International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 6 Issue 4, April - 2022, Pages:14-21

Agricultural Robotic Platforms

Svitlana Sotnik[1], Vyacheslav Lyashenko[2]

[1]Department of Computer-Integrated Technologies, Automation and Mechatronics, Kharkiv National University of Radio Electronics, Ukraine

[2]Department of Media Systems and Technology, Kharkiv National University of Radio Electronics, Ukraine
e-mail: lyashenko.vyacheslav@gmail.com

Abstract*—the review of robotics application in agriculture is carried out. The features of robots use and robotic platforms in agriculture are revealed. The main tasks in development of robots and robotic platforms have been determined. A classification of agricultural robotics is proposed. The reviewed review summarizes knowledge from field of agricultural robots in order to improve design of robots to expand potential of work performed.*

Keywords—robots; robotic platform; agriculture application features.

1. INTRODUCTION

Promising directions of robotics development are industry, agriculture (AC), medicine, military technician, special-purpose equipment [1]-[9]. At the same time, various research and analysis tools can be used here [10]-[16]. AC occupies a special place among such areas. This is due to fact that development of agriculture requires advanced technology and innovation. Since goal of AC is to increase productivity and labor productivity, this goal can be achieved using, among other things, robotics.

Agriculture can be broadly classified into: crop and livestock production. The article will focus on crop production.

In agriculture, farmers are constantly looking for new ways to increase yields per acre and at same time are struggling with rising input costs and therefore an active agricultural robotics market is emerging. From self-propelled tractors to weeding robots, agricultural automation companies are transforming agriculture into completely modern environment. Agriculture also uses: robots with machine vision, smart robots, autonomous robots.

The benefits of agricultural automation are clear: prices for consumers are falling and labor costs are falling across board.

The leading manufacturers of robotic systems for agriculture include: Abundant Robotics (USA), Agrobot (Spain), Agro Intelligence (Denmark), AgXeed (Netherlands), Carre (France), Directed Machines (USA), Ecorobotix (Switzerland), Ekobot (Sweden), ELEKS (Ukraine), FarmBot (USA), Farmertronics Engineering (Netherlands), Jacto (Brazil), Winstar Technology (Ukraine), etc.

Thus, main purpose of article is to provide an overview of robotics used in crop production.

2. RELATED WORK

Today, research and development of robotics continues in agriculture, which is at same time place for development of important new technologies and an area of their application.

Modern articles consider prospects for agricultural robotics, discuss consequences of robot's introduction, as well as their structural features, explore issues related to expanding capabilities of existing robots.

The most common agricultural tasks (pruning, harvesting, mowing) are described in [17]-[21].

Work [17] is directed to field of weed control. The authors proposed method for signaling agricultural crops for robotic weed control, which allows classifying crops from weeds using machine vision.

Work [18] is devoted to systematic review of literature on research and commercial agricultural robotics used in field. The generalized distribution of robotic systems in various agricultural environments is given.

Cotton picking robots are discussed in [19]. The authors provided detailed overview of common agricultural robotic operations. Considered relationship and similarity of robotic systems in agriculture. Analyzed questions. Associated with mobility, sensing, path planning and manipulator design.

In [20], authors describe recent and ongoing work to automate collection of iceberg lettuce and propose their experimental platform called Vegebot.

The paper describes mechanics and control strategy, and also describes in detail results of experiments.

A robot for cutting grass and irrigation with water is discussed in [21]. All components that are used in mowing grass and spraying water are listed, as well as rover, which includes all sensors, controllers, pump and motors.

Robots are now used for variety of tasks, such as planting, harvesting, monitoring environment, supplying water and nutrients, and others [22]-[27].

The development of multifunctional robot-seeding bed is described in [18], and authors also provide design scheme and open source code for such robot.

A survey paper on robotics for selective harvesting with examples of different systems for teaching horticulture [23]. The limitations of existing systems are discussed.

In [24], issue of environmental monitoring using information collected by network of mobile, wireless and noise sensors used in agricultural robotics is considered.

An overview of state of current landscape based on Agriculture 4.0 is given in [25]. Analysis of research trends and technologies used in context of Agriculture 4.0.

