Development of an agricultural mobile robot for use in precision agriculture

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ABSTRACT

Precision Agriculture and agricultural practices which take into account environment protection leads to several research challenges. Sampling scale and the precision required by these new agricultural practices are often higher than those required by traditional agriculture, raising the costs of production. This whole process requests an expressive number of researches in developing automation instruments. Among them, highlights the use of remote sensing techniques based on the use of On-the-Go sensors technology, coupled to a Geographic Information System (GIS) adapted and developed for agricultural use. Aiming this, the application of Agricultural Mobile Robots is a strong tendency, mainly in the European Union, USA and Japan. In Brazil, researches are necessary for the development of robotics platforms, serving as a basis for semi-autonomous and autonomous navigation systems, facilitating data acquisition in the field. The aim of this work is to describe the project of an experimental platform for data acquisition and for the development of autonomous vehicles technologies to operate in agricultural environments. The proposal is based on a systematization of scientific work containing the main methodologies and technologies employed in agricultural vehicles and robots, which were used as a basis for construction of the presented model. The platform shall allow acquisition of field data to study the spatial variability through sensors and equipment that will be loaded in the structure.

Keywords: Agricultural precision, CAD, ISOBUS, robotic, on-the-go sensors.

1. INTRODUCTION

The idea of robotic agriculture (agricultural environments serviced by smart machines) is not a new one. Many engineers have developed driverless tractors in the past, but they have not been successful as they did not have the ability to embrace the complexity of the real world. Most of them assumed an industrial style of farming, where everything was known before hand and the machines could work entirely in predefined ways – much like a production line. The approach is now to develop smarter machines that are intelligent enough to work in an unmodified or semi natural environment. These machines do not have to be intelligent in the way we see people as intelligent, but must exhibit sensible behavior in recognized contexts. In this way they should

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have enough intelligence embedded within them to behave sensibly for long periods of time, unattended, in a semi-natural environment, whilst carrying out a useful task. One way of understanding the complexity has been to identify what people do in certain situations and decompose the actions into machine control (BLACKMORE et. al., 2005).

Autonomous vehicles have been widely used in industrial production and warehouses, where a controlled environment can be guaranteed. In agriculture, research into driverless vehicles has always been a dream but serious research started in the early 1960's (FOUTAS et al. 2007). In recent years, the development of these vehicles has experienced increased interest. This development has led many researchers to start developing more rational and adaptable vehicles. In the field of agricultural autonomous vehicles, a concept is being developed to investigate if multiple small autonomous machines would be more efficient than traditional large tractors (BLACKMORE et al., 2004). These vehicles should be capable of working 24 hours a day all year round, in most weather conditions and have the intelligence embedded within them to behave sensibly in a semi-natural environment over long periods of time, unattended, while carrying out a useful task (PEDERSEN et al., 2005)

In scientific literature can be find studies that seek to adapt business agricultural machinery to make autonomous agricultural platforms (vehicles or autonomous agricultural mobile robots) as can be seen in REID et al. (2000) and KEICHER & SEUFERT T (2000). A more recent trend is the development of platforms built specifically for agricultural autonomous vehicles or robots as can be seen in ÅSTRAND & BAERVELDT (2002), BACK & JAKOBSON (2004), MOORE & FLANN (2000) and SOUTHALL et al. (2002). In the second case, it identifies two challenges: developing a physical structure suitable for the agricultural environment, and develop an architecture to integrate the various electronic devices in systems allowing its expansion through the addition of new devices.

A trend that can assist in the development of more complex machines that meet the needs of the new practice in agricultural area is the Virtual Prototyping. This consists of many capabilities, the best known of which is the creation and viewing of three-dimensional solid models with various colors and surface textures. A Virtual Prototype may be represented as a series of graphical images or computer aided design (CAD) models, in animated or still format, created in the form of mathematical models and stored digitally in computer usable memory. Virtual Prototyping is about presentation, testing and analysis of three-dimensional CAD models prior to creating any physical prototypes. The technology for using virtual prototypes was pioneered and adopted initially by large automotive and aerospace industries (ZORRIASSATINE et al. 2003). With the rapid increase in both computing power and sophistication of computational methods and models of physical phenomena and the growing ability to transport results between various models are improving the scope of applications, robustness, accuracy, realism and cost effectiveness of Virtual Prototyping technology at an incredibly fast pace (MILLER, 1998).

The finite element method (FEM) is the most popular simulation method to predict the physical behaviour of systems and structures. Since analytical solutions are in general not available for most daily problems in engineering sciences, numerical methods have been evolved to find a solution for the governing equations of the individual problem. Although the finite element method was originally developed to find a solution for problems of structural mechanics, it can nowadays be applied to a large number of b equations that can be solved numerically (WANG & NELSON, 2002).

Considering the context presented, the purpose of this work is to develop a mechanical structure to form an Agricultural Mobile Robot, with Virtual Prototyping, including a CAD model and a finite elements analysis at the normal operating conditions and the worst-case conditions. The Agricultural Mobile Robot can be developed to test different sensor systems and tools in the field, and should be able to work under field conditions. In this paper, the principal parts that compose the set of the Agricultural Mobile Robot and its functions were descript.

