Robotique, Systèmes autonomes

Project report

School year 2022-2023

"Vitis, the robot at the service of the vines"

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Introduction

With the scarcity of chemical molecules available for vineyard weed control, due to the inauguration of new environmental regulations, mechanical weed control is the most credible and effective alternative. Unfortunately, this type of weeding requires more presence in the vineyard as it has to be applied more regularly throughout the year. The automation of this task would allow winegrowers to save time on a tedious job that does not require human intervention. Our robot will therefore have the task of weeding a plot of low vines in complete autonomy. To complete this task and optimise the robot's usefulness, it will also be tasked with detecting certain visible vine diseases such as mildew, oidium and botrytis. Thus the robot will be able to inform the winegrower of any outbreak of disease and locate it.

To meet these needs, we have broken down our study into the stages of the robot's energy chain and information chain below (Figure 0):

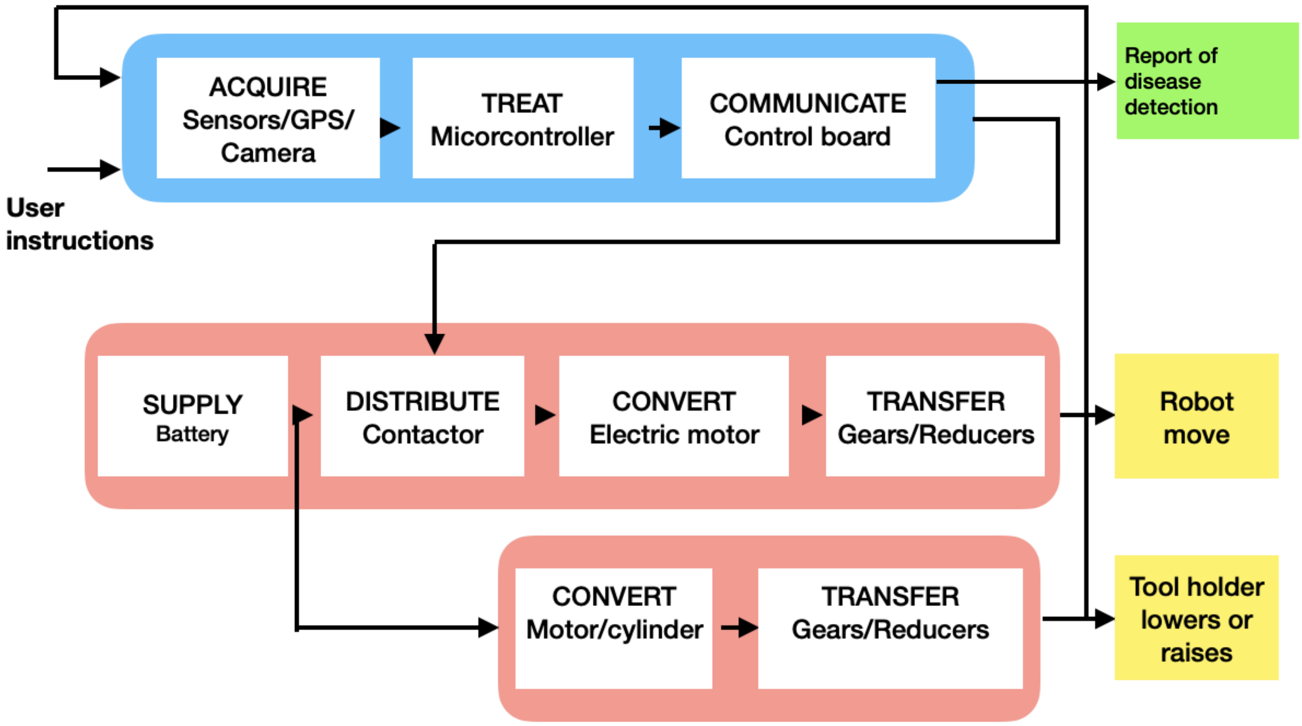


Figure 0- Diagram of the information chain and the energy chain of the robot

Chapitres I: The design

I.1.Specification

The robot will have to carry out weeding of low vines throughout the year. It must therefore respect certain shape criteria in order to be adapted to its environment.