Robots for supplying water and caring for ornamental plants in [26], authors focus on development of an irrigation model based o sliding window strategy.

In [27] describes development of robot for home growing flowers and plants – an intelligent watering robot based on STM32.

3. FEATURES OF ROBOTIC PLATFORMS USE

The global market for agricultural robots is so wide that we will consider key areas of robotic platforms (RP) application.

There are different classifications of mobile robots (MR) and mobile platforms (MP) in agriculture, depending on work performed.

Consider MR and MP in vegetable growing and highlight most common ones:

- soil / field preparation (plowing);

- sowing / planting;

- watering;

- monitoring of farmland;

- collection of fruit crops;

- pest control (sprayers);

- automated multifunctional platforms (analog of tractors).

1. Preparation of soil / field. Every process in agriculture is important for good harvest. The main and very first factor in farming process is preparing soil for sowing. The main challenge is to create soil that will firmly hold roots of plants or seeds, and have good ability to absorb water and other essential elements for bountiful and healthy harvest.

Mechanical weeding will allow farmers to eliminate costly and harmful herbicides.

For example, FarmWise is robot with computer vision systems designed for mechanical weeding of fields [28], [29].

Ladybird – Autonomous robot for weeding and cleaning weeds. Supports autonomous mode, manual mode, as well as "follow", in this mode, robot can, for example, carry some kind of goods behind person. The wheeled platform is driven by four 110 W electric motors, and robot is powered by rechargeable battery. Operating time without recharging – up to 7 hours (depending on operating mode) [30].

Case IH Magnum wheeled robot prototype – no cockpit, cameras, radar and GPS. The decision on serial production has not yet been made. It can work in foggy conditions, automatically stops working if it rains. The autopilot system was developed by CNH Industrial and Autonomous Solutions, Inc (ASI) [30]

2. Sowing / planting.

Autonomous precision seeding is especially common today, relatively new technology that combines robotics and geographic information system mapping.

Let's take Prospero as an example – for automation of crop sowing processes. This spider robot is able to determine required place of sowing point by itself, can independently dig hole for seeds and plant it. The robot also has fertilizer container. Six-legged robot. "Teach" robot to recognize where seeds are already by marking place where seed is planted with spot of white paint [31], [32].

One robot can use LEDs to inform another robot that it needs help planting seeds.

Ladybird or "Ladybird" is robot cartographer that monitors state of crops [33].

It is used to monitor farm and draw up technological maps. It has range of sensors and solar panels that allow robot to monitor plant growth and pests around clock. Tests have shown that robot can work for three days without recharging. The "ladybug" also has mechanical arm that allows removing weeds from field [33], [34].

FarmBot is precision farming tool (farming platforms). Consists of Cartesian machine for coordinate robot. It is metal frame with rails, equipped with robot with replaceable attachments for planting seeds, watering and removing weeds. Plastic components are 3D printed, and robot itself is equipped with built-in microprocessor [35].

3. Watering.

Yardroid is mini tank for plant care and watering.

At front is turret with main water cannon, camera and LED flashlight mounted in fully stabilized gimbal. The suspension, along with swing tower, allows Yardroid to spray water in almost all directions. Weed and pest control nozzles are mounted in turret at an angle of approximately 45 degrees. At the rear are fluid tanks, pumps and drive section. Yardroid is driven by caterpillars. It is able to turn around on spot and overcome vertical obstacles up to 15 cm high. Computer vision and artificial intelligence are used to plot route.

Yardroid uses its camera and LED light to constantly monitor its environment [36].

4. Monitoring of farmland.

MP "Siberian Tiger" – is able to move over rough terrain and irrigate plants. It is equipped with camera to monitor operation of platform. Special attention is paid to image recognition using camera. Using camera: identifying plant; analysis of plant by leaf shape, characteristic angles; determining diameter of stem, identifying symptoms of disease or developmental disorder (lesions, wilted leaves, etc.). One of main functions of device is to monitor plants and warn farmer about occurrence of exceptional conditions, for example, appearance of pests [37].

5. Collection of vegetables and berries.

Soft Robotics manufactures soft-grip robotic arms that can be used to pick fragile fruits such as tomatoes, apples, strawberries, and lettuce [38].