2. DESIGN OF THE MOBILE ROBOT

The Agricultural Mobile Robot is designed to do the sensing of agronomic parameters of most important Brazilian culture in large areas. It doesn't require actions that demand high power, as in agricultural operations, but only moving efficiently in this environment. The mechanical structure was designed by the studying of work conditions required in field and desired characteristics of the project. It was established that the structure should be in portico, capable of operating in cultures up to 1.8 m of height, with adjustable gauge to operate in various row spacing cultivation and should be light and flexible compared with commercial agricultural vehicles, with the possibility to insert new sensors and actuators. According MADSEN & JAKOBSEN, 2001 the considerations made about the principles of the vehicle and the choices of concept for the mobile robot were: traction, steering, dimensions, frame, motors and power supply.

2.1. Traction

The most common traction systems found are wheels and tracks. The tracks system have better distribution of load on the soil, significantly reducing compaction and disturbance in the soil; it also have the ability to pull more, especially in loose soils, are common in large equipment or those who require high performance, however, have high production cost and maintenance.
For the Agricultural Mobile Robot, these properties are not very important, but accuracy in direction, low power consumption and low cost are desirable. Systems with wheels are cheap and, in function of the low need for traction and load to be distributed, meet the needs of this project. In this project, we adopted a four wheels system and to increase the ability of vehicle pull in adverse conditions, we adopted independent traction in each wheel; primarily system will be dimensioned with full traction.

2.2. Steering

Among the steering systems found, there are differential steering, articulated steering and wheel steering. Differential steering works by the difference between the speed of rotation of right and left wheels. This principle is used in system traction with track, but it can also be used in systems with wheels. This system is frequently utilized for vehicles that should be very maneuverable. The vehicle steering using this method can turn on the spot. The transmission is also simple to build, because the wheels turning in one side are at the same speed and the position and orientation of the wheels are fixed, but the method has also some major disadvantages. In a turn, the vehicle also turns around a vertical axis through the center of the vehicle, which means that the wheels have to slide sideways which spends too much power.

The principle of articulated steering is to change the angle between the front and the rear axle of a vehicle. This is a system by which a four-wheel drive vehicle is split into front and rear halves which are connected by a vertical hinge. The front and rear halves are connected with one or more hydraulic cylinders that change the angle between the halves, including the front and rear axles and wheels, thus steering the vehicle. An advantage of this system is the simplicity of construction.

The methodology of wheel steering or Ackerman, is the most used by road vehicles for steering. This methodology describes the relation between the angles of outside and inside the wheel in a turn. However, this criterion is very difficult to implement mechanically, because it is a non linear model. Therefore, on most vehicles, steering angles only approximate for small steering angles, however, deviations do not necessarily mean that the steering geometry is not optimal under real driving conditions.

In function of structure configuration is in portico format and with adjustable gauge, it was chosen a system that could be independent for each wheel, with easy construction and accuracy of steering, so we opted by the system Ackerman in front wheels.

2.3. Dimensions and Frame

Four wheels were placed in each corner of a rectangle with the length parallel to the crop rows were chosen for the vehicle. This configuration provides a great stability and the rear wheels can run in the tracks of the front wheels, which decreases the rolling resistance.

As the Agricultural Mobile Robot is designed to operate in the main cultures of Brazilian agricultural sector, during almost the entire cycle of growth and post harvest, it requires versatility of the frame, aiming to meet all situations. It was established that the structure would be in portico with 2m of height, and according to the different distances between rows of crop plants, it was chose a frame where the gauge could be adjusted. To accomplish this, the system was designed in independent modules (side frame and top frame), together by telescopic bars, to meet the maximum possible situations. The steering module, the propulsion module and central box complete the system.

Due to the Agricultural Mobile Robot height, distance between axles must allow overcome ramps commonly found in agricultural environments. The short wheelbase improves the maneuverability of the vehicle, but also makes it harder to control. Our goal is to build a flexible vehicle, the wheelbase is therefore chosen, so that it will just leave room for tools and give the best maneuverability. As work speed of the Agricultural Mobile Robot is low, there is no need to design a suspension or compensation system.

2.4. Motors and Power supply

The motors for the vehicle must be easy to control, to supply and to install. It is also preferred that they could be used indoors for tests. DC-motors best meets above demands. DC-motors can be used indoors and can be supplied by battery. Power amplifiers and gears for DC-motors are off-the-shelf products, which makes it a flexible and easy to install solution.

The vehicle should be completely autonomous and therefore have its own power supply. Power supply should be able to drive DC-motors and the computer. Batteries where chosen for the vehicle, because they are easier to install and should be able to deliver power for 2 - 4 hours of testing, without getting to heavy.

2.5 Mechanical structure of the robot

Mechanical structure of the Agricultural Mobile Robot was designed using the virtual prototyping methodology. The development of the project followed the flow chart shown in Figure 1. A detailed solid model was design in Solid Edge (UGS Corp.), CAD commercial software. By using this model, finite element model was constructed. Deformation, stress and elastic strain analyses were performed via ANSYS Workbench V11.0 commercial finite element software. The structure was developed using the process steps descript in Figure 1.

