Advanced Control Subsystem for Mobile Robotic Systems in Precision Agriculture

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Abstract: This concept paper presents Mobile Agricultural Robots (MARs) for the development of precision agriculture and implicitly the smart farms through knowledge, reason, technology, interaction, learning and validation. Finding new strategies and control algorithms for MARs has led to the design of an Autonomous Robotic Platform Weed Control (ARoPWeC). The paradigm of this concept is based on the integration of intelligent agricultural subsystems into mobile robotic platforms. For maintenance activities in case of hoeing crops (corn, potatoes, vegetables, vineyards), ARoPWeC benefits from the automatic guidance subsystem and spectral analysis subsystem for differentiation and classification of the weeds. The elimination of weeds and pests is done through the Drop-on-Demand spray subsystem with multi-objective control, and for increasing efficiency through the Deep Learning subsystem.

Keywords: Mobile agricultural robots, Real-Time control, Smart farm, Modelling, Weeds subsystem, Precision agriculture.

1. INTRODUCTION

Starting from the needs of precision agriculture, our team proposes the development of a complex concept, innovative under certain aspects, in which multiple components of mechatronics are combined by artificial intelligence (AI). The framework developed includes MARs that operate in the field of Agriculture 4.0 [15].

Thus, we characterize farm through low expenses, quality harvests and sufficient quantities. The reality demonstrates that are necessary major changes in agriculture. The needs of precision agriculture are multiple, from workforce to smart machines, from hybrid seeds and saplings to high-performance herbicides, from monitoring plant to irrigation, from animal monitoring to their feeding.

All of these are parts of a large future program, in which small-sized ARoPWeC will be built and tested using new herbicide spraying methods.

The existence of smart farms is based upon the strategies, methods and algorithms taking into account in order to perform certain tasks by the robots, but also upon the retechnologisation of agricultural processes through sustainability (efficiency and low pollution) [19].

The current global situation requires the rapid development of intelligent communities, implicitly of the precision agriculture. Agriculture 4.0farms with large areas cultivated with wheat, corn, vegetables, fruit trees or vineyards in addition to the related buildings need equipment to extent.

The paradigm of this concept is based on the interaction between the mobile robotics platform and the smart agrarian community, which takes into account knowledge, reason, technology, interaction, learning and validation. For maintenance activities in case of hoeing crops, ARoPWeC benefits from the automatic guidance subsystem and spectral analysis subsystem for differentiation and classification of the weeds [21].

The elimination of weeds and pests is done through the Drop-on-Demand spray subsystem with multi-objective control, and for increasing efficiency through the Deep Learning subsystem. All these subsystems are in interaction with MAR's mechatronic subsystems, so that the degree of accuracy of the executed works and their efficiency fulfill the current sustainable development requirements.

The urban environment, through the smart city [4, 11, 12] and the rural area, through farms, are on top of current scientific researches. Along with other economic fields, agriculture [1-3, 7-10, 13, 14] benefits from advanced researches in order to obtain qualitative growth and quantitative harvests, reduced costs [1, 2], ecosystems protection [12] and smart equipment. The application of AI in agriculture determined the emergence of robots and controlled processes. The robots moving on wheels [1-3, 9, 10, 14] and / or with

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autonomous motion [1, 3, 19] include modern components and advanced technological solutions.

Scientific researches for precision agriculture targeted the crops of carrots, tomatoes and lettuces [13] and demonstrated that much better results can be achieved by weeds controlling. Thus, Neural Networks (NN) [7, 10, 19], Genetic Algorithms (GA) [2], Simultaneous Localization And Mapping algorithms (SLAM) [5, 10] Denevit-Harterenberg method [9], Monte Carlo algorithm [3], Kalman filter [14], Pareto principal [2], multi-objective optimizations [2], Deep Learning [1, 7, 8, 10], Deep Reinforcement Learning (DRL) and Imitation Learning (IL) [4] were implemented, independently or in interaction.

The agricultural activities subjected to this research were carried out in the field [1, 3, 7-10, 13, 14], in the greenhouses [2], or in the nurseries and were: herbicide spraying [1, 3, 8, 14, 22] and harvesting of heavy products (such as pumpkins) [9].

The control of robotic subsystems was aiming the trajectory [2, 5, 6], navigation [2, 10, 14], image acquisition and processing [7, 8, 13, 14, 21], obstacle avoidance [10], permanent observation of process parameters [1], bidirectional Human-Robot Interactions [6, 11, 12].