AgroBot – uses artificial intelligence technologies to determine ripeness of berries and their automatic collection [39].

To protect berries from crushing or falling, they are cut from stem with two thin, razor-sharp knives and immediately fall into tiny basket lined with rubber rollers.

The SW 6010 has two working modules for inspection and packaging and four steerable wheels for maximum maneuverability. Its dimensions and large steering angle are ideal for working inside and outside greenhouses.

The BX Pro system helps to soften most rugged terrain for more efficient, safe and comfortable working in fields.

A highly efficient 2-cylinder Lombardini diesel with power of 28.5 and has low fuel consumption and tanks adapted for autonomous operation [39].

6. Pest control (sprayers). An example is Ecorobotix, fully autonomous drone that recharges from sun. He will work all day to identify and spray weeds. To do this, drone has multiple cameras and fast-moving arms that deliver small dose of herbicide [40].

Autonomous Tractor Corporation (USA) is developing modular robotic Spirit tractor without an AT400 Spirit control cabin for processing, harvesting and transporting crops in agricultural sector [41].

Power is transferred to rubber tracks with increased ground contact. The Spirit is equipped with laser and radio navigation system, which has improved positioning accuracy in comparison with traditional GPS. The robot's navigation system uses two lasers mounted on tractor, which reflect signals from three or four mobile transponders installed around perimeter of field. Additionally, there are 150 MHz radios that are more needed to correct motion in event of problems with laser systems [42].

The intensification of introduction of robots and RP in crop production, yes, in agricultural sector as whole, has become prerequisite for studying development processes and their production directly.

For this, let us single out several main tasks in development of robots and RP [43]:

- choice of rational kinematic schemes;

- optimization of accuracy characteristics;

- development of methods for damping elastic vibrations;

- creation of lightweight structures of manipulators;

- when creating drives, strive to improve their dynamic accuracy and energy characteristics.

Thus, manufacturers of AC products are presenting growing demand for equipment, actions with high performance, speed, accuracy; actions performed in hazardous environments; actions based on operational analysis of large amounts of data, as well as eliminating uncertainty in field of production management due to unpredictability of human behavior, etc.

3 Classification of agricultural robotics

A classification of agricultural robotics is proposed, which is presented in table. 1. In work, key industry is – crop production, therefore, special attention is paid to this particular component of agricultural production.

By type of work performed, AC robotics can also be classified as: performing heavy, physical and monotonous work [44].

Table 1: Classification of AC robotics

<table>
<tr><td colspan="7">Application industry</td></tr>
<tr><td rowspan="9">AH</td><td colspan="6">CP</td></tr>
<tr><td>By type of work</td><td>By nature of movement</td><td>By control type</td><td>By level specializations</td><td>By environment of use in AC</td><td>By operating condition</td></tr>
<tr><td>PS</td><td rowspan="2">ST</td><td rowspan="2">OC</td><td rowspan="2">SP</td><td rowspan="2">greenhouse</td><td rowspan="2">Conditions displacement</td></tr>
<tr><td>SP</td></tr>
<tr><td>WT</td><td rowspan="2">MB</td><td rowspan="2">SA</td><td rowspan="2">SPL</td><td rowspan="2">field</td><td rowspan="2">Climatic conditions</td></tr>
<tr><td>FM & PM</td></tr>
<tr><td>HT</td><td rowspan="3">DU</td><td rowspan="3">AT</td><td rowspan="3">UN</td><td rowspan="3">garden, nursery</td><td>Features of AC products</td></tr>
<tr><td>PC</td><td rowspan="2">Informational consistency, etc.</td></tr>
<tr><td>WD</td></tr>
</table>

AH – animal husbandry; CP – crop production; PS – soil / field preparation; SP – sowing / planting; WT – watering; FM – farmland monitoring; PM – plant mapping; HT – harvesting; PC – pest control (sprayers); WD – weeding; ST – stationary; MB – mobile; DU – drones / unmanned; OC – operator controlled; SA – semi-automatic; AT – autonomous.

Although, existing classifications also distinguish separate class of robots – for auxiliary production of organization [17]:

monitoring of agricultural land; sorting of AC products; packaging of AC products.