Pruning constraints: The rows of the vine are 90 to 150 cm apart, so the robot must have a maximum width of about 70 cm. The length will have to be decided according to the components such as the wheels and the tool holder..., the length of the robot will have to be able to compensate for the weight and the forces applied to the tools. For the height, the robot should be high enough for the camera to identify the diseases, i.e. about 80 cm.

I.2. The shape of the robot

We have two possible solutions for the shape of our robot:

- First solution: the robot will be in the shape of an arch which will be on both sides of the row like the TED robot created by the company Naïo (Image I.2.1)

Image I.2.1- robot TED

- Second solution: the robot moves between two rows of vines and is composed of two independent assemblies, a base that will allow the robot to move through a vineyard and a tool that will be attached to the base and will allow the weeding of the soil (Figure I.2.2)

Figure I.2.2 - Robot diagram

I.3. The materials

The robot must meet several criteria that will allow us to determine the ideal material:

- The robot should not be too heavy to avoid soil compaction.
- Its structure must be strong enough to support the tool holder.
- Its structure must protect the electronic components from rain so that it can work even during bad weather.

Possible solutions:

Materials	Weight	Solidity	Shaping	Oxidation	Hardness
Wood	Heavy	Strong	Easy	Fast	medium
Plastic	very light	Fragile	Very Easy	Very slow	medium
Aluminium	light	Very strong	Easy	Slow	High

I.4. Mass estimation

La structure	Bâti	1000g
	Coque	1000g
La chaîne d'énergie	Batterie	2000g
	Moteurs	300gx4
	Transmission	500g
	Roues	360g
La chaîne d'information	Capteurs	200g
	Cartes	800g
Annexe	Porte-Outil	1000g
	Outil	1000g
Batterie		500g
Total		9560g

I.5. Summary

For our robot we therefore chose a compact rectangular shape with a tool holder at the rear and moving between the rows of vines.

For the size we first estimated its real size, i.e. allowing its use in vineyards. These dimensions are 130cmx60cmx80cm. Unfortunately these dimensions are too large and do not respect the size constraint imposed for the project, so we decided to make a reduced robot of 1:3, i.e. 430mmx200mmx270mm (Figure I.5.1).

The robot will be built around an aluminium frame and the rear face on which the tool holder is fixed will also be made of aluminium in order to have solid fixings and to resist the traction forces when the tools are in the ground.

The interior of the robot can be broken down as follows: (See figure I.5.2)

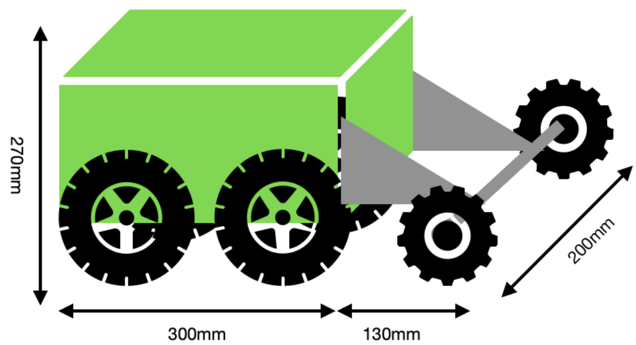


Figure I.5.1-Dimension of the robot

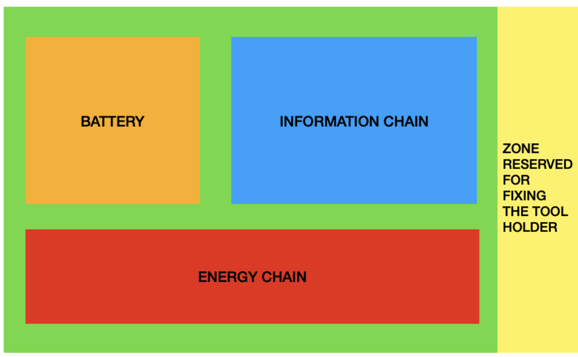


Figure I.5.2-Robot layout (side view)

Chapitres II: The energy chain

II.1. Specifications

The energy chain will allow us to move the robot through a vineyard, knowing that the vineyard is made up of rows that require the robot to rotate when it reaches the end of the row.