Many articles studied focus on the individual robots [2, 3, 5, 7-11, 13, 14] or on the multi-agent systems [1, 3], where the timing and coordination of agents converge toward the achievement of the collective objective.

Performing the activities of precision agriculture requires optimal technological solutions, intelligent measures and methods, reduction of production costs, protection and conservation of soil and environment, protection of biodiversity and protection of ecosystems. In [2] studied the implementation and optimization of multi-objective GA for the route taken by mobile robots with spray function. The presented solution is validated in the virtual environment of a greenhouse and ensures the reduction of navigation costs on the basis of the Pareto principle and the generated planner, thus minimizing the distance travelled. The use of mobile robots in precision agriculture is mandatory. In [7] propose a solution for real-time classification of weeds identified in the carrots crop. Identifying weed types in real-time is a necessity. Thus, spraying of herbicides is carried out using an autonomous mobile robot. Particularly complex images recorded in the field are processed at high speed through AI and Convolutional Neural Networks (CNN). At the same time, Deep Learning increases the accuracy of identification and classification of weeds, ensuring their destruction in a much higher percentage. In [14] presents an effective alternative solution to the classical spraying for weeds control and reduces herbicide consumption in vegetable crops. The developed autonomous MAR navigates, identifies weeds on the vegetable row and uses the Drop-on-Demand subsystem to remove them. The robot's construction includes GPS location, navigation and image processing subsystems adapted to specific weed removal activities. The movement of the robot takes into account small terrain bumps, the slope with inclination of less than 5 degrees. The method annihilates each weed punctually. The results obtained imposed this weeds control solution. Abandoning the Global Navigation Satellite System (GNSS), [10] developed an autonomous MAR. For travel, the team proposed new visualization and detection subsystems in association with a learning subsystem. The method is based on SLAM and CNN. The experimental results obtained in real-time are remarkable due to the increasing accuracy of the robot and the rapid identification of the objects encountered on the route. At the same time, the obstacles have been classified and successfully avoided. Setting well defined rules in the field of robotics is an effective mean of standardizing mechatronic components, increasing quality and saving resources. In [4] improve control behaviour of the robots in the smart city by creating Internet of Robotic Things (IoRT), as a subsystem of Internet of Things (IoT). Also, skills control is achieved by means of the Deep Learning process, which is divided into two components, Deep Reinforcement Learning (DRL) and Imitation Learning (IL). In [9] propose to adapt an existing agricultural machine for harvesting heavy crops. Thus, a smart robotic arm coordinated by a control algorithm that is based on the Denevit-Hartenberg method is attached to a tractor. The tests showed that the proposed solution is viable, because the positioning accuracy of the arm and the repeatability of the movement have small errors, less than 5 mm, compared to the object. The projected algorithm considered was the point-to-point (PTP) motion; movement parameters being calculated by inverse and direct kinematics. In [12] present the results obtained from the analysis carried out in the field of interaction between Robot and City. Aspects, features, influence factors, challenges, forecasts and key areas in this interaction have been identified and classified. Robots included in the infrastructure of urban service networks, autonomous robots, along with the need to regulate them are mentioned. The main areas of interaction identified are citizen assistance, mobility in urban space, transport, security and maintenance.

Next, this article is structured in topics as follows: chapter 2 supports the necessity of designing and developing ARoPWeC in smart farms and the importance of intelligent development of the main subsystems (Perception, Recognition and Navigation); chapter 3 presents intelligent solutions for modelling and controlling the behaviour of mobile robots; chapter 4 focuses on the advantages resulting from the implementation of the new solution.

2. MOBILE ROBOTS IN THE SMART VILLAGE

Urban robotics has appeared within the development of AI in areas such as natural resource consumption, health, construction, public services, and transport. The urban robot is an essential tool, part of the smart city based on information, disturbances, initiative, evolution, adaptability, sustainability. The interaction of the robot with the human being and urban environment aims to provide real advantages for increasing the life quality.

The village space, especially smart farm, has multiple peculiarities, different from the urban area. The smart village and the robotic platforms are a smart solution, part of industrial revolution 4.0, which do not exclude the bidirectional Human-Robot Communication (HRC). Given the new objectives, the reality in today's agrarian village shows that existing concepts and infrastructure are outclassed. The world of the modern village is a smart ecosystem where the environment encompasses objects, plants, animals, humans, robots and many phenomena. In the smart farm space mobile robots will be of various types and will provide activities specific to each type of workspace.