In this paper, it is proposed to combine FM – monitoring of farmland and PM – mapping of plants in, since these works are necessary for analysis and description of plants and soil relief.

SP (special) – performs one operation or maintenance of specific technological equipment.

SPL (specialized) – target, that is, robots have narrower purpose and carry out one specific operation.

UN (universal) – perform various basic and auxiliary operations (multipurpose).

Such a subclass of RP is also proposed – according to operating condition:

1) Moving conditions, for example, difficult-to-pass places – greenhouses (moving conditions include: track width of seedlings in greenhouse and width of ground clearance, etc.). 2) Climatic conditions. 3) Features of AC products. 4) Information consistency with other similar devices (when one platform transmits information to another and there can be several of them, and they work together), etc.

Table 2 proposes classification of robotic platforms, taking into account division into categories (Table 1).

Table 2: Robotic platforms

Application industry – CP		
By type of work performed		
Designation	Image	Name and manufacturer
PS		DOT from Dot Technology Corp. Treat equipment of "tractor" type [45].
SP		MARS from AGCO. There is possibility of simultaneous sowing of different crops in different parts of field, for which each robotic seeder receives its own set of seeds [46].
WT		Growver from Revely Microsystems LLC [47]. Optimized for traversing lawns and open areas with rough terrain.
FM		SwagBot from Agerris [48], [49]. Can identify and destroy weeds while controlling pastures and crops.
PM		Tom from Small Robot Company [50], [51]. Monitoring and mapping of plants. 20 hectares / day according to plant data.
HT		Technofruit CF – 105 from Frumaco [52], [53]. Equipped with self-leveling mechanism, thanks to which machine can adapt to any garden relief.
PC		R150 from XAG [54], [55] for pest control. And with runtime of up to 4 hours and 15-minute battery charge, R150 can cover 5 hectares per hour.
WD		Dick from Small Robot Company [51]. A weeding robot that removes weeds either by spraying area with micro doses of pesticides or by crushing.

4. Conclusion

Thus, on basis of review of existing classification, features of robots and RP use for agriculture have been identified.

Based on review and taking into account proposed generalized classification, it was determined that today in robotics they strive for openness in terms of "hardware modularity", that is, ability to rebuild robots and RPs to adapt to work in different conditions and environments (fields, gardens, greenhouses) and to perform tasks necessary for specific situation – heavy, physical and monotonous work. At the same time, it is also necessary to take into account variety of technologies for obtaining AC products.

As a result, classification of AC robotics has been proposed.

The general overview of agricultural robots includes following parts: navigation system; control system; level of specialization; environment of use in AC and operating conditions.

5. REFERENCES

[1] Baranova, V., & et al.. (2019. Wavelet Coherence as a Tool for Studying of Economic Dynamics in Infocommunication Systems. In 2019 IEEE International Scientific-Practical Conference Problems of Infocommunications, Science and Technology (PIC S&T) (pp. 336-340). IEEE.

[2] Matarneh, R., & et al.. (2017). Building robot voice control training methodology using artificial neural net. International Journal of Civil Engineering and Technology, 8(10), 523-532.

[3] Attar, H., & et al.. (2022). Zoomorphic Mobile Robot Development for Vertical Movement Based on the Geometrical Family Caterpillar. Computational Intelligence and Neuroscience, 2022, Article ID 3046116, https://doi.org/10.1155/2022/3046116.

[4] Abu-Jassar, A. T., & et al.. (2021). Some Features of Classifiers Implementation for Object Recognition in Specialized Computer systems. TEM Journal, 10(4), 1645-1654.

[5] Maksymova, S., & et al.. (2017). Voice Control for an Industrial Robot as a Combination of Various Robotic Assembly Process Models. Journal of Computer and Communications, 5, 1-15.

[6] Sotnik, S., & et al.. (2020). Some features of route planning as the basis in a mobile robot. International Journal of Emerging Trends in Engineering Research, 8(5), 2074-2079.

[7] Baker, J. H., & et al.. (2021). Some interesting features of semantic model in Robotic Science. SSRG International Journal of Engineering Trends and Technology, 69(7), 38-44.

[8] Matarneh, R., & et al.. (2019). Development of an Information Model for Industrial Robots Actuators. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 16(1), 61-67.