Here are the criteria that our robot must respect:

- Speed of about 5km/h, the recommended speed for good weed control. (1.38m/s)
- Power to climb a slope of up to 30% with a robot weight of approximately 15kg.
- It is possible to make a U-turn at the end of the row.
- 100% electric.

II.2.Transmission

There are different possible solutions to allow the robot to move:

- Caterpillars (Image II.2.1):


Image II.2.1- Robot chenilllard

The use of caterpillar tracks provides a wide base that improves the stability of the vehicle. The tracked robot is steered differentially, with two tracks on each side of the robot driven by a motor via a sprocket. The robot is steered by reversing the direction of rotation of one of the tracks allowing a quasi-static 360.

Avantages	Déplacement sur terrain accidenté.	Stabilité et hauteur constante par rapport au sol.	Vitesse du véhicule sur un terrain accidenté.
Inconvénients	Très coûteux.	Compaction du sol en profondeur	

- 4 wheels (Image II.2.2):


Image II.2.2-Robot à 4 roues

The use of 4 wheels is the most common solution in the agricultural world today (tractor, high clearance tractor, etc.), it allows a stable, relatively efficient robot with multiple manoeuvring solutions (forward rotation with steering linkage, etc.).

However, the choice of a 4-wheel drive requires each wheel to be motorised in order to move on terrain that may be uneven and sloping. This requires the purchase and installation of 4 motors that must work together. This makes the robot heavier and more difficult to rotate. The use of wheels also has an impact on the soil with surface compaction that favours run-off and erosion.

- Other modes of movement such as 2 wheel drive with an idler wheel have no advantage in view of the terrain on which the robot must move.

II.3. Motorisation

A. Motor sizing

The mass of the robot will be about 10 kg, it has 4 motorised wheels and therefore 4 motors.

The wheels have a diameter of 6 cm.

We want the robot to go at a speed of 5km/h, so 1.4 km/h.

The maximum slope inclination is 30°.

With these data entered into the robotshop motor sizing tool, we obtain the following characteristics:

Vitesse angulaire	Couple	Puissance	Ampérage max
223 tr/min	1.1 Nm	26.950W	2.2A

B. Types of motors

- DC motors (or MCC):

Avantages	Couple toujours optimal	Alimentation simple	Vitesse de rotation proportionnelle à la tension d'induit	Changement de sens simple	Couple de démarrage élevé
Inconvénients	Rendement moyen	Prix relativement élevé	Vitesse de rotation limité		

- Brushless motors :

Avantages	Durée de vie	Gestion de la vitesse	Faible consommation	Haut Rendement	Plus petit
Inconvénients	Prix élevé	Plus compliqué d'utilisation			

- Step motors :

Avantages	Précision	
Inconvénients	Vitesse limité	Couple faible qui décroît rapidement quand la vitesse augmente.

II.4. Summary

We therefore decided to opt for the solution of 4 wheels driven by a DC motor. This is the most optimised solution to allow the robot to move in a vineyard plot (Figure II.4.1).