The fourth industrial revolution requires for the precision agriculture to develop a management plan based on complex advanced intelligent command and control models. We need to build high-performance agricultural machines, develop new technologies and especially we have to counteract the effects of abnormal, sudden and unpredictable events on the community and on the environment.

2.1. Integration of Mobile Robots in Smart Farms

The organic, green and smart farm necessarily comprises AI - robots, which either move on wheels or on feet, or fly. They are useful both in the house and in the yard or on farmland. It provides to the population from the city and village cheaper and higher quality products in larger quantities. At the same time, natural resources are saved, chemical treatments on crops are reduced, and a less polluted environment that guarantees better health for people is offered.

The biodiversity of smart farms must be a mandatory feature for them. In addition, the optimization of chemical fertilizer treatments, the multiplication of sustainable agricultural processes and the rehabilitation of degraded ecosystems are of high priority.

Broadleaf (Dicot) or narrow leaf (Monocot) weeds, annual or perennial, pose the greatest danger to agricultural crops. Only through new combat methods (*e.g*. one-off drive, irradiation, hybrid or microbiological solutions) and advanced technical subsystems/equipment attached to intelligent systems can be achieved higher results. Current pesticides need additional power to combat diseases, pests and weeds in agricultural and horticultural crops. All zoocides, fungicides, herbicides, growth regulators, attractions and repellents must be correlated with new intelligent methods.

Figure 1: Smart farm structure.

Trophic chains from the nature should be carefully and permanently observed and controlled in order not to be damaged. Stationary sensors, flying robotic platforms – drones, mobile robots that perform different activities in the field contribute efficiently to this goal (see Figure **1**).

2.2. Perception, Recognition and Navigation

For outstanding results, mobile robots need real-time control related to perception, recognition, navigation, communication, Deep Learning processes.

The robot perception of objects and phenomena in the real environment is achieved using laser sensors and video subsystem that transmit data and information useful to the following actions and processes. Our concept involves high-precision monitoring and warning sensors to:

- bypass the obstacles encountered;

- correct the motion angle of the robotic platform so that the culture not to be "trampled";

- differentiate and classify weeds based on specific spectral characteristics, in order to eliminate weeds and pests.

Robotic platforms have sensors, communicate through internet networks and soft applications about the emergence of situations or phenomena whose parameters influence their operation/balance or indicate the need to monitor and optimize causes with unwanted effect.

Recognition shows the identification of objects, situations or beings in the working environment in relation to already known landmarks. This is useful to evaluate and act quickly to increase the chances of solving a certain unknown situation. It shows the level of development and experience gained. Achieving a complete level of recognition is extremely difficult to realize, requiring a lot of time and energy. The recognition process is related to learning, memory and video and audio visualization and processing subsystem. Recognition uses formal, non-formal and informal data.

Navigation is defined as the motion of a mobile robot to the final point of travel, as a mandatory part for achieving the required goal. The elements of this route are: position in space, trajectory, time, distance, speed, acceleration, forces and inertia. Finding the optimal path compels to detect and bypass obstacles [17].

The communication of mobile robots located in smart farms is carried out through the Internet of robotic things (IoRT), part of the Internet of things (IoT).

Learning is realized in time, gradually, based on the data and information already known by the robot to which other data from constraints or complex situations solved by it is progressively added.

It is written more and more about integrating robots into agricultural activities. Unfortunately, this is done to a very small extent. The potential of robots is huge, but the integration process is extremely complex. That is why this project refers to the precision prevention activity of weeds in agricultural crops. Weeds significantly affect the performance of crops, so removing them through intelligent control is a viable solution.

3. MODELLING & CONTROL OF ROBOTS BEHAVIOUR

It is necessary to prepare carefully ethics strategies and action plans, where the security of missions, citizens, robots and the environment should be high, without affecting the peculiarities of the habitat and the democracy of the community.

The proposed model includes intelligent architecture based on an innovative infrastructure that interacts in a rural environment and has to become familiar while multi-objective control copes with unexpected events.

The methodology used for hierarchical, multi-objective control of robot behaviour includes: the systematization of the collected information whose relevance is significant; the establishment of the optimal strategy by defining each level of action and control in a decentralized and distributed manner; their correlation; continuous monitoring of the result obtained to ensure acceptable actions and the fulfillment of tasks (see Figure **2**). The optimal strategy is based on elements of creative synthesis that combine various methods of control.

