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

Ce robot tondeuse s'inscrit dans une logique de développement durable. Les objectifs sont:

- Supprimer l'utilisation d'herbicides polluants et dangereux pour la santé et la nature.
- Diminuer les émission de CO2 en n'utilisant pas de carburant fossiles et non renouvelables.
- Diminuer les coûts d'exploitations.

  Afin de pouvoir rapidement s'insérer dans une logique de développement durable, les plans et logiciels du robot sont distribuées sous licence GNU General Public License (GPL), saus les éléments que nous achetons tout faits, tels que les moteurs, LIDAR, circuits électroniques, etc. qui sont sous la license du fabriquant[1].

  Le robot pourra également être vendu complètement assemblé, ou sous forme de kit soit complet soit partiel. Le kit partiel comprenant, par exemple, des éléments usinées spécifiquement pour le robot.

  Tous les plans et logiciels sont librement disponibles sur Internet.

[1]Ces éléments peuvent être sous license propriétaire.

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:

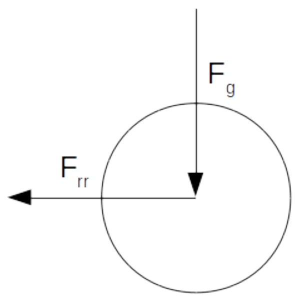
- Wheel forward resistance
- The slope to be crossed

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/s^2.

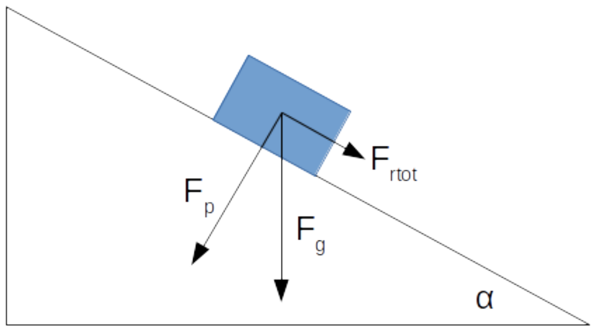
With our specifications, F_{rr} is, for a flat vehicle, with all wheels identical.[1] and that the weight is evenly distributed:

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

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

$$V = 2 \cdot \pi \cdot \mathrm{r}.\omega$$

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

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

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

Le robot tondeuse est constitué de différents éléments mécaniques, électroniques et logiciels. Les différents paragraphes ci-dessous donnent les détails de chaque élément.

Conception mécanique

A faire

Châssis

A faire

Roues

La tondeuse dispose de 4 roues de 30cm de diamètre.

Carrosserie

A faire

Propulsion

La propulsion est assurée par quatre moteurs électriques de 25W chacun au minimum (voir the section called “Propulsion power” et the section called “Propulsion torque”). Les caractéristiques des ces moteurs sont:

- Puissance: 22,5W
- Couple: 6,75 Nm
- Vitesse de rotation: 33 t/min

Par ailleurs, le moteur comportera un encodeur, pour mesurer le nombre de tours effectués, ainsi qu'un réducteur.

Moteur

Moteur brushless à encodeur

Réducteur

Encodeur

L'encodeur permet de compter le nombre de tours effectivement réalisés par le moteur. En connaissant le rapport de réduction du réducteur ainsi que le diamètre des roues, on en tire rapidement la distance parcourue.