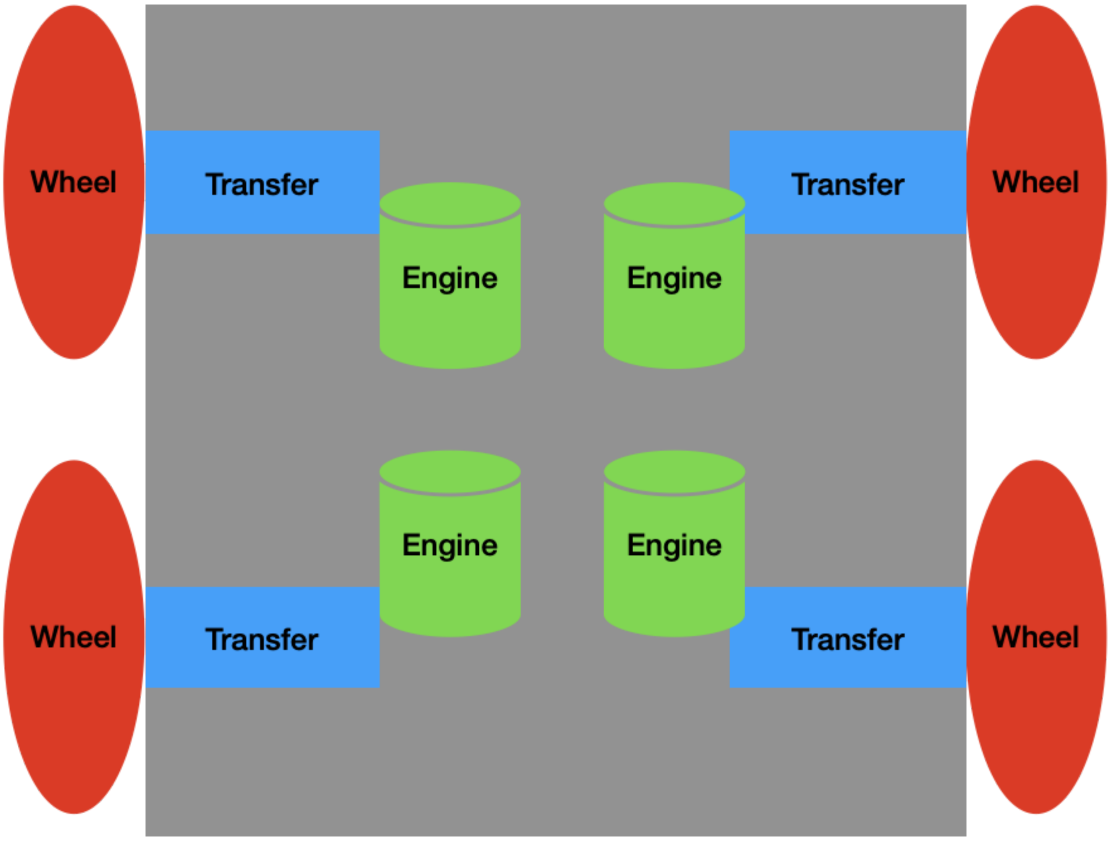


Figure II.4.1-Schematic of the motor arrangement in the robot

Chapitre III: The information chain

III.1. Specifications

The information chain will enable us to acquire and process data and communicate it to the user. The robot will have to respond as well as possible to the client's instructions and provide the information necessary for its work.

Some points to respect:

- The robot will be able to move in its row without hitting obstacles
- The customer will have the possibility to program the robot on the execution time and the type of tools used
- He should provide a complete map with the coordinates of all diseased plants

III.2. Acquiring

There are several alternatives for the robot to move properly in its environment:

- Using an ultrasonic sensor

The principle of this sensor is to measure the travel time of a sound wave, the closer the object, the shorter the time and vice versa. Thanks to this we can estimate a distance since in our medium (air) the speed of sound is approximately constant.

Avantages	Peu cher	Adapté aux objets proches	Fonctionne avec presque tous les matériaux
Inconvénients	Fonctionne à faible distance	Sensible à la température et à la pression	Objets avec angles

Figure III.2.1 - Ultrasonic sensor

- Using an infrared sensor

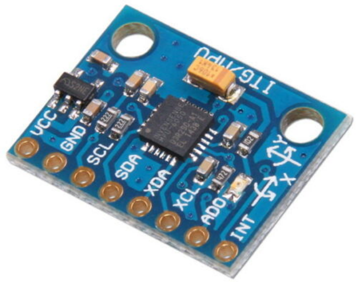
This sensor also works on the principle of return time, but this time with light, since it has an infrared transmitter and receiver (>800 nm). Unlike the ultrasonic sensor, this sensor does not wait for a signal but rather for a change.

Avantages	Consomme peu	Capte de 5 à 80 cm	Plus précis sur la direction
Inconvénients	Fumée, poussière ou lumière du jour peuvent interférer	Sensible à la couleur (le noir absorbe)	

Figure III.2.2 - Infrared sensor

In order for Vitis to be able to find its way in space, several sensors will be at its disposal:

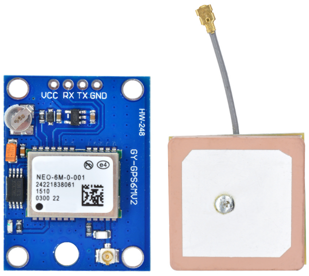
- An accelerometer



Its principle is very simple, it measures the acceleration (speed variations) in three dimensions and allows the robot to know its inclination on each axis. Thanks to this, we can know if the robot is lying in the ground, if the slope is too steep or if the tool is too deep or not deep enough in the ground.

