Agricultural robot for small farms

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Abstract. This paper presents a new concept of the robots dedicated to small farming activities. A walking robot is remote controlled in order to perform agricultural operations in small farms or peasant household. The robot should perform all operations during crop development respectively tilling seeding, fertilization, harvesting, etc. The robot structure is conceived in order to achieve low energy consumption criteria by gravitational decoupling and static gait. The power of the robot is calculated robot power is calculated by reference to the power of a man or a horse. The purpose of this work is to approach some aspects of a robot according with the requirements of work environments: energy consumption, influence to the environment, the proper locomotion method, etc.

1. Introduction

The economic and social objectives provide for meeting market requirements for organic products as well as the application of advanced domestic technologies in the process of cultivating the land. Tillage is a huge effort and we can still remember the periods when a lot of agricultural work was done by hand (eg digging, mowing, harvesting, etc.). The price of agricultural land is proportional to the level of technology of agricultural works. According to this criterion, Romania is on the last place in the European Union. In addition to the economic inefficiency of Romanian agriculture, there are two risks: desertification - climate and environmental criteria and alienation, the Romanian agricultural land being very attractive for foreign investors ("Foreign investors currently hold over 40%, respectively 5.3 million hectares of Romania's total agricultural area (13.3 million hectares), according to the report commissioned by the European Commission Committee on Agriculture at the Dutch Research Institute Transnational Institute (TNI), quoted by the League of Romanian Agricultural Producers Associations (LAPAR).

Human and animal physical activities engaged in the development of agricultural crops are currently almost non-existent in Europe. The technologization of agriculture has replaced the power of horses with the power of tractors that have spread in a wide variety, from low power (20 hp) to power over 600 hp. The trajectory of the labor force in agriculture, throughout history is as follows: the force of man is the force of the horse, which is approx. 750 W, 10 times the power of a horse [1] which is approx. 750 W, 10 times the force of man) and then to replace the power of horses with the power of tractors that can develop powers hundreds of times greater than those of horses. The problem that arises in the approach of this work is not to replace the drills and other high-performance agricultural equipment but to go back to the time when human and animal power could have been replaced by agricultural robots but due to technological limitations this it was not possible then.
The economic criteria would not allow small farms and small households to purchase a set of robots dedicated to carrying out agricultural operations dedicated to purchasing a range of robots to cover all the requirements for carrying out operations for the small crops they manage. It is not known in the literature a multifunctional robot to perform all the work specific to a crop development from soil preparation to harvesting, much less such a robot is not commercially available.

The Four Industrial Revolution (4IR) will have a major impact on agriculture for at least three reasons: a) optimization such as irrigation water consumption, b) repopulation of rural areas by raising living standards c) mitigating the impact of climate change on agricultural crops [2].

Unlike cereal crops for which no continuous maintenance activity is required during the development period in the case of vegetables, the intervention of the human factor is necessary almost daily. The purpose of this paper is to describe some aspects that need to be highlighted when designing a robot. An agricultural robot is mechanically structured on three subsystems: the mobile platform, the manipulator arm and the effector. The mobile platform, depending on the locomotion method, can be on wheels, on tracks, stepping or hybrid: wheels-tracks, tracks-legs, etc. [3].

2. Robotic System Architecture
The autonomy of an agricultural robot presupposes its capacity to carry out independently the works for which it is intended without the intervention of a human operator, which makes necessary the existence of equipment with high processing power for each robot. There are technical solutions that aim to reduce the individual equipment of robots by adopting central processing and sending commands to individual robots that are part of a network or "swarm". One project dedicated to such a concept is MARS (Mobile Agricultural Robot System). Each robot in the network is equipped with a minimum of intelligence and sensors and the data is processed by a central unit (OptiVisor) that performs the functions of planning and supervising the robot network [4], Figure 1.

![Figure 1. Agricultural robots network](image)

The architecture of the robotic system is structured on three major subsystems: the mechanical subsystem, the electrical / electronic subsystem and the computer subsystem. The mechanical subsystem is represented by the mechanical structure of the robot which consists of the mobile platform, the manipulator structure and the effector. The electrical / electronic subsystem consists of the electrical component, represented by the drive motors and electrical circuits and of the electronic
component represented by the command and control circuits, communication modules and the command and control equipment (laptop, tablet, etc.).

The computer subsystem is composed of applications through which a human operator controls the activity of the robot in the work environment. “Online to Offline in robotics” (O2O) The human operator analyzes the culture online, makes decisions on the operations to be performed and then establishes an execution plan for the robot that will perform all the prescribed operations offline. (to enter the augmented reality sequence). For example, a human operator remotely analyzes the shoots of a tomato crop and will mean those shoots that need to be removed.

"Online to Offline" is a coordinate of the fourth industrial revolution and is used in digital marketing through online analysis of goods or services by the user and making purchases in the physical environment. The “Online to Offline” technology has its applicability in robotics through the online analysis of a working environment by a human operator and the performance of operations in the physical environment by a robot. An advantage of this technology is that it sequentially controls several robots by a single human operator when the times of online analysis and order setting are shorter than the times of execution of operations by the robot in the physical working environment. "Online to Offline" is applicable where video processing algorithms are too complex and by applying them would increase the risk of crop compromise. One such example may be that of early tomato growth where, for automatic programming, it is very difficult to determine which shoot should be removed, there is a risk of cutting useful parts of the plant.

