Robotic platform for agriculture

System Specifications

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Robotic platform for agriculture: System Specifications

by Guy Corbaz

Dedication

To the planet

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Preface

We want to accelerate the transition to sustainable development, that's why we develop an open source agriculture robotic platform. We distribute all the plans license and software of our robot under Apache 2.0, except for ready-made items such as motors, GPS modules, LIDAR , etc. which are under the manufacturer's license.

Chapter 1. Introduction

We very often talk about precision farming and agricultural automation. However, most of these projects consist in improving the traditional way of doing things, without radically changing it. As an example, grass management in crops such as vines, fruit trees, or plot ends is done in a very traditional way: with a tractor and mower or gyro mower, and with weed killers for areas that are not or not easily accessible by machines. The same problem can be found in the maintenance of roadsides or large non-agricultural grassy areas.

Objectifs du robot tondeuse

This mower robot is part of a sustainable development approach. The objectives are:

- Eliminate the use of polluting herbicides that are harmful to health and nature.
- Reduce CO_2 emissions by not using fossil and non-renewable fuels.
- Reduce operating costs.

  In order to be able to quickly integrate into a sustainable development logic, the robot's plans and software are distributed under the GNU General Public License (GPL), including the elements we buy ready-made, such as engines, LIDAR, electronic circuits, etc. that are under the manufacturer's license[1].

  The robot can also be sold completely assembled, or as a kit either complete or partial. The partial kit includes, for example, elements machined specifically for the robot.

  All plans and software are freely available on the Internet.

[1]These elements may be under proprietary license.

Chapter 2. Specifications

This chapter describes the general and detailed specifications of the robot lawnmower.

General specifications

General specifications are the following:

- Weight: 25 kg (±20%)
- Working width: 60cm
- Maximum working speed: 1,8 km/h, that is 0.5 m/s.
- Travel speed: 1,8 km/h
- Minimum treatable area: 20'000 m^2
- Delimitation of the surface to be treated by GPS RTK (Real Time Kinematic). Installation of a wire is excluded.
- Ground clearance (chassis to ground distance): min 10cm
- Autonomy: 4h minimum.
- Autonomous navigation and obstacle avoidance.
- Trajectory optimization strategy to save battery power.
- Minimum passable obstacle height: 10cm.
  - Maximum crossable slope: 45°.
- Safety and protection of users and animals.
  - Users and animals must not be allowed to come into contact with sharp parts (e. g. mower knives).
  - The machine must stop when someone approaches too close.
  - Cutting elements (e.g. mower knives) must stop if the machine tilts too much.
  - The machine must stop completely and go into alarm if it overturns.
  - The machine must stop completely and go into alarm if it is blocked.
- Security and remote access
  - System must be protected against unauthorized remote access.
  - Only user who need to access the robot will be allowed to access it.
  - Robot ownership must be tracked: if the owner sell his robot to someone else, a mechanism has to be put in place to track this transaction. All access right and ownership parameters have to be transmitted to the new owner.
- Remote access
  - Robot activation/deactivation.
  - Status information.

- Position information.
- Programming the operating area.
- Access via an application on a mobile phone.
- Access via a website.
- Recharging
  - Two types of charging stations
    - Charging station connected to the electricity grid.
    - Recharging station with solar panels and wind turbine (next step).
  - Recharge time with network connection: max 4h
  - Recharging time with solar or wind stations: max 6h
  - The robot automatically and alone returns to its charging station.
  - When the robot is connected to its charging station, it stops all unnecessary electrical consumers.

Detailed specifications

Resistance to advancement

The resistance to advancement depends on two factors:

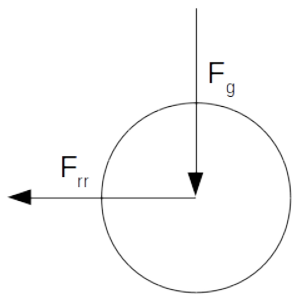
- Wheel forward resistance
- The slope to be crossed

The calculations below give an order of magnitude of the forces, torques and powers at play. However, these values will have to be checked and confirmed on the prototypes, as they are based on worse case.

Wheel resistance to driving

According to [wiki01], rolling resistance calculations can be simplified if the vehicle does not move fast, which is our case. Not having found the rolling resistance coefficient for a tire on grass, we take the sand coefficient, 0.3.

Figure 2.1. Forces on a wheel



The rolling resistance is given by:

Equation 2.1. Rolling resistance

$F_{rr} = C_{rr} \cdot F_g$

Equation 2.2. Gravitational force

$F_g = m \cdot g$

where:

F_{rr}: rolling resistance force in N.

