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# SOME NOTES REGARDING THE CONSTRUCTION AND OPERATION OF A STRAWBERRY PICKING ROBOT

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**Abstract:** Mechanized, automated and robotic agriculture starts from seeding the field and spraying fertilizer, to irrigating the land and controlling weeds, then moves on to harvesting, sorting and packaging. The main area of application of robots in agriculture today is at the harvesting stage. When harvesting and picking fruits or vegetables, the progress is most obvious these days. Technology allows them to have sophisticated mechanisms, the possibility of visualizing the space in which they are going to carry out their activity. Undoubtedly, robots have a positive effect on the labor market and worldwide, and the trend is sure to continue. This paper presents notions about an agricultural robot, how can be made, and the activity it can carry out. It is the case of a robot for picking strawberries with purpose to ease people's work and to apply advanced technology in agriculture. The robot moves and is programmed to pick a certain amount of fruit with the help of a robotic arm, improving work productivity. Also, with the help of the automatic localization and navigation system, the human no longer intervenes while the robot is working. However, continuous robotization and automation solutions are needed for improvement and to continue the evolution.
**Keywords:** strawberries, picking robot, digital agriculture, robotic arm

## INTRODUCTION

The evolution of technology has allowed mechanized, automated and robotic equipment to be obtained, which can ease or even replace human work in many fields of activity. With the evolution of technology, various automatic systems have been adopted to improve the performance of some activities and to contribute to the improvement of the quality of life. This also had a major impact on the development of technologies in the agricultural field that is how robots appeared that replace, through work, man.

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The form of automation could be doubled by artificial intelligence, making no job safe, according to an analysis by the International Data Corporation, cited by Gizmodo (*International Data Corporation, 2017*). For this, robotization and automation solutions are needed to succeed in evolving in this field (*https://revistadinlemn.ro/2019*).

Fruit production that requires selective harvesting is heavily dependent on humans as labor. This applies to harvesting fruits, such as strawberries and raspberries, or vegetables, such as peppers, tomatoes, cucumbers, etc. Some fruits, such as strawberries and tomatoes, tend to grow upright. These are difficult to pick up without causing them to be hit. It is one of the primary challenges for fruit harvesting systems.

Fruits, leaves, stems and other surrounding obstacles are difficult to separate from the target, both within detection and handling. In the field of agricultural robotics, many researchers are trying to avoid obstacles in both vision and manipulation.

Thus, a robot capable of distinguishing the quality of fruits and sorting them without damaging them is the Rubion robot, made by a Belgian company in 2014 (*Bonirob, Aranvid et al., 2017*), which not only moves through the strawberry fields, it finds the ripe fruits, he picks them without damaging them and sorts them immediately, choosing those that are ready for the final packaging (Figure 1).

Also, this company intends to launch robotic assemblers for other crops in the future [5]. A strawberry harvesting gripper that can open its fingers to capture a target from below is presented in ref. [6]. In the field of robotic manipulation, most studies focus on obstacle avoidance.

However, there are some studies that separate obstacles for simple situations. For a picking application, in the 2D environment, two linear directions were proposed to separate rigid obstacles during the picking path, to reach the targeted fruit [7]. All objects were placed on the 2D surface without stacking, which is simple compared to naturally growing plants.

Figure 1 – Rubion robot

Therefore, this work brings a consistent contribution to the knowledge, analysis, and use of robots in agriculture, with the aim of making human life easier and highlighting the evolution of technology. The main purpose of this work is to exemplify and present some mobile, automated robots that have the ability to ease people's work, as well as to improve the quality of techniques and services used in agriculture. The robots for picking strawberries are based on the same operating principle.

## MATERIALS & METHODS

The essential problem in selecting the target fruits to be picked with the help of robots is avoiding obstacles. Fruits, leaves, stems and other surrounding obstacles are difficult to separate from the target, both within detection and handling.

Without moving obstacles in the way, which prevent the robotic arm from grabbing the target and also being able to be lowered with the target if they are located close to it. Similar problems arise when we approach fruit from other angles.

To solve this problem, it was proposed to use a single operation of linear displacement of the obstacles below the target based on their detection, from a 3D camera.