3.1. Robots Design

ARoPWeC will move in the field of hoeing crops and will carry out agricultural activities of benefit to crops, including the detection and combating of weeds. At the same time, it will be monitored remotely and will receive permanently information on the working environment from strategically implemented equipment. The requirements and specifications of the mobile robotic platform are: working under unstructured field conditions; maximum distance of 70 cm between the rows of the crop; minimum transport capacity of 100 kg; maximum travel speed 5 km/h; suitable equipment with accessories for crop monitoring, performing mechanical works (precision hoeing) and treatments.

The main mission of the team is to design and obtain a MAR prototype that travels on unstructured land and successfully carries out agricultural activities. At the same time, there will be designed other robots which, in addition to ARoPWeC, will help precision agriculture through advanced technologies. ARoPWeC will be designed after having discussion with consulting specialists, analyzing in detail influence-makers and identifying state-of-the-art materials that can ensure compliance with the principles of sustainable agriculture. The identification, differentiation and classification of the weeds will be based on the multispectral characteristics, comparing shapes and calculating vegetation indices [21].

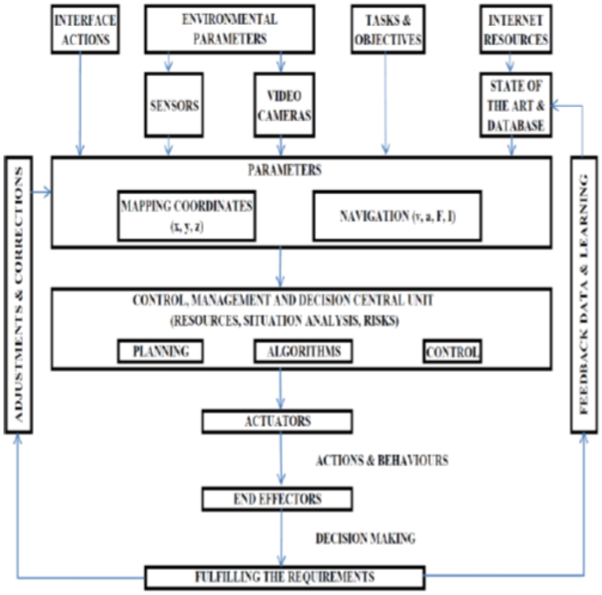

Figure 2: Constructive scheme of MARs.

For the maintenance of hoeing crops, ARoPWeC benefits from the automatic guidance subsystem (see Figure **3**) and spectral analysis subsystem. It consists of: subsystem A which ensures differentiation of plant rows, subsystem B of direction of travel tracking and central control, management and decision unit C. At subsystem A level, the images are acquired and filtered by video camera 1 and processed by data processing unit 2. The algorithm of discrimination of the row of plants according to the spectral signature specific to each crop plant identifies the rows of plants and their direction. This data is sent to central unit C. Steering angle 3 monitoring sensor and speed monitoring sensor 5 take data from the real environment and transmit it to central unit C. The data are processed and possibly corrected, so that the direction of travel, identified by the angle φ of deviation from the optimal direction of movement, is corrected by the correction angle Ө. Feedback sends the command to electric motor 5 which operates the reducer gear 6 coupled with the steering system of the agricultural platform (see Figure **5**).

The increased efficiency of ARoPWeC will result from adapting the speed in real-time to the relief of the surface of the land and to the set of weeds identified on the rows of the crop. ARoPWeC subsystems, the predictive control algorithm and the dedicated software provide important information for performing the tasks.

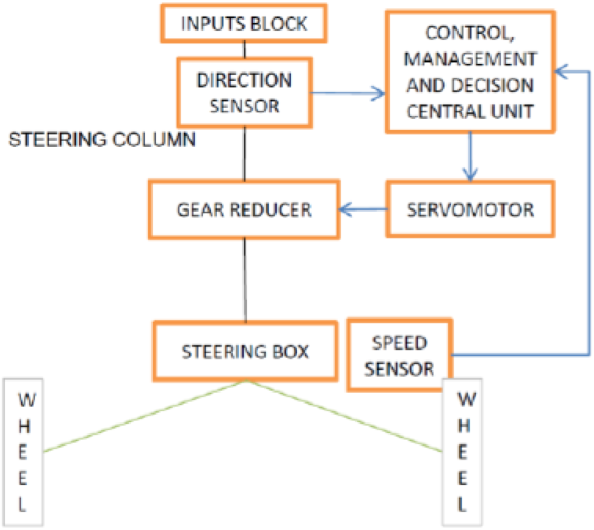

Figure 3: Automatic guidance subsystem.