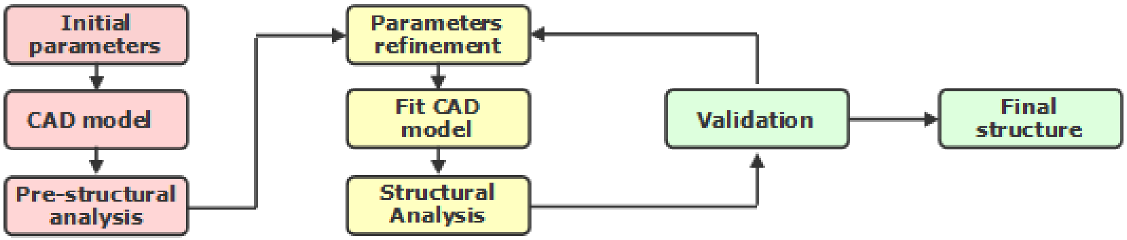

Figure 1. Flow chart of Agricultural Mobile Robot design.

Figure 2 shows the assembly and size of Agricultural Mobile Robot. Figure 2a shows the front view adjusted with the highest gauge and Figure 2b adjusted with the minimum gauge. It is possible to get any distance between two extremes, because the regulation is made through telescopic bar and their attachment by screws (item 10 of Figure 3). Figure 2c shows side views of the set, highlight batteries positioning, format of side and top frame, connected by tubular bar and the central box where there are the electronic devices to control.
Figure 3 shows the isometric view of the Agricultural Mobile Robot with all its main component. It is observed that heavier items such as batteries and propulsion and steering systems are at least one meter of the soil, which contributes to lower the structure center of gravity, increasing its stability on sloping land.

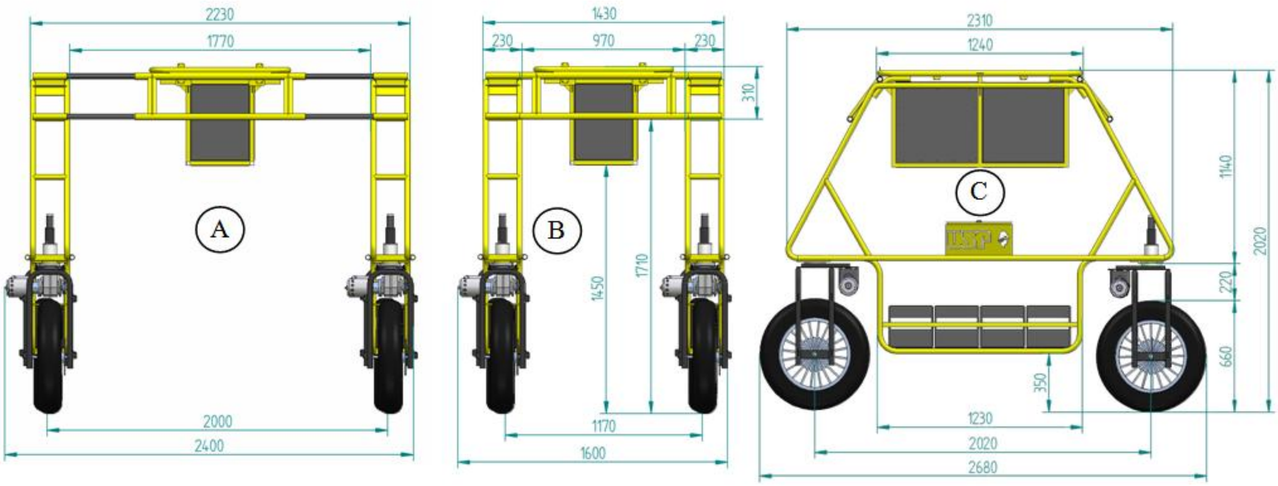

Figure 2. Agricultural Mobile Robot views; (A) Front view with the highest gauge; (B) Front view with the minimums gauge; (C) Side view.

(1) Side frame
(2) Fork
(3) Wheel
(4) Batteries
(5) Propulsion system
(6) Steering system
(7) Side box
(8) Top frame
(9) Central box
(10) Telescopic bar

Figure 3. Isometric view of the Agricultural Mobile Robot.

Figure 4 shows results of development of propulsion and steering system of the Agricultural Mobile Robot. In highlight is shown in Figure 4a the steering system components, where: (1) shaft, (2) retainer, (3) bottom flange, (4) bearing (5) bushing, (6) lock washer, (7) nut, (8) top flange; (9) reducer; (10) DC motor; (11) encoder. Figure 4b show propulsion system components, where: (1) encoder; (2) DC motor; (3) bearing; (4) shaft; (5) bushing; (6) reducer; (7) gear support and (8) gear.