Without stacking, the vision system can easily track the target and obstacles, which are easy to control, closed–loop vision.

Unfortunately, in the agricultural environment, for strawberry plants for example, the fruits are located in 3D in diverse and unlimited environments. Selective picking of a ripe fruit in clusters requires 3D motion planning to separate the target from obstacles if using obstacle separation methods. Occlusions make it difficult for the vision system to track object changes. Also, flexible peduncles, deformable fruits, and many other crop variations make separation operations extremely difficult, and the dynamics of these objects are difficult to calculate and predict.

To avoid occlusions in fruit picking, a "3D–move–to–see" method has been proposed to find the best view with fewer occlusions (Xiong & Ge, 2020).

If an obstacle is located above the target, such as the cases shown in Figure 2(a), the handle may swallow or damage the obstacles when moving up to capture the target strawberry. Furthermore, obstacles can stop the fingers from closing, thus resulting in a failure. To solve this problem, manual operation is proposed, which opposes the move operation used in other layers.

The pulling operation allows the grabber to select the target fruit without catching unwanted obstacles. The operation comprises a pull–up step to move the target to an area containing fewer obstacles (Figure 7(b)) and a backward move that lifts upside obstacles (Figure 7(c)), before closing the grippers (Figure 7(d)). The handle moves higher to a cutting position. The pulling operation is performed only when there are obstacles in the center block.

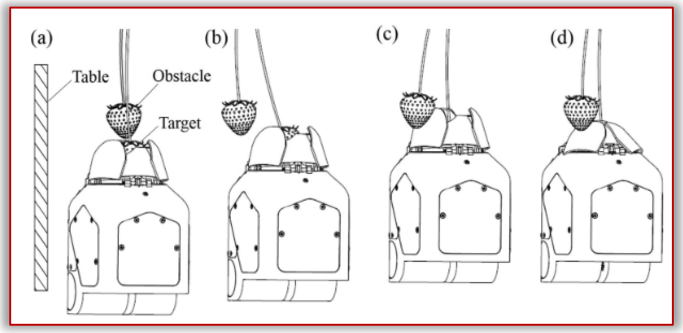


Figure 2 – Operation to avoid obstacle capture: an upward thrust moves the target to an area containing fewer obstacles (a) and (b); an upward step moves the upper obstacles one side (c) the position before closing the grippers (d)

Object detection using deep learning operation and point cloud to display both target position and obstacle information is one of the main objectives, Figure 3.

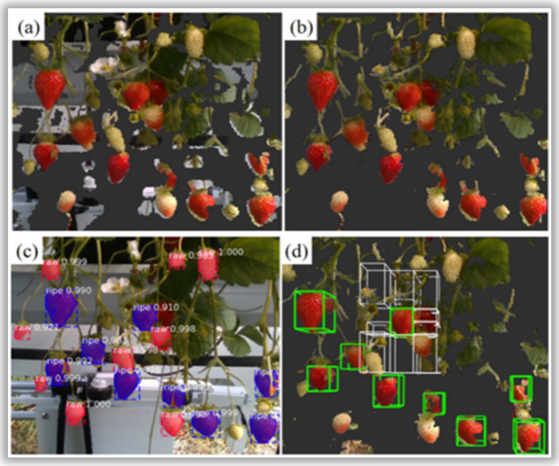


Figure 3 – Selecting the target plant and avoiding obstacles: (a) – the entire visual field; (b) –separating ripe strawberries from raw ones; (c) – using deep learning to detect ripe strawberries in an RGB image: (d) – localizing ripe fruit

The workflow for fruit detection and obstacle determination is to visualize the entire field (see Figure 3(a)), separate ripe from unripe strawberries (see Figure 3(b)), use deep learning to detect ripe strawberries in an RGB image (see Figure 3(c)) and the location of ripe fruits (see Figure 3(d)).

An old robot used Cartesian arms, Figure 4(a), and the new, low–cost type no longer uses Cartesian arms, Figure 4(b). The new arm is lighter and moves faster than the old Cartesian arms.