Figure III.2.4 - Accelerometer

- A GPS (Global Positioning System)



We all have GPS in our pockets, which allows Vitis to know its coordinates so that it can report the position of diseased plants to the farmer.

The problem with the chosen model (GY-NEO6MV2) is its accuracy of about 2.5 m. To overcome this problem, we will use map generation in parallel with the robot's movement.

Figure III.2.5 - GPS

Finally, the sensor that will allow us to detect diseases is simply a camera:

- A WebCam

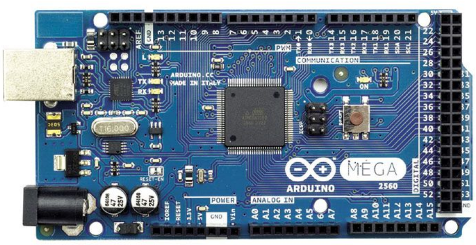
The latter sensor will be used to identify diseases on the vine. The camera will send a series of images to an electronic card which will analyse them to find spots. The disadvantage of this system is that only visual diseases can be detected.

Figure III.2.4 - Cam

III.3. Processing

In order to process the information we need electronic cards:

- Arduino MEGA



The Arduino mega board is the big sister of Arduino Uno, it is more powerful with more ports available for connections. It will be the main brain of our engine, it will make sure that the different parts can communicate with each other.

Figure III.3.1 - Arduino MEGA

- JN30D-Nano (NVIDIA)

The Nvidia card will manage all the artificial intelligence part which requires a lot of resources. It will be connected directly to the camera and cannot be controlled from the robot.

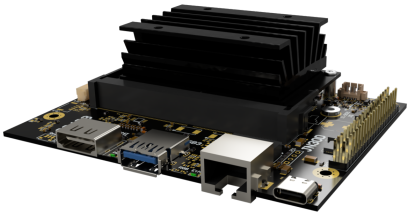


Figure III.3.2 - JN30D-Nano

III.4. Communicate

Finally, to complete the information chain, it is necessary to be able to communicate with the user and for him to access the robot's information.

First, the user must be able to give it an instruction:

- Push button and potentiometer wheel

These two elements will be used to navigate through the robot's menus so that the user can choose a programme.

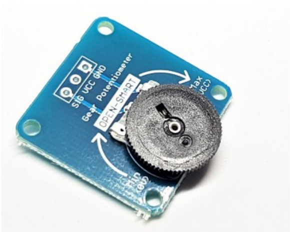


Figure III.3.3 - Push button

Figure III.3.4 - potentiometer wheel

Then the robot must be able to transmit information directly to the user:

- Screen LCD :

The user interacts with the screen using the buttons seen earlier and can select the desired programme.

Figure III.3.5 - Screen LCD

- Buzzer and Flashing light

Like the LCD screen, these devices allow information to be transmitted to the user (sound or light signals), such as a danger or a problem.

Figure III.3.6 - Flashing light

Figure III.3.7 - Buzzer

III.5. Summary

All the technical solutions mentioned above will be used for our robot, in order to have the best user experience and a good understanding of the machine.