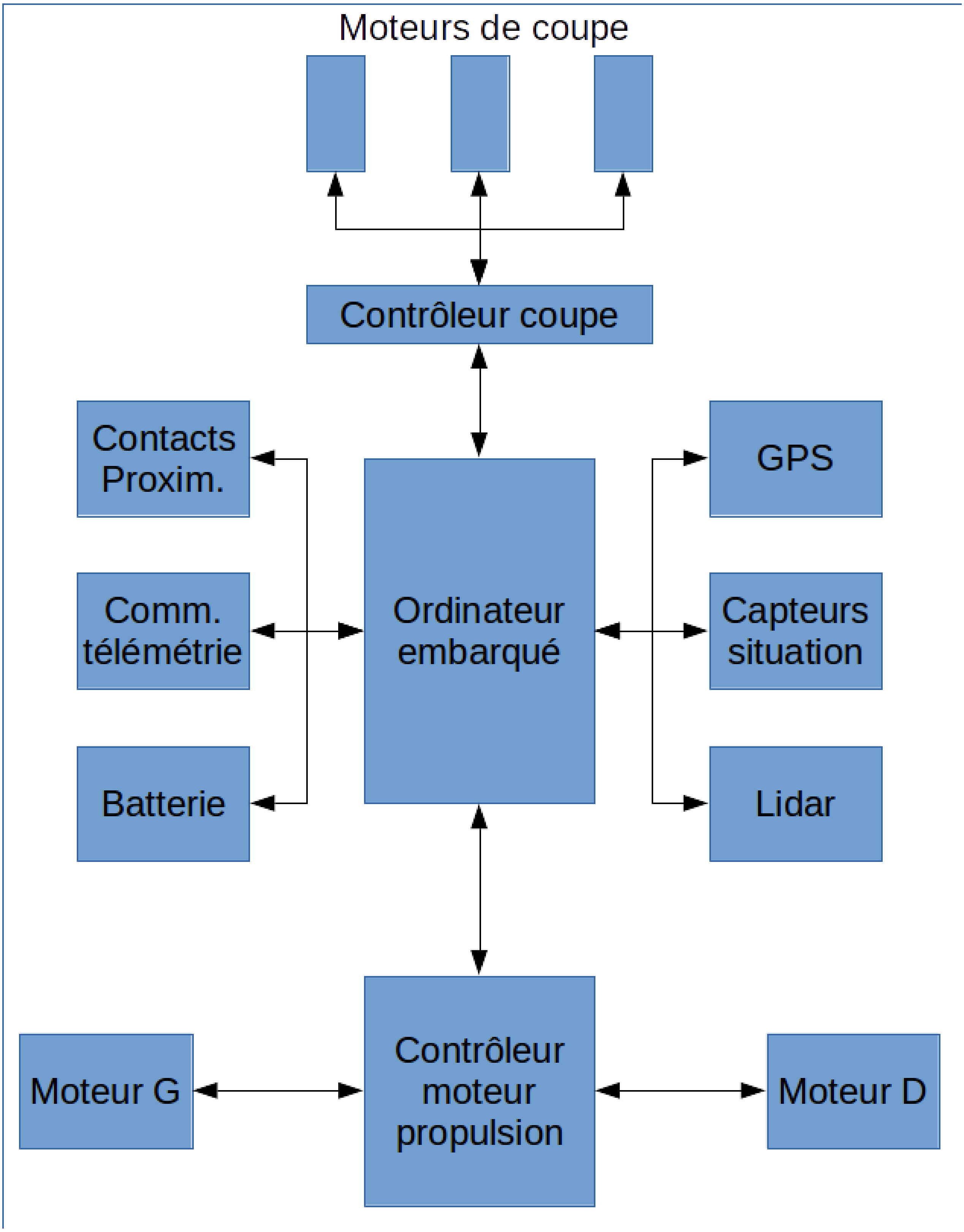
Coupe

Moteur brushless à encodeur.

Architecture électronique

L'électronique de commande est constituées de plusieurs blocs distincts, comme le montre le schéma ci-dessous.

Figure 3.1. Architecture de la commande du robot



Contrôleur de moteur de propulsion

A faire

Contrôleur de moteur de coupe

A faire

Lidar

A faire

GPS

A faire

Contacts de proximité

A faire

Batterie

A faire

Ordinateur embarqué

A faire

Capteurs de situation

Accéléromètre, gyroscope, magnétomètre

Communication

WiFi, GSM

Architecture informatique

Le logiciel du robot tondeuse fonctionne sur un Raspberri Pi III. Il est constitué des deux importantes briques suivantes:

- Le système d'exploitation Linux Ubuntu
- L'environnement de robotique ROS (Robot Operating System).

Chapter 4. Prototype

Ce chapitre concerne la réalisation du prototype. Il décrit les hypothèses à valider ainsi que les tests et mesures à effectuer.

Hypothèses à valider

Les hypothèses à valider sont:

1. Lidar
   a. Possibilité d'utiliser le lidar pour la navigation, en se basant sur des repères au sol connus (arbres, poteaux, murs, etc.).
   b. xxx
2. GPS
   a. Vérifier la précision du GPS RTK.
   b. Étudier la possibilité d'utiliser le réseau GNSS Suisse et étranger dans le futur.
   c. Valider la méthode de délimitation du terrain.
   d. xxx
3. Propulsion
   a. xxx
4. Coupe
   a. Valider la vitesse de rotation des couteaux
   b. Valider la possibilité de varier la vitesse de rotation en fonction du type d'herbe, afin d'économiser de l'énergie.
   c. xxx
5. Accès à distance
   a. xxx
6. Situation
   a. xxx

Tests et mesures à effectuer

Les tests et mesures à effectuer sont:

1. Lidar
   a. Mesurer la précision du LIDAR
   b. xxx
   c. xxx

   d. xxx
   e. xxx
2. GPS
   a. Mesurer la précision du GPS
   b. xxx
3. Propulsion
   a. Mesurer la courbe de puissance en fonction de l'utilisation
   b. xxx
4. Coupe
   a. Mesurer la puissance consommée par les moteurs en cours d'utilisation
   b. Tester la qualité de coupe à différentes vitesses de rotation.
   c. xxx
5. Accès à distance
   a. xxx
6. Situation
   a. Tester les accéléromètres
   b. Tester les magnétomètres, principalement leurs interactions avec les moteurs.
   c. Tester les 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.

Glossaire

GPS RTK	La Cinématique temps réel (Real Time Kinematic, en anglais ou RTK) est une technique de positionnement par satellite basée sur l'utilisation de mesures de la phase des ondes porteuses des signaux émis par les systèmes GPS, GLONASS ou Galileo. Une station de référence fournit des corrections en temps réel permettant d'atteindre une précision de l'ordre du centimètre. Dans le cas particulier du GPS, le système est alors appelé Carrier-Phase Enhancement ou CPGPS.
SLAM	Simultaneous Localization And Mapping, signifie localisation et cartographie simultanées.
GPL	GNU General Public License

Chapter 7. Bibliography

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