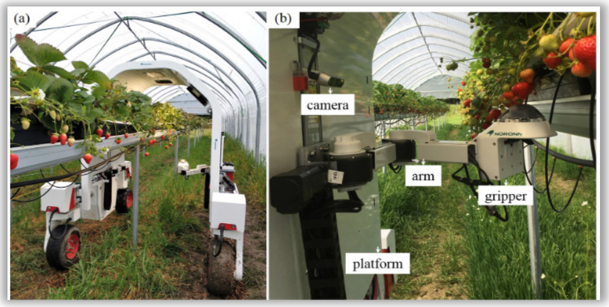


Figure 4 – The low–cost robot model, mounted inside in the shape of a "U" (a), the picking system with camera, manipulators and LED panels (b)

The picking system (Figure 4(b)), including the camera, manipulators and LED panels, was mounted inside in a “U” shape. The robot passes through the mass of strawberries, covering all the plants, with the possibility of using several manipulators that pick on each side of the tablet (see Figure 2(a)), following the detection of ripe strawberries, their location and detachment.

## RESULTS

The robot, like any machine, must be assigned a series of tasks. This operation, generally called programming the robot, is of great importance, competing alongside the practical construction, for the success of the realization. Programming difficulty increases with:

- increasing the degree of autonomy of the robot – to be autonomous, the robot must "know" what it has to do in all possible situations, and even more, it must have a strategy for the unforeseen;
- increasing the number of operations performed – each additional operation brings with it the subprogram/ subprograms necessary to perform it, as well as the conditions under which it is launched;
- increasing the complexity of the robot structure – more actuation elements and/or more sensors lead to additional command lines;
- the possibility of evolution in unknown spaces – situations of ignorance require more complex approaches, compared to the situation of a completely known evolution space;
- possibly other constraints imposed, specific to a certain application.

There are numerous concerns in the field, starting from the optimization of trajectories or operations, in the case of knowledge of the evolution space, or the development of algorithms in order to "learn" and adapt the robot to changes in the evolution space.

Depending on the required performance, the level of autonomy, the sensors it has, and its mode of locomotion, an optimal possible trajectory can be determined for a robot.

Determining the optimal trajectory for a mobile robot is an important concern in the study of mobile robots. On the world level, the establishment of new methods of optimizing trajectories is being sought. For example, researchers from Japan proposed to determine a method for establishing the optimal trajectory of a mobile robot located in a known closed enclosure. The proposed method is based on genetic algorithms (GA), which represent a computational model of biological evolution. GAS is useful both for solving given problems and for modeling evolutionary systems.

The robot has a map of the premises, a map divided into identical units, one unit being equal to the size of the robot. Each unit has been associated with a code; with the help of GA the robot chooses the optimal trajectory. Thus, an example of some experimental results is shown in Figure 5.

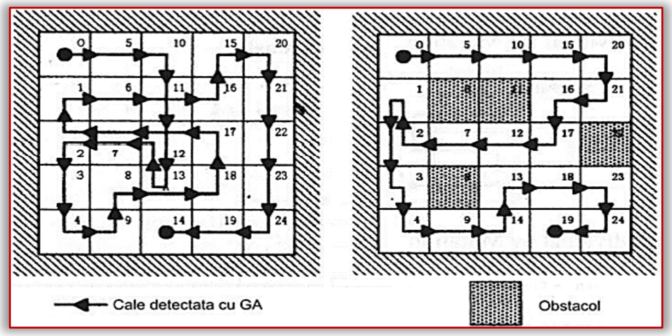


Figure 5 – GAS experimental results: workspace without obstacles (a); workspace with 4 obstacles (b)

They consist in determining a path for the robot to move in the chosen workspace. To begin with, an optimal trajectory was determined in the absence of any obstacles. The same problem was solved in the case of the appearance of four obstacles (see Figure 5(b)).

There are concerns of developing new control methods for mobile robots with evolution in unknown environments, also in Japan. There is the problem of adapting the robot to the space of evolution, to its eventual modification. The aim is to establish some learning techniques. For this, the Classifier System (CS), the machine learning method, is applied.

Experimental results are also obtained with GA. In general, CS consists of 2 important parts: the conditions part and the action part.