C_{rr}: rolling resistance coefficient..

m: .mass of the vehicle (the robot for us) in Kg.

g: gravitational constant, in $m/s2$.

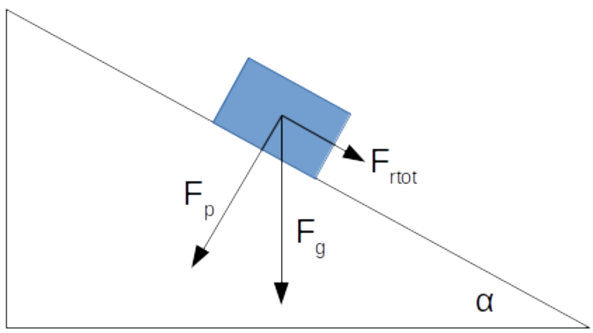
With our specifications, F_{rr} is, for a flat vehicle, with all wheels identical.[1] and that the weight is evenly distributed:

$F_{rr} = C_{rr} \cdot m \cdot g = 20 \cdot 9.81 \cdot 0,3 = 58,8N \cong 60N$

Total resistance

Taking into account the slope, the calculation is a little more complex: it is necessary to add the components due to gravitation. In addition, the rolling resistance force decreases with increasing slope..

Figure 2.2. Total resistance



The total resistance is due to the force of gravity and rolling resistance, which is:

$F_{rtot} = F_{rr} + F_{rg}$

where

F_{rr} is the rolling resistance force.

F_{rg} is the resistance force due to gravitation.

F_{rot} is the total resistance force: the one that the motors must overcome.

From the diagram Figure 2.2, “Total resistance” and the triangle of forces, we calculate:

Equation 2.3. Rolling resistance

$F_{rr} = C_{rr} \cdot F_p = C_{rr} \cdot F_g \cdot \cos(\alpha)$

1

It is easy to demonstrate that this force does not depend on the number of wheels but only on the surface of the floor and the wheels.

Equation 2.4. Gravity resistance

$$F_{rg} = F_g \cdot \sin(\alpha)$$

Equation 2.5. Gravitational force

$$F_g = m \cdot g$$

by replacing the terms, you get:

Equation 2.6. Total resistance

$$F_{rtot} = C_{rr} \cdot F_g \cdot \cos(\alpha) + F_g \sin(\alpha) = F_g (C_{rr} \cdot \cos(\alpha) + \sin(\alpha)) = m \cdot g . (C_{rr} \cdot \cos(\alpha) + sin(\alpha))$$

From the general specifications, the total resistance force in the grass is easily calculated for a maximum slope of 45°.

Equation 2.7. Maximum resistance

$$F_{rtot} = 20 \cdot 9,91 \cdot (0,3 \cdot 0,7 + 0,7) = 177,5N \cong 180N$$

Note

The values calculated above correspond to the maximum forces with which the robot could be confronted.

Wheel diameter

The diameter of the wheels is determined by the ground clearance of the robot mower chassis. Wheels with a diameter of 30cm are chosen: this ensures the minimum ground clearance required in the general specifications and leaves some room for the layout of the electric propulsion motors. In addition, wheels with a diameter of 30cm allow the use of inflated tires (at low pressure) which makes it easier to travel on slightly uneven ground such as in crops.

The relationship between the rotational speed and the wheel radius is given by:

Equation 2.8. Speed as a function of rotation speed

$$V = 2 \cdot \pi \cdot r . \omega$$

where:

V: speed in m/s

r: wheel radius in m

ω: rotational speed in rad/s

The rotational speed can be calculated from the linear speed as follows:

Equation 2.9. Rotational speed as a function of speed

$$\omega = \frac{V}{r}$$

or, in our case:

$$\omega = \frac{0,5}{0,15} = 3,33 rd/s = 1,05 t/s = 63 t/min$$

Propulsion torque

The torque required depends directly on the diameter of the wheels and the maximum resistance force. Power, on the other hand, depends on the torque and rotational speed of the wheels, or on the forward speed and resistance force.

The total force required for the movement is 180N. However, it is evenly distributed over all 4-wheel drive. It is therefore 45N per wheel

Equation 2.10. Maximum torque per motor

$$T = F_{rr} \cdot r = 45 \cdot 0,15 = 6,75 Nm$$

This represents the total torque. For 4 motors, the torque per motor is a maximum of **6.75Nm**.