[9] Al-Sharo, Y. M., & et al.. (2021). Neural Networks As A Tool For Pattern Recognition of Fasteners. International Journal of Engineering Trends and Technology, 69(10), 151-160.

[10] Jassar, A. A. (2018). An analysis of QoS in SDN-based network by queuing model. Telecommunications and RadioEngineering, 77(4), 297-308.

[11] Abu-Jassar, A. T. S. (2015). Mathematical tools for SDN formalisation and verification. In 2015 Second International Scientific-Practical Conference Problems of Infocommunications Science and Technology (PIC S&T) (pp. 35-38). IEEE.

[12] Lyashenko, V., & et al.. (2021). Wavelet ideology as a universal tool for data processing and analysis: some application examples. International Journal of Academic Information Systems Research (IJAISR), 5(9), 25-30.

[13] Lyashenko, V. V., & et al.. (2016). Hurst Exponent as a Part of Wavelet Decomposition Coefficients to Measure Long-term Memory Time Series Based on Multiresolution Analysis. American Journal of Systems and Software, 4(2), 51-56.

[14] Khan, A., & et al.. (2015). Some Effect of Chemical Treatment by Ferric Nitrate Salts on the Structure and Morphology of Coir Fibre Composites. Advances in Materials Physics and Chemistry, 5(1), 39-45.

[15] Kobylin, O., & Lyashenko, V. (2014). Comparison of standard image edge detection techniques and of method based on wavelet transform. International Journal, 2(8), 572-580.

[16] Rabotiahov, A., & et al.. (2018). Bionic image segmentation of cytology samples method. In 2018 14th International Conference on Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET) (pp. 665-670). IEEE.

[17] Raja, R., & et al.. (2019). Crop signalling: A novel crop recognition technique for robotic weed control. biosystems engineering, 187, 278-291.

[18] Fountas, S., & et al.. (2020). Agricultural robotics for field operations. Sensors, 20(9), 2672.

[19] Fue, K. G., & et al.. (2020). An extensive review of mobile agricultural robotics for field operations: focus on cotton harvesting. AgriEngineering, 2(1), 150-174.

[20] Birrell, S., & et al.. (2020). A field - tested robotic harvesting system for iceberg lettuce. Journal of Field Robotics, 37(2), 225-245.

[21] Subrahmanyam, R. V., Vikas, N., & Prashanth, B. N. (2019, November). Design and fabrication of grass cutting and water spraying rover. In IOP Conference Series: Materials Science and Engineering (Vol. 577, No. 1, p. 012170). IOP Publishing.

[22] Li, X., & et al.. (2021, June). Design of Multifunctional Seedbed Planting Robot Based on MobileNetV2-SSD. In 2021 IEEE International Conference on Artificial Intelligence and Computer Applications (ICAICA) (pp. 272-278). IEEE.

[23] Kootstra, G., & et al.. (2021). Selective harvesting robotics: current research, trends, and future directions. Current Robotics Reports, 2(1), 95-104.

[24] Nguyen, L., & et al.. (2021). Mobile robotic sensors for environmental monitoring using gaussian markov random field. Robotica, 39(5), 862-884.

[25] Araújo, S. O., & et al.. (2021). Characterising the agriculture 4.0 landscape—Emerging trends, challenges and opportunities. Agronomy, 11(4), 667.

[26] Zhang, M., & et al.. (2021). Modeling and optimization of watering robot optimal path for ornamental plant care. Computers & Industrial Engineering, 157, 107263.

[27] Liu, X., Yin, H., & Zang, C. (2019). Design of intelligent watering system based on STM32. Academic Journal of Engineering and Technology Science, 2(1).

[28] Guizzo, E. (2019). Your next salad could be grown by a robot. IEEE Spectrum, 57(1), 34-35.

[29] Fennimore, S. A., & Tourte, L. (2019). Regulatory burdens on development of automated weeding machines and herbicides are different. Outlooks on Pest Management, 30(4), 147-151.

[30] Katalog avtonomnyh selskohozyajstvennyh robotov dlya raboty v pole, v sadu ili teplice. - URL: http://robotrends.ru/robopedia/katalog-avtonomnyh-robotov-dlya-raboty-v-selskom-hozyaystve.