3. Robot architecture
The role of the stepping mobile platform is to support and move the manipulating structure of the robot and the effector device and to provide stability during the performance of agricultural operations. The conditions they must meet are: precision, robustness ... In the case of a mobile robot, mobility and speed are considered as performance parameters and between these parameters we could call them antagonistic because a robot with a high speed will have limited mobility while a robot with good mobility will be able to move at low speeds. Another parameter of interest is the positioning accuracy (to represent a graph). The wheels, in contact with the ground, are limited in obtaining a good deposition accuracy because during the movement inevitably there are landslides (skids) in the contact area between the wheel and the ground which leads to loss of accuracy. Crawler robots offer better positioning accuracy by "sticking" the "claws" into the ground (look for the right term).

The manipulator structure has the role of moving the gripper so that it is in the vicinity of the work area and we can assimilate it with the manipulator arm of the robot. A manipulative structure in Cartesian coordinates offers several advantages: good positioning accuracy, "gravitational decoupling", robustness and stability. In addition to positioning, it also ensures the movement of the effector when it performs some operations such as loosening the ground. A disadvantage of the Cartesian manipulative structure is the development of translational movements, which involves the use of linear actuators (which are expensive) or mechanisms for converting rotational motion into translations.

|   | Robot specifications |
|---|------------------|
| 1 | Locomotion       | Walking, static gait, sequential |
| 2 | Number of legs   | 6 or 8 |
| 3 | Power            | Small (<1kW) |
| 4 | Power supply     | Electric, solar panels |
| 5 | Work surface     | 4 – 9 m² |
| 6 | Functionality    | Multifunctional |
| 7 | Mass             | <50 kg |
| 8 | Autonomy         | Semi-autonomous |
The choice of locomotion by stepping was made according to the following criteria: a) avoiding crushing the ground during movement (movement on wheels or tracks provides a permanent contact between the tracks and the ground) b) good mobility, allowing an omnidirectional movement c) efficiency high - friction is reduced at the bearings where the friction forces are much smaller than those between the wheels / tracks and the ground d) positioning is much more precise by stepping because the slips between the foot and the ground are smaller than the slips between the wheel and the ground (slipping being an unwanted and difficult to control movement).

The number of legs is chosen according to the criterion of stability and the condition is that the center of mass of the robot remains inside the support polygon which will be triangular or rectangular. A solution to reduce energy consumption is to adopt the gravitational decoupling technique [5] which means that during the actuation of the actuators in the joints of the moving legs, the mass of the robot will be supported on feet in contact with the ground.

The power developed by the robot during movement and operations is estimated to be equivalent to the average power developed by ten men. A worker who works eight hours a day using the force of his arms develops an average power of 75W [6] therefore the resulting average power is 750 W. Taking into account the efficiency of the motors and the efficiency of the mechanisms we propose an average developed power of approximately 1000 W.

Energy - Surface (for sizing solar panels) part of the sun part of preloaded batteries. Functionality: the operation performed by the robot is established by choosing a suitable gripper, therefore the effector type mechanisms will be easy to mount on the structure / manipulator arm.

4. Robot Structure

The mechanical structure of the robot, Figure 2, consists of three subsystems: the mobile platform with the role of locomotion that rests on the legs L1, L2, ..., L3, the manipulative structure that is made in Cartesian coordinates and has the role of positioning and moving after a certain trajectory of the third subassembly which is the gripper. The mobile platform has as reference the coordinate system with origin in Man, the manipulating structure has attached the reference system with the origin in OCS and the gripper is attached to the reference system with the center in OE. The position and trajectory of the robot are related to a fixed reference system with the origin in Or.

![Figure 2. The agricultural walking robot structure.](image-url)
For the manipulating structure, a suspended arm solution was adopted, which is also applied in greenhouses, bringing the advantage of a free space in which human operators can also move [7]. In this case, there is no problem for the robot to operate in areas of human activity, but this variant of suspended structure also involves a lower energy consumption during operations by the gripper element which acts directly and individually on the plant in weed control, soil moisture measurement, spraying, irrigation and harvesting operations.

In the resting and operating stages, the robot rests on all six legs in contact with the ground. The movement of the robot is done sequentially (Figure 3), assuming a movement in the ym direction, the robot will be permanently supported on four legs while the other two will move through a translational movement.

![Figure 3. The gait sequences of the walking robot](image)

In static motion the center of gravity of the robot (COG - center of gravity) must remain inside the stability polygon during all phases of movement [8].

5. Conclusion
The development of robots dedicated to small farms and peasant households can be developed based on the current technological level. Small robots powered by solar energy could be the basis of a new trend in agriculture and the food industry by individually producing part of the food needs. The most suitable mechanical structure for such a robot is the stepper with suspended drive mechanism and sequential movement by static travel.

6. References
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