It receives signals from the environment and searches until they match an existing condition. After finding it, the decision of an action is taken.

A new stage in increasing the degree of autonomy of robots is represented by self–calibration methods. Studies in this sense are carried out at the Department of Aeronautics and Space Engineering of Tohoku University in Japan [8]. As is known, there are differences between the theoretical design and the practical implementation, as a result of working assumptions, dimensional tolerances, errors from sensors, etc.

An optimal solution is the creation of a device capable of self–calibration, allowing the identification of the real kinematics of the robot.

Also, communication with the robot on mission is also a problem of command and programming. A completely autonomous mobile robot, it no longer responds to external commands, until the completion of the cycle of operations for which it was programmed.

The operation of programming such a robot is very difficult, involving the anticipation of all unforeseen events that may occur.

That is why most of the time a compromise is accepted between autonomy and remote control, i.e., the introduction of a human operator on the control loop capable of making decisions in unforeseen situations, or of taking over the management completely in certain cases.

In this case, the need for fast communication between the robot and the operator becomes obvious, and the amount of information needed to be transmitted or received is very large. The success of the mission may depend on the quality of the transmission.

The field of communications is a field in full swing. Radio communication lines, by electric cable, by optical fiber, optical transmissions, etc. were made. Wireless communications are in continuous development.

Communication protocols have also emerged as a necessity, being logical structures that normalize the flow of communicated data, identify errors and request retransmission, possibly replacing certain data lost during transmission. There are two main types of protocols:

- asynchronous links – taking as examples the RS232 links in electric cable communication;
- synchronous – with example RS422;

Coding – in certain fields, the data transmitted from and to the robot must be protected, to avoid their interception. Thus, the need for codification is imposed, as numerous methods have been developed to achieve this (*Steffen, 2020*).

CONCLUSIONS

The paper highlights some notions in the knowledge, analysis, and use of robots in agriculture, with the aim of making human life easier and highlighting the evolution of technology. At the same time, it highlights certain procedures for the analysis and use of robots in agriculture. The primary field of application of robots in agriculture today is at the harvesting stage.

To exemplify and present some mobile, automated robots, which have the ability to ease people's work, as well as to improve the quality of the techniques and services used in agriculture, there are also the analyzed robots for picking strawberries.

They represent a way to capitalize on the method of picking strawberries, to manage to ease people's work, and to apply advanced technology in agriculture.

The robotics and automation solutions presented come with obvious and demonstrable improvements in precision, efficiency, yield, flexibility and last but not least, significant cost reductions.

A well–planned and integrated automation system can improve labor productivity by more than 50%. However, continuous robotization and automation solutions are also needed in this field in order to succeed in evolving.

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**References**

[1] International Data Corporation, cited by Gizmodo, https://www.zf.ro › business–international › A devastating future for employees: The introduction of robots on the labor market will lead to a decrease in wages and the replacement of people. A revolution that will change everything, March 29. 2017 (zf.ro).
[2] https://revistadinlemn.ro/2019/06/20/robotizare–automatizare–productie–mobilier/.
[3] Bonirob with a soil penetrometer/Download Scientific Diagram (researchgate.net), Available online.
[4] Aranvid K.R, Raja P., Pérez–Ruiz M. Task–based agricultural mobile robots in arable farming: A review, Spanish Journal of Agricultural Research 2017, 15(1)
[5] https://agroverde.ro/blog/a–fost–nevoie–de–cinci–ani–pentru–a–crea–un–robot–de–capsuni.
[6] Xiong Y.,Ge Y., From P. J. An obstacle separation method for robotic picking of fruits in clusters, Computers and Electronics in Agriculture 2020, 175, 105397
[7] Danielczuk M., Mahler J., Correa C., Goldberg K. Linear push policies to increase grasp access for robot bin picking 2018, IEEE 14th international conference on automation science and engineering (CASE), 20–24 August, Munich, Germany
[8] Steffen L. Meet Odd.Bot – The Weed–Pulling Robot That Uses No Chemicals (intelligentliving.co) 2020, March 2, Available online.
[9] Gramescu B. Mobile robots 2018, CD–ROM electronic edition, Bucharest

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