Propulsion power

The power required to propel the mower, according to the basic specifications, is:

Equation 2.11. Required power

$$P = F_{rtot} \cdot V = 180 \cdot 0.5 = 90 W$$

With 4 propulsion engines, each engine must have a power of **22.5W#25W** per engine.[2]

Table 2.1. Characteristics of propulsion engines

	Value	**Comment**
Power	25W	
Torque	6,75Nm	
Rotational speed	60t/min	avec réducteur
Power supply	12 ou 24 V	

Power for accessories

We reserve 180W of power for connecting accessories, such as cutter bar, arm, etc. to the robot.

Battery pack

To estimate the battery capacity, we start from the robot's autonomy, 4 hours, and the total electrical power required, namely the power of the accessories and the propulsion power.

- Autonomy: 4h
- Total power: $90W + 180W = 270W$

12V or 24V batteries are possible. The necessary capacities are:

Table 2.2. Battery capacity

Nominal voltage	Power	Current	Capacity
12V	270W	22.5A	90Ah
24V	270W	11.25A	45Ah

[2]with the assumption that the motors and their controls have an efficiency close to 100%.

Warning

In the above estimates, we did not take into account the efficiency of motors, electronic circuits, etc. However, we have calculated the necessary capacity using the maximum continuous power, which will not always be the case.

Chapter 3. Architecture

The mower robot consists of various mechanical, electronic and software components. The following paragraphs provide details of each element.

Mechanical design

To be done

Chassis

To be done

Wheels

To be done

Bodywork

A faire

Propulsion

Propulsion is provided by four electric motors of at least 25W each (see the section called “Propulsion power” and the section called “Propulsion torque”). The characteristics of these engines are:

- Power: 22,5W
- Torque: 6,75 Nm
- Rotational speed: 33 t/min

In addition, the motor will include an encoder, to measure the number of revolutions performed, as well as a gearbox..

Engine

Brushless engine with encodeur.