Figure 4c shows the assembly of the steering and propulsion system fixed in front fork and how they are fixed in the side frame. At the base of the side frame, where the front wheels are fixed, there is a hole through which the bushing of the steering system is inserted in order from bottom to top, and fixed by four screws. After assembly of the bearings in the bushing, the fork that supports the wheel is fixed to the shaft of the steering system by three screws. This set is designed to support all loads and impacts bound for the wheel and that would be easy to maintain. Finally the set reducing-motor-encoder is fixed to the bushing by four screws. The

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reducer used has a reduction rate of 1:230 and the transmission of torque to the shaft made by pin. It is essential that no gap exists between the bushing and the motor to be possible the control of the steering with the desired precision. The system allows for turning radius of 90 ° and -90 ° degrees, resulting in large capacity maneuver.

The propulsion system consists of a motor that is coupled to a reduction with rate of 1:25 (item 6 of Figure 4b). As the reduction used in the propulsion system has no bearing of its internal components, it was necessary to build the coupling system shown below (item 5 of Figure 4b). This aimed to ensure the alignment between the motor and reducer, avoiding stress accumulation in any component and premature wear of the system. The system is fixed by four screws connecting the reducer to the base of the fork. Torque transmission between the output of the set motor-reducer and the shaft of the wheel of propulsion system is based on the pinion / chain / crown, as shown in Figure 4c (detail of the chain has been omitted to simplify the drawing), with rate reduction of 1:3, resulting in total reduction of 1:75.

Both the transmission system (crown, pinion, chain, shaft and bearing) and the wheels and tires are components used in Honda motorcycle NX Falcon, with features of mixed use (on-road and off-road). It was choose to adapt the project to commercial use of mechanical components, reducing costs of design and of parts manufacture. Propulsion system is similar to the front back, except for the absence of steering system.

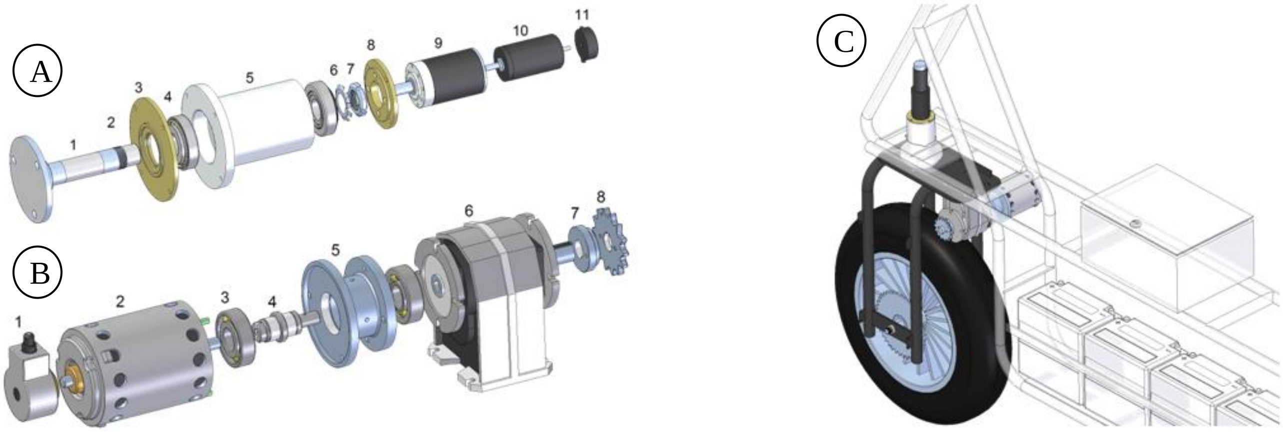


Figure 4. Agricultural Mobile Robot: (A) Steering system; (B) Propulsion system; (C) Detail of the front wheel module.

Table 1 shows the estimated weight of the components that constitute the Agricultural Mobile Robot, obtained by the Solid Edge software, in function of the mechanical properties of the materials used in building the model and the information contained in the manuals of the items used. Draws attentions to the weight percentage of the batteries, which corresponds to 27% of the total weight of the robot.

Table 1. Weight of the components of the agricultural mobile robot.

Item	**N^o items**	**Unitary weight (kg)**	**Total weight (kg)**	**% total weight**
Side frame	2	66.34	132.68	22.3
Top frame	1	33.18	33.18	5.6
Central box	1	18.40	18.40	3.1
Telescopic bar	8	1.78	14.24	2.4
Fork	4	9.57	38.28	6.4
Tyre and cube	4	8.54	34.16	5.7
Steering system	2	6.30	12.60	2.1
Propulsion system	4	19.60	78.40	13.2
Battery	8	20.00	160.00	26.9
Side box	2	7.63	15.26	2.6
Cable	-	-	8.60	1.4
Electronic system	1	50.00	50.00	8.4
Total			**595.80**	**100.0**

Robotics structure was designed symmetrically between right and left sides, which allows the homogenous distribution of weight, simplifies the development of the project, reduces design time and costs, build, install and accomplishes the maintenance of electromechanical components installed in the system. All these characteristics reflect in programming and operation of propulsion and steering systems controls, since these are independent of each side. The following will describe the electrical equipment that comprises each side of the structure and its function. Table 2 presents the main components used in the project.