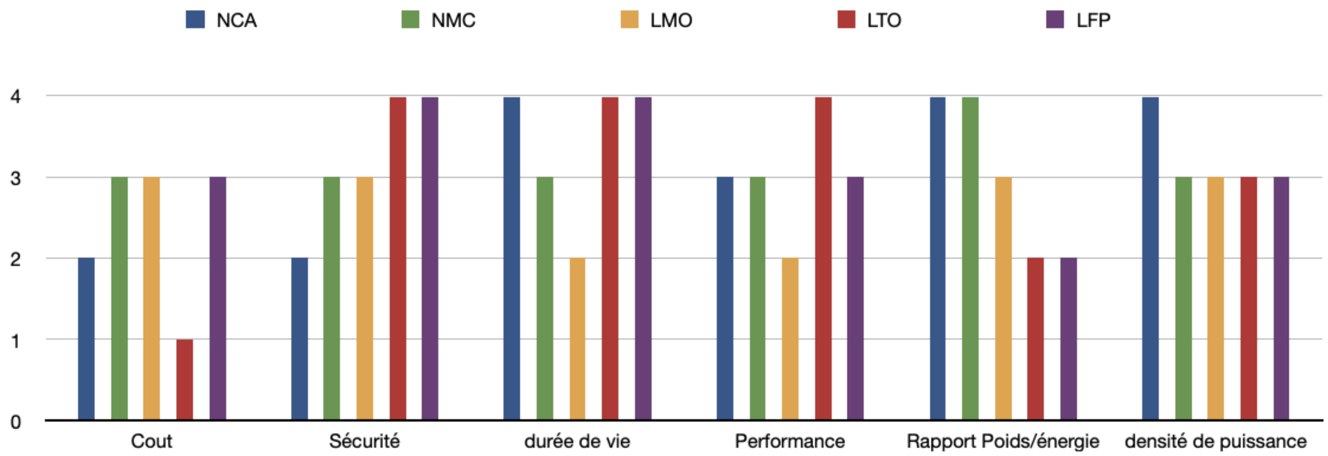
Chapitre IV: Power supply

IV.1. Specifications

The power supply of the robot is a part that requires many choices. You have to decide if you want a long autonomy which requires a heavier battery and can have an impact on the choice of motors. Or if we prefer a shorter autonomy but this requires the robot to be recharged more times to perform its task and therefore the battery degrades more quickly.

With the sizing of the motors we have seen that a 12V and 5Ah battery is needed.

IV.2. Batteries



NCA= Lithium-nickel-cobalt-aluminum………………….Note= 3,2/4

NMC=Lithium-nickel-manganese-cobalt………………...Note= 3,2/4

LMO=Lithium-manganese spinel………………………..Note=2,7/4

LTO=Lithium titanate……………………………………...Note=3/4

LFP=Lithium Fer-Phosphate…………………………….Note=3,4/4

IV.3. Summary

After analysing the different types of Li-ion batteries, we have chosen to use a 5Ah Lithium Iron battery. This would allow us to have a battery allowing a 1h autonomy with a battery of approximately 700g which joins our estimate of the part I.

Chapitre V: Tools

V.1. Requirements

The last part of our robot is the tool holder. This is attached to the back of our robot and must meet several criteria to ensure effective weeding. It must allow several tools to be attached to the robot, such as inter-weeder blades, crumbling discs or dethatchers. It must also ensure that the tools are raised when the robot is at the end of the row and must rotate to access the next row. We therefore need to find a system that allows the tool carrier to be raised and lowered by about ten centimetres from the ground.

V.2. The solutions

- The first solution is to install two cylinders between the robot and the tool holder to make a pivot as shown below (Figure V.2.1):

Avantages	Inconvénients
Stabilité	Cout
Puissance	Alourdi l'arrière du robot
Précision	

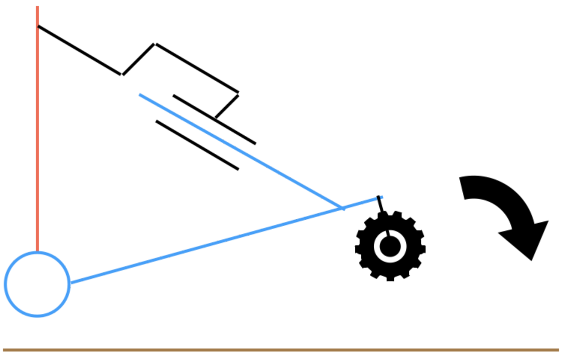


Figure V.2.1-System for lifting tools by jack.

There are different types of cylinders with different characteristics:

Vérin pneumatique	Vérin hydraulique	Vérin électrique
		
Simple d'utilisation	Système complexe	Système complexe
Bonne puissance	Très puissant	Bonne puissance
Moins précis	Moins précis	Positionnement et vitesse réglable
Très rapide	Rapide	Rapide
Supporte les chocs sur la charge	Supporte les chocs sur la charge	Supporte peu les chocs
Peu cher	Cher	Cher
Besoin d'énergie pneumatique	Besoin d'énergie hydraulique	Entièrement électrique

- The second solution is to use a motorised pulley system to raise or lower the tools (Figure V.2.2):

