **[18] [19]**

List of materials

Here is a sum up list of all the components that will be required in order to build the robot:

Components	Model	Quantity	Price (€)	Purchase link
Temperature / Humidity Sensor	DHT11	1	1,16	Aliexpress
Light Sensor	LM393	1	1	Link
GPS	NEO-6M	1	3,12	Aliexpresss
Inclination Sensor	MPU6050	1	1,42	Aliexpress
Stepper	NEMA17	3	4	link
DC Motor		7	15	link
Servo motor		2	5	Link
Hub		1	11	link
Mounting Bracket		1	9	link
Battery 12V, 5Ah		1	46	aliexpress
Wheels		6	5	aliexpress
Lidar		1		
Toothed belt		1	1,93	Link Aliexpress
Drill Tip		1	18	Link Aliexpress
Auger		1	15	Link Amazon
Rake		1	5	Link Aliexpress
Seed Reservoir		1	/	Own production
Seed		10	3	Seed Link
Clapper		1	/	Own production
Pipe		1	2	Link Aliexpress
Frame in Aluminum		4	15	Link

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Planning

GANTT DIAGRAM

PROJECT NAME	E-Gaïa
PROJECT MANAGERS	Jaime, Brice
DATE	13/09/22

NUMBER	TASK TITLE	WHO	START DATE	DUE DATE	DURATION (days)	TASK PROGRESSION	PHASE ONE		
							10 Hours	10 Hours	10 Hours
1	**Robot conception**								
1.1	Robot ideas	Jaime Brice	13/09/22	20/09/22	7	100 %			
1.2	Robot research and viability	Jaime Brice	20/09/22	08/10/22	18	100 %			
1.3	Research report (biblio)	Jaime Brice	20/09/22	08/10/22	18	100 %			
1.4	Mass estimation	Jaime	04/10/22	08/10/22	4	100 %			
1.5	Gantt diagram	Brice	04/10/22	08/10/22	4	100 %			
2	**Modelisations**								
2.1	Frame	Jaime	10/10/22		0	0 %			
2.2	Wheels	Brice	10/10/22		0	0 %			
2.3	Drill and auger	Brice			0	0 %			
2.4	Rake	Jaime			0	0 %			
2.5	Water and Seed Reservoir	Brice			0	0 %			
2.6	Sensor connections, cards...	Jaime			0	0 %			
2.7	Modelisations Assembly	Jaime Brice			0	0 %			
3	**Machinery**								
3.1	Robot Manufacturing	Jaime Brice			0	0 %			
3.2	Sensor connections, cards...	Jaime Brice			0	0 %			
4	**Code**								
4.1	Sensors	Jaime Brice			0	0 %			
4.2	Reaction to sensor results	Jaime Brice			0	0 %			