Table 2. Description of the items utilized in the project.

Item	**Manufacturer / Model**	**Technical characteristics**
Steering motor	Maxon Motors RE 40 - 148877	Nominal voltage: 48 V Nominal power: 150 W Nominal current: 3.12 A Nominal speed: 7000 rpm Continuous torque: 0.2 Nm
Propulsion motor	Bosch Motors GPA 0 130 302 014	Nominal voltage: 24 V Nominal power: 750 W Nominal current: 40 A Nominal speed: 3300 rpm Continuous torque: 2.2 Nm
Propulsion reducer	Macopema MC 50 Series C105-4	Reduction: 1:25 Number of stages: 2 Max. continuous torque: 49.1 Nm Weight: 11.0 kg
Steering reducer	Maxon Motors GP 52 C - 223101	Reduction: 1:230 Number of stages: 4 Max. continuous torque: 30 Nm Weight: 0.92 kg

Table 2. Description of the items utilized in the project (continued).

Item	**Manufacturer / Model**	**Technical characteristics**
Propulsion encoder	Hohner Series 75 – 7512 0212 0100	Counts per turn: 100 Number of channels: 2 Max. operating frequency: 100 kHz Nominal voltage: 5 - 28 V
Steering encoder	Maxon Motors MR Type L - 228452	Counts per turn: 500 Number of channels: 3 Max. operating frequency: 200 kHz Nominal voltage: 5 V
Propulsion power controler	Roboteq AX2550	Channel: 2 Max. current per channel: 140 A
Steering power controller	Maxon Motors EPOS 70/10	Channel: 1 Max. current per channel: 10 A
CAN circuit	National Instruments	-
D/A converser	-	Own manufacture
Battery	Baterias Tudor TT18MED	Nominal voltage: 12 V Nominal capacity 70 Ah Weight: 20 kg
Tube frame	Steel SAE 1020	Tube: 1¼” x 1/8”
Tire	Pirelli MT 60 - 120/90 R17	Tyre mix use
Cube and rim	Honda Motorcycle Honda NX Falcon	Transmission reduction: 1:3
Cable	Pirelli	Various
Electric duct	Tigre Electric duct 1"	-

It were used four engines of 24V and 750W which were responsible for propelling the robot, as can be seen in item 2 of Figure 4b. Measurement of engine rotation was made by an incremental encoder with resolution of 1:100 fixed in motor shaft (item 1 of Figure 4b). During robot traffic, the power required for its displacement will fluctuate depending on the condition of the land, acceleration parameters and speed required, so it is necessary a constantly monitoring and adjustment of the power for each engine, aiming to obtain required parameters. Thus it was used a power controller equipped with two independent channels, installed inside the side box (item 7 of Figure 3) for each side of the robot, which was responsible for controlling front and rear motor of corresponding side. Control is done according to data obtained by the encoder, which is processed according to the programming included in system or in dynamic mode by use of a remote control. It can also be attributed a tolerance for this control to avoid overloading of the system with little variations, which do not influence in operation performance.

To provide the steer of the front wheels we used two engines of 48V and 150W, as can be seen in item 10 of Figure 4a. The measurement of engine rotation is provided by an incremental encoder with resolution of 1:500 fixed in motor shaft (item 11 of Figure 4a). Observe that, for small changes in the angle of the wheels of steer, it is generated a large amount of points, which ensures an accuracy more than necessary for the great functioning of steering system. In this case, it is inserted a condition of tolerance, so the system cannot work overloaded. The main feature of the steering system is the necessity to position the motor so that the wheels of the steering system are positioned at correct angle; so it is important that the two steering systems are calibrated with the same tolerance and working synchronized. If any system present a failure may occur damage in structure.

For integration between electronic devices, it was deployed a network CAN (Control-area network) in the Agricultural Mobile Robot. The network developed not only enables the integration of sensors, actuators and computer systems relative with tasks of steering and navigation, but also enables integration of device relate of data acquisition of agronomical variables, which will eventually compose the system. The data from controllers that are in analog system pass through a digital-analog converter to be transmitted to a CAN system. For viability of robotic structure operation in the field is necessary to develop a base station that has the function of managing the operations performed by robots or receive data from the analysis, permitting planning, controlling and monitoring tasks in real time via digital link for data communication.

All these systems are accommodated in a metal box fixed by screws on the side frame of the Agricultural Mobile Robot (item 7 of Figure 3). They have the function of protecting electronic components from weather and are positioned to facilitate maintenance of the system. In central box (item 9 of Figure 3), are inserted the computers that do the processing of the collected data and control of the navigation, steering and position system. For electric cables passage it is used a flexible electric duty attached to structure robotics.