[31] Byrdina, M. V., & et al.. (2021, June). Simulation of flexible protective shells for agricultural robotic devices. In 2021 IEEE International Conference on Artificial Intelligence and Computer Applications (ICAICA) (pp. 383-388). IEEE.

[32] Byrdina, M. V., & at al.. (2021, June). Simulation of flexible protective shells for agricultural robotic devices. In 2021 IEEE International Conference on Artificial Intelligence and Computer Applications (ICAICA) (pp. 383-388). IEEE.

[33] Bender, A., Whelan, B., & Sukkarieh, S. (2019). Ladybird cobbitty 2017 brassica dataset.

[34] Bogue, R. (2017). Sensors key to advances in precision agriculture. Sensor Review.

[35] Pandya, J. R., & et al.. (2019). FarmBot-A Platform for Backyard Precision Farming: Installation and Initial Experimental Layout. In 2019 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers.

[36] The Yardroid Yard Robot Takes Care Of All Of Your Outdoor Lawn Chores. Odditymall, 2021.

[37] Guizzo, E. (2018). Your next t-shirt will be made by a robot. IEEE Spectrum, 55(1), 50-57.

[38] Shintake, J., Cacucciolo, V., Floreano, D., & Shea, H. (2018). Soft robotic grippers. Advanced materials, 30(29), 1707035.

[39] Kauser, N., Banu, S., & Yuvaraja, T. (2018). IOT Based Agricultural Application Using Robot—Agrobot. Journal of Computational and Theoretical Nanoscience, 15(6-7), 2137-2139.

[40] Champ, J., & et al.. (2020). Instance segmentation for the fine detection of crop and weed plants by precision agricultural robots. Applications in plant sciences, 8(7), e11373.

[41] Kondratieva, O. V., & et al.. (2021). Using digital technologies in horticulture. In IOP Conference Series: Earth and Environmental Science (Vol. 723, No. 3, p. 032033). IOP Publishing.

[42] Krishna, K. R. (2017). Push button agriculture: Robotics, drones, satellite-guided soil and crop management. CRC Press.

[43] Zhang, Q. (2016). Precision agriculture technology for crop farming (p. 374). Taylor & Francis.

[44] Zhang, Q., & Karkee, M. (2021). Agricultural and field robotics: an introduction. In Fundamentals of Agricultural and Field Robotics (pp. 1-10). Springer, Cham.

[45] Garvey S. (2019). Dot Technology Corp. opens R&D centre in Alberta. Machinery & Shop, Machinery and Shop, News.

[46] Horváth, J., & Schmitz, B. (2019). Digitalisation in agriculture–From the perspective of a global agricultural machinery producer. Hungarian Agricultural Engineering, 36, 63-68.

[47] Guy J. (2020). Growver 2020 is live. The Growver Project.

[48] Wallace, N. D., & et al.. (2019). Motion cost characterisation of an omnidirectional WMR on uneven terrains. IFAC-PapersOnLine, 52(22), 31-36.

[49] Wallace, N. D., & et al.. (2021). Experimental validation of structured receding horizon estimation and control for mobile ground robot slip compensation. In Field and Service Robotics (pp. 411-426). Springer, Singapore.

[50] Lujak, M., Sklar, E., & Semet, F. (2021). Agriculture fleet vehicle routing: A decentralised and dynamic problem. AI Communications, 34(1), 55-71.

[51] Spencer, J. (2019). Meet Tom, Dick and Harry. Farmer's Weekly, 2019(19015), 58-58.

[52] Tecnofruit cf 105 levelling. Frumaco, 2020.

[53] Salzer, Y., & et al.. (2021). Time study for improving outputs and apple quality using integrated harvest platform conveyors. In Bio-Economy and Agri-production (pp. 221-233). Academic Press.

[54] Fryer, T. (2020). Innovate and celebrate: A virtual celebration of some very real winners will take place on 19 November 2020. What's more–you're invited!. Engineering & Technology, 15(11/12), 46-49.

[55] Peskett M. (2021). XAG R150 autonomous ground vehicle tackles Japan's pollination problem . FoodandFarmingTechnology.