Avantages	Inconvénients
Cout	Instabilité
Facile d'installation	Doit être lourd pour être bien enfoncé dans le sol
Puissance	
Précision	

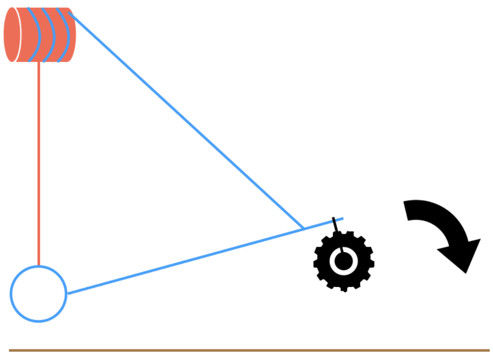


Figure V.2.2-System for lifting tools by pulley

- The last solution is to have only one motorised rotation axis powerful enough to lift the tools (Figure V.2.3):

Avantages	**Inconvénients**
Facile d'installation	**Instabilité**
Plus compact	**Puissance requis multiplié par l'effet de bras de levier**
Permet de bien enfoncer l'outil dans le sol	

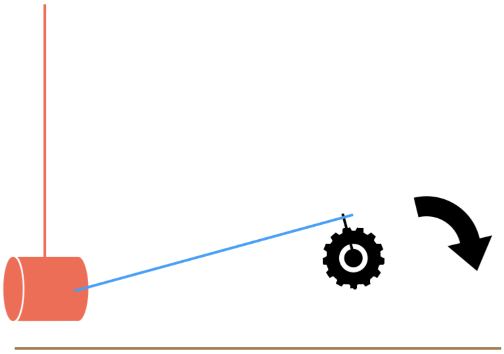


Figure V.2.3-System for lifting tools by motorised pivot link

- Now we need a list of the tools needed for good weeding:
  - The decavaillonneuse: it allows the soil to be worked between the vines. To avoid damaging the vines, a sensor detects the vine and triggers the tool to move.

  - The crumbling discs: they are composed of two or three discs with cut and more or less twisted ends and allow to carry out the ridging work.

  - Weeding fingers: this is a disc made up of fingers that allow for quick maintenance of the cavaillon. However, the soil must be soft and clean (without stones or piles of dried earth).

- The tools will be attached to the tool holder using a screw/nut system and the robot will perform the weeding work one tool at a time. This will require the user to be present for the tool change.

V.3. Summary

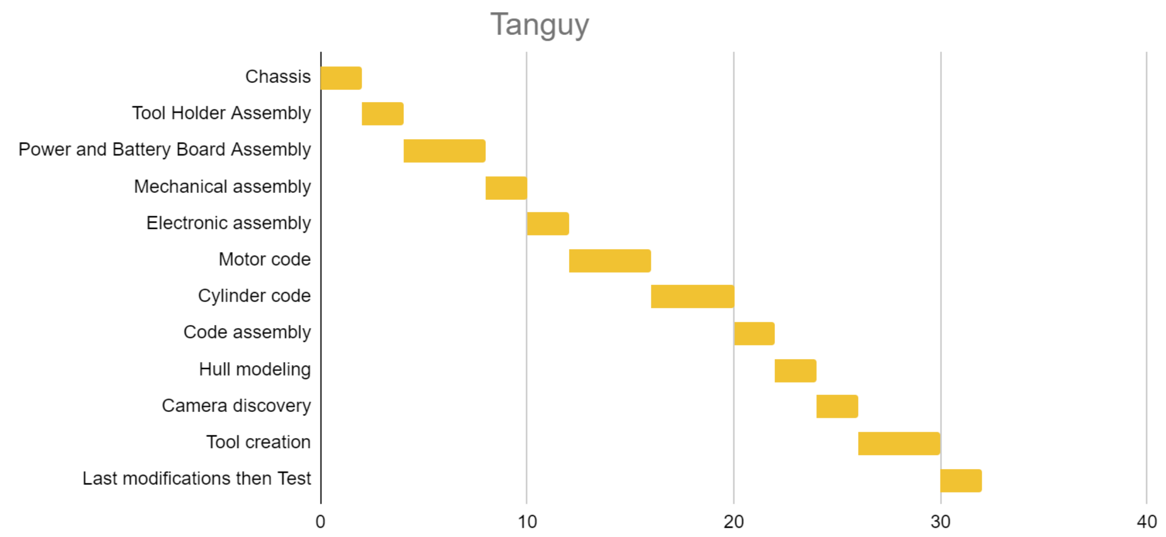
In order to have tools that are as adjustable as possible we decided to keep the cylinder solution because it allows the tool to be lifted when the robot is rotating but also to adjust the depth at which the tool is driven into the ground, which allows the settings to be changed according to the different tools. It is also an advantage to keep the tool in the ground.