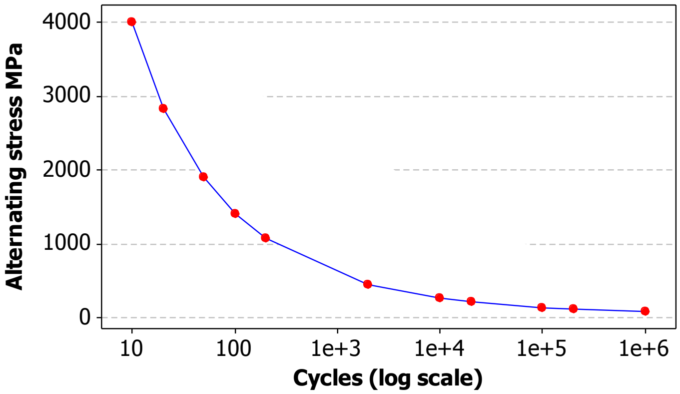
For the power of the controllers and motors we used eight tractioned batteries of 12V and rated capacity of 70 Ah, arranged four on each side as seen in item 4 of Figure 3. Each propulsion motor uses two batteries connected in series and the steering motor uses four batteries connected in series. To load the system, it was developed a circuit to load eight batteries at the same time, reducing the time to recharge and ensuring that all batteries receive the same load.

Interconnected with the set, it was installed a security system that has the task of cutting controllers and motors power in case of any accident or unforeseen. This system consists of a button fixed in a strategic place of robotics structure which, when activated, interrupts system power, in function of the amperage demanded we developed a circuit to disarm the system.

2.6 Structural analysis

The material properties which were utilized in finite elements analyses were obtained from ANSYS library and are descript in Table 3. To simplify the model, elements that have no structural function as central box, batteries, motors and steering system were removed from analysis, only side and top frame stayed duly established by telescopic tubular bars. Removed items were replaced by resulting forces. Simulation was performed considering the structure under condition of dynamic strain in three severe conditions of use (steering system badly calibrated, across obstacle, traffic with lateral inclination).

Table 3. Material property of Structural Steel used in build of Agricultural Mobile Robot.

Constants of Structural Steel	
Young's Modulus	2.e+005 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg.mm^{-3}
Thermal Expansion	1.2e-005 1.°C^{-1}
Tensile Yield Strength	250 MPa
Compressive Yield Strength	250 MPa
Tensile Ultimate Strength	460 MPa
Alternating Stress	
	

Steering system badly calibrated: In this case the robot is operating in ramp angle of 0° (inclination to be overcome for the vehicle subdue in the direction of displacement) and 0° lateral inclination (inclination to be overcome by the vehicle perpendicular to the displacement), with four wheels supported on the soil, with angle of divergence (angle of opening formed by the plans of the two wheels of the same directional axis) of the front wheel raise, causing strength for opening the structure of 500 N in each direction.

Across obstacle: In this case the robot is operated with a ramp angle 0° and 0° lateral inclination, with two wheels supported in the soil (front right and rear left) and lateral strength on each wheel support, to open the structure of 500 N.

Traffic with lateral inclination: In this case the robot is operated with a ramp angle 0° and 25° lateral inclination, with the convergence angle (angle of closing formed by the plans of the two wheels of the same directional axis) of the front wheel moderate, causing strength for closing the structure of 500 N in each direction.

The details of the structure with the forces applied to the three tests are presented below (Figure 5). For the three situations are common following loads, however the situation C was rotation of coordinate system in 25° in Y axis, to represent the lateral inclination of the ground.

- Standard Earth gravity: acceleration of 9,8 m.s^{-2} in -Z direction operating on entire surface;
- Batteries: concentrated force of 1200 N in -Z direction inserted at the bottom of the side frame on both sides;
- Side Box: concentrated force of 500 N in -Z direction inserted in the middle bars of the side frame on both sides;

- Central Box: concentrated force of 1000 N in -Z direction inserted bottom of the top frame;
- Wheel module: moment of 3,5 N.mm in Y direction inserted in the base of the wheel support module, in the four wheels for situations A and C. In situation B the support is made only in two wheels (front left and rear right) to represent the seesaw effect that the structure is subject to cross an obstacle.
- Support system: were utilized to dislocate support in 880 mm of the base of each wheel module, with two degrees of freedom, X and Y.

Two loads of 500 N are specific to the situation A, applied in the side frame, the right side in Y direction and the left side in -Y direction, fix to 880 mm in -Z direction of the base of the front wheel module.

For situation B, two loads of 500 N, applied in the side frame, the right side in Y direction fix to 880 mm in -Z direction of the base of the front wheel module and the left side in -Y fix to 880 mm in -Z direction of the base of the rear wheel module; two loads of 1500 N applied on the side frame, both in -Z direction, fixed at the base of the left front wheel module and on the rear right wheel module representing the weight in he wheel module, which are not in contact with the ground.

For situation C, coordinate system was rotated by 25° in the Y axis to represent the side inclination of the land. It were placed two loads of 500 N, applied in the right side frame in Y direction, fix to 880 mm in the -Z direction of the base of the wheel modules.