Gearbox

To be done

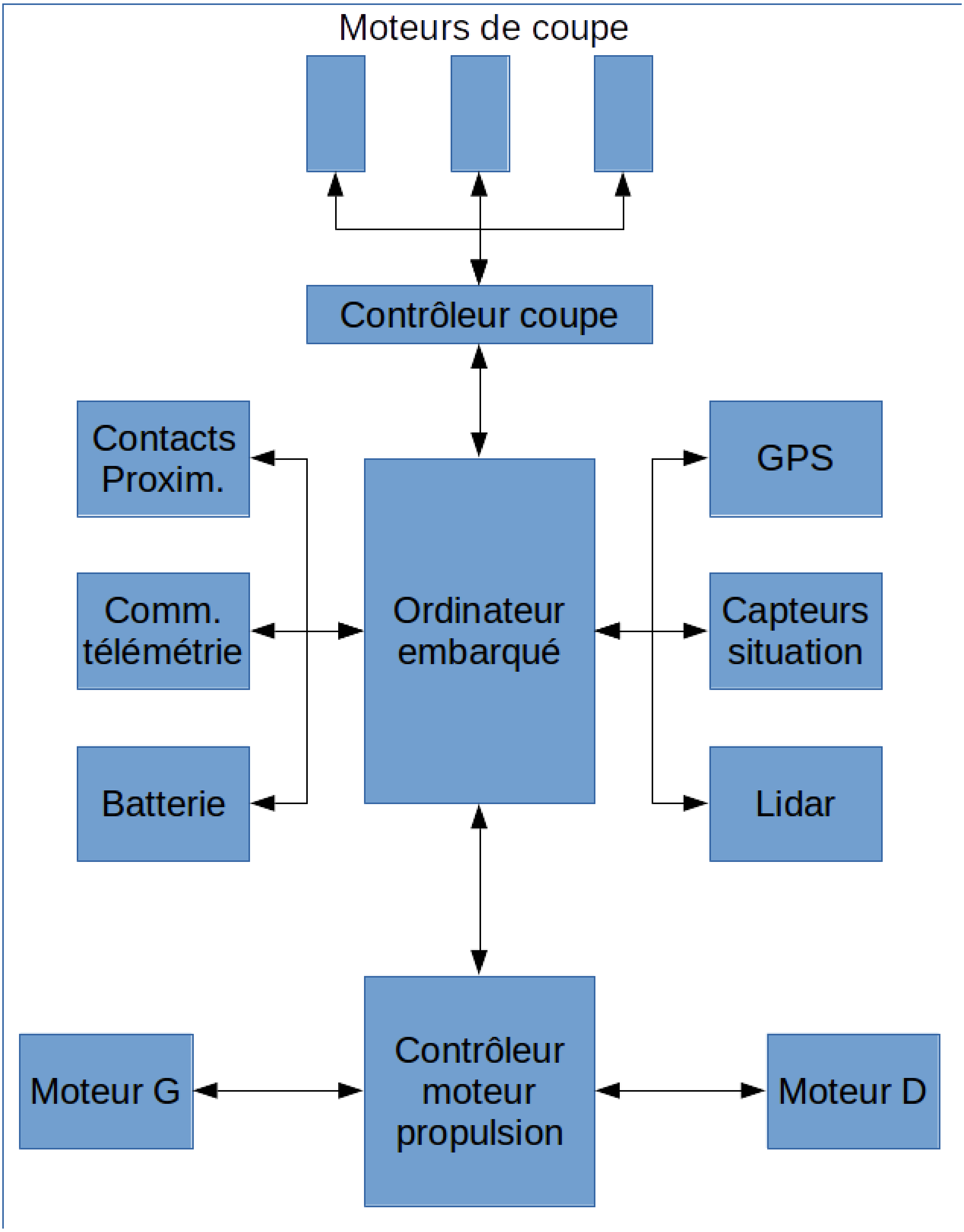
Encodeur

The encoder allows you to count the number of revolutions actually performed by the motor. By knowing the reduction ratio of the gearbox and the diameter of the wheels, we can quickly determine the distance covered.

Electronic

The control electronics are made up of several separate blocks, as shown in the diagram below.

Figure 3.1. Robot control architecture



Propulsion engine controller

To be done

Accessories engine controller

To be done

Lidar

To be done

GPS

To be done

Local contacts

To be done

Battery

To be done

On-board computer

To be done

Attitude sensors

Accelerometer, gyroscope, magnetometer

Communication

WiFi, GSM, IP

Software architecture

The robot software runs on a Raspberri Pi III. It consists of the following two important bricks::

- Operating system: Linux Ubuntu.
- ROS (Robot Operating System).

Chapter 4. Prototype

This chapter concerns the realization of the prototype. It describes the assumptions to be validated and the tests and measurements to be performed.

Assumptions to be validated

The hypotheses to be validated are:

1. Lidar
   a. Possibility to use the lidar for navigation, based on known ground references (trees, poles, walls, etc.) instread of GPS.
   b. xxx
2. GPS
   a. Check the accuracy of the RTK GPS.
   b. Explore the possibility of using the Swiss and foreign GNSS network in the future, if the price is affordable.
   c. Validate the method of delimiting the land.
   d. xxx
3. Propulsion
   a. xxx
4. Cutting
   a. Validate the rotation speed of the knives
   b. Validate the possibility of varying the speed of rotation according to the type of grass, in order to save energy.
   c. xxx
5. Remote access
   a. xxx
6. Situation
   a. xxx

Tests and measurements to be carried out

The tests and measurements to be performed are:

1. Lidar
   a. Measure the accuracy of the LIDAR
   b. xxx
   c. xxx

   d. xxx
   e. xxx
2. GPS
   a. Measure GPS accuracy
   b. xxx
3. Propulsion
   a. Measure the power curve according to the use
   b. xxx
4. Cutting
   a. Measure the power consumed by the motors during use
   b. Test the cutting quality at different speeds.
   c. xxx
5. Remote access
   a. xxx
6. Situation
   a. Testing accelerometers
   b. Test magnetometers, mainly their interactions with motors.
   c. Testing gyroscopes
   d. xxx

Chapter 5. Electronic

Motor control

Brush-less motor are controlled via a CANOpen brush-less controller. We are using the KYDBL 2430-1E manufactured by Keya Electron.

Chapter 6. Software

Security

Security is a critical feature that must be implemented in the robot, as it will be connected to the Internet to be remotely accessible, for software upgrade, remote maintenance, remote operations, etc.

Glossary

GPS RTK	Real Time Kinematic (RTK) is a satellite positioning technique based on the use of phase measurements of the carrier waves of signals emitted by GPS, GLONASS or Galileo systems. A reference station provides real-time corrections to achieve an accuracy in the centimeter range. In the particular case of GPS, the system is then called Carrier-Phase Enhancement or CPGPS.
SLAM	Simultaneous Localization And Mapping.
GPL	GNU General Public License

Chapter 7. Bibliography

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