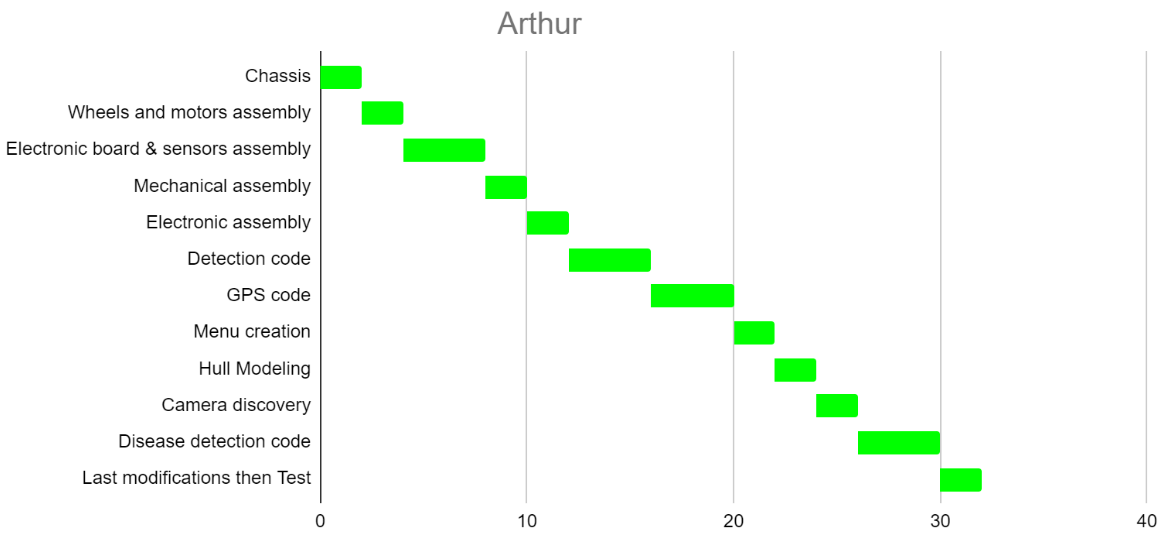
Conclusion

To conclude this bibliographic report, we reviewed the possible solutions and decided which one was the most optimal for each robot need. The robot will be a rectangular robot with 4 driving wheels that will allow it to move in a vineyard plot with a slope of up to 30°. The robot will navigate using proximity sensors and a camera that will also allow it to detect certain visible vine diseases. For weeding, the robot will have a tool holder connected to the robot by jacks and a pivot link that will be adjustable in height and will allow the tool to be inserted into the soil. The tools will be fixed to the robot with screw-nuts so that the user can change them as required.

Annex

A. Planning





B. Liste du matériel

Matériel	Quantitée	Lien
Batterie	1	Lien Batterie
Moteurs	4	Lien Moteur
Vérin	2	Lien Vérin
Capteur ultrason	1	Lien Capteur Ultrason
Capteur infrarouge	1 (paquet de 5)	Lien Capteur Infrarouge
Accéléromètre arduino	1	Lien accéléromètre arduino
GPS	1	Lien GPS
Caméra	1	Voir avec M.Masson
Arduino MEGA	1	Arduino MEGA
Carte NVIDIA	1	Voir avec M.Masson
Molette potentiomètre	1	Lien Molette Potentiomètre
Ecran LCD	1	Lien écran LCD
Gyrophare	1	Commande plus tard

C. Bibliographie

Contact viticulteur: -Nicolas Potel, Domaine de Bellene, 21200 Beaune

-Danièle Bonnardot, Domaine Bonnardot,21698 Villers-la-Faye

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