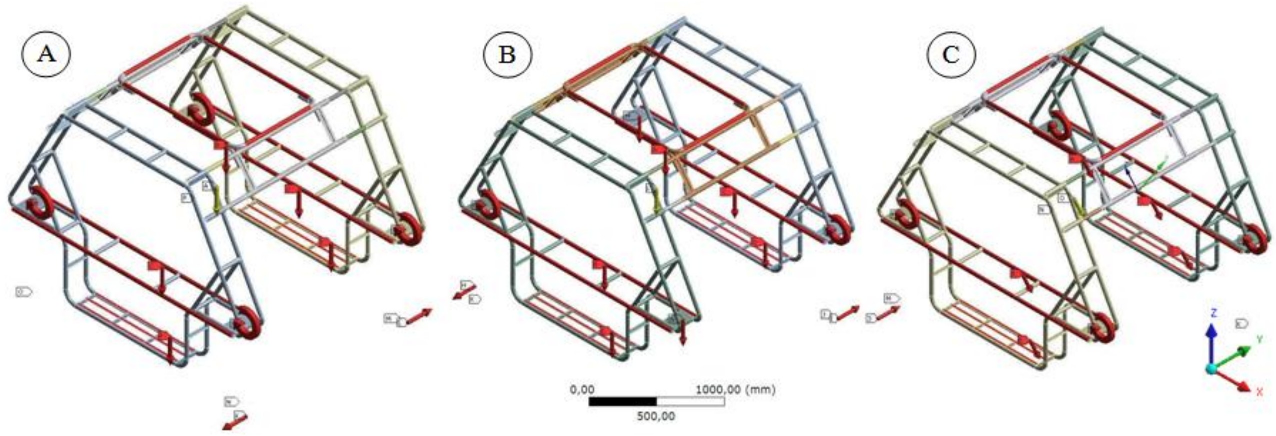


Figure 5. Loads applied on the structure: (A) Steering system badly calibrated, (B) Across obstacle, (C) lateral inclination 25º.

The result of simulation, containing data of total deformation and equivalent stress (von-Mises) are presented below. It is emphasized that the scale of deformation used in the figures is increased to facilitate viewing. In Figure 6 appears the result of the simulation of the system (steering system badly calibrated). It is observed that most deformation occurred in the lower area of the frame, but without compromising the performance of the set, regarding tension, it occurred points of stress accumulation at the junction between the top and side frame, but not enough to generate disruptions.

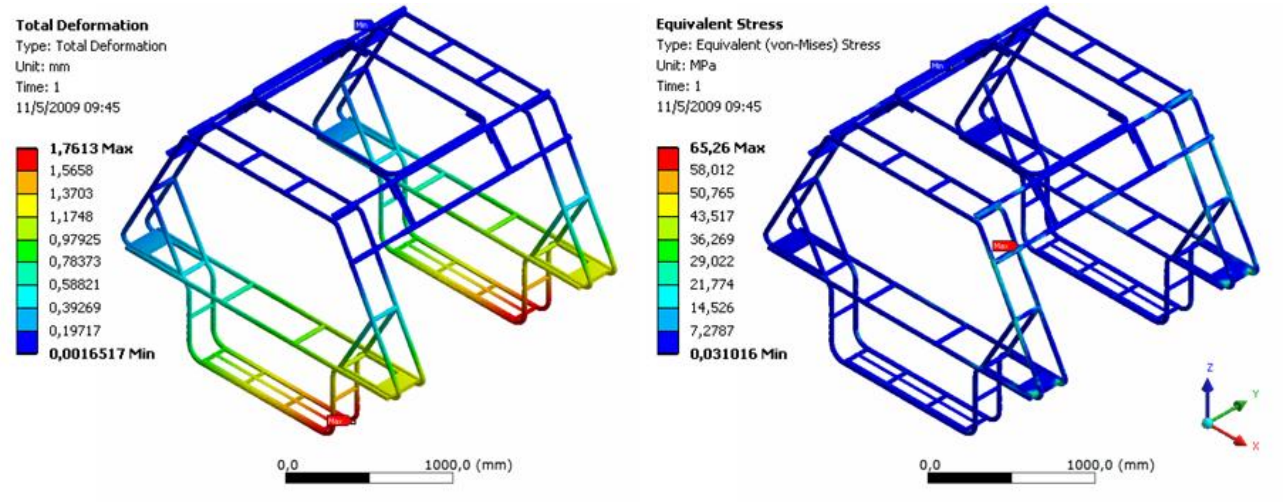


Figure 6. Total Stress and Deformation of the structure in the situation A (Steering system badly calibrate).

In Figure 7, we show the result of simulation B (across obstacle). Compared with situation A, deformation was larger, tending to twist the structure. With respect to stress, it was increased significantly due the twist of the structure, focusing on the same point of the situation A.

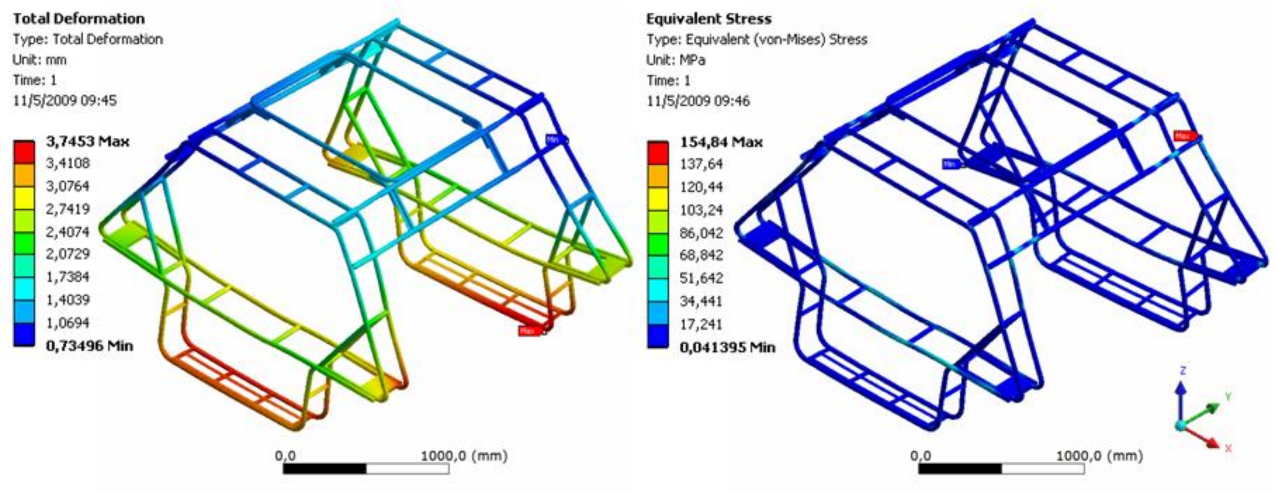


Figure 7. Total deformation and Stress of the structure in situation B (crossing obstacle).

Figure 8 shows the result of simulation of situation C (traffic with lateral inclination). Note that this is the most severe situation which structure was submitted. Strain was superior to the two previous cases, and showed an increase of 290% compared with situation A. In this case, forces tend to close the structure. We believe that there would be problems with the navigation of the vehicle in this condition, because the front and rear wheels are aligned. Note that the site of accumulation of strain is the same of the above, so the increase was 320% compared with the situation A. With the use, it may occur appearing of cracks in this region due to change in efforts to traction and compression.

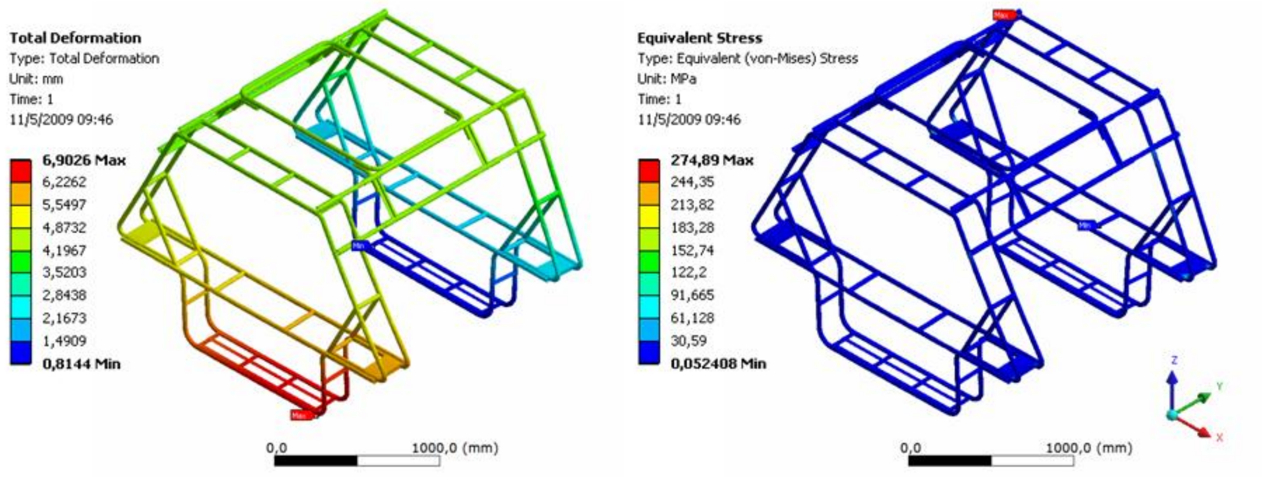


Figure 8. Total deformation and Stress of the structure in situation C (traffic with lateral tilt).

2.7 Robot operation

The robot was manufacture based on the parameters presented, presently, is in development of the communication and navigation modules. The preliminary tests indicated that the structure met the requirements originally proposed. Future work will be performed to finalize and integrate the communication and navigation modules in the CAN network and test the operation with all components installed in the structure, and evaluate the operational parameters of the robot.

3. CONCLUSION

The study showed the possibility of the robot application for carrying out remote sensing in agricultural environments. Initially were identified the possible areas of activity and the main consumer markets. Was verified the operations what could be performed and defined the most important features that make up the agricultural environment. With these data was selected the technical options available, in view of the set parameters of operation, and among those, that best fit the prerequisites of the project. Was performed the computational modeling and latter the simulation and validation of the structure designed by specific software. With the manufacture of the platform was possible find that the methodology used to develop the agricultural robot was efficient, accord all the needs.

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