In this way ARoPWeC is repositioned in the direction of the rows of plants (see Figure **4**). The control, management and decision central unit C runs the general software of the robot, which includes navigation, correction of movement direction and differentiation and weed classification based on specific spectral characteristics (see Figure **5**).

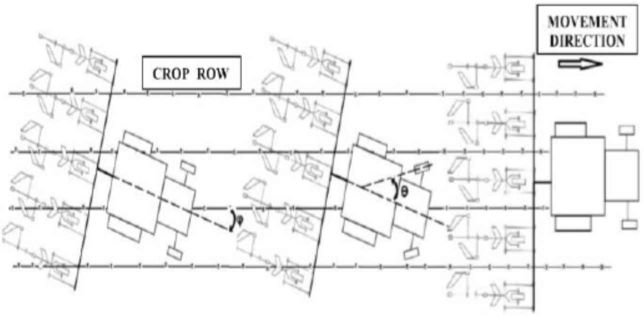

Figure 4: Automatic repositioning of MARs.

ARoPWeC will incorporate a very low weight optical sensor. The detection radius precisely measures the distance from a deformed surface or objects near the robot; maximum accuracy range is between 2.50 m and 3.50 m. This distance is to be travelled by the robot and provides sufficient time for the software for calculations and maneuvering corrections, but also to the robot for repositioning.

We specify that the triangulation method is used to make sure that the generated movements are safe. Over the image captured by the video camera, the geometric perception will be superimposed, practically ensuring dynamic control of immediate relief. The unstructured environment will be identified by the degree of inclination towards the horizontal and its surfaces. In addition to ensuring precise displacement, this method indicates the existence of weeds and pests, their position and type, in conjunction with CNN.

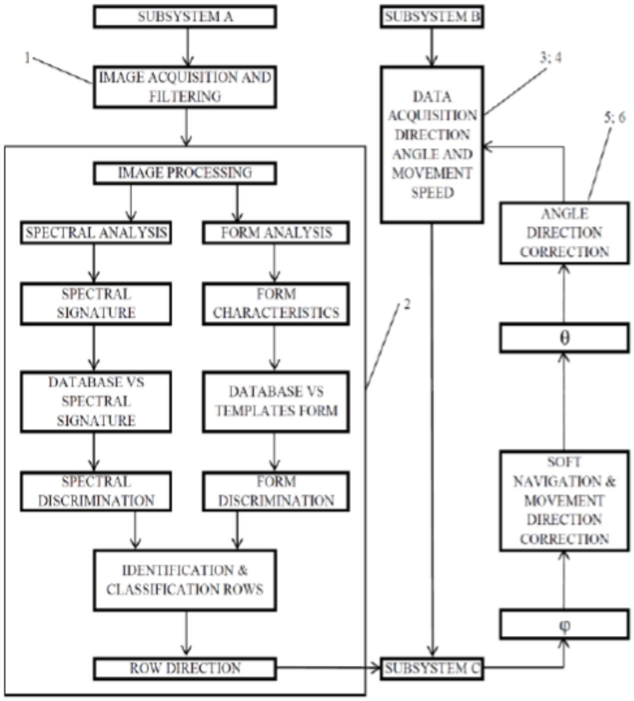

Figure 5: Differentiating and classifying weeds subsystem.

In Figure **5** we see:

1 = video camera;

2 = data processing unit;

3 = sensor attached to the steering subsystem of the mobile robot, which monitors the angle of its direction of movement relative to the direction of the crop row (provides information for maintaining and controlling the stability and traction);

4 = sensor attached to the mobile robot running subsystem, which monitors the movement speed;

5 = electric motor that transmits the mechanical movement to the reducing gear of the steering box attached to the displacement subsystem;

6 = reducer gear attached to the steering column and coupled to the steering box.

The steering system of the mobile robot consists of steering column, steering box and central unit C for control, management and decision.

The central unit C comprises the navigation software that permanently regulates the activity of the functions of the mobile robot subsystems, including adjusting the movement direction. Through AI, electronic control is much more efficient, adapting quickly to important changes determined by the triplet formed by the Pareto principle, Gerbner method, Ishikawa diagram.

The experience and performance of the mobile robot evolve with the increase of the database as a result of the validation of experimental results, the development of methods and control algorithms.

To eliminate weeds and pests, the Drop-on-Demand spray subsystem (see Figure **6**) with multi-objective control is attached, so that Deep Learning subsystem substantially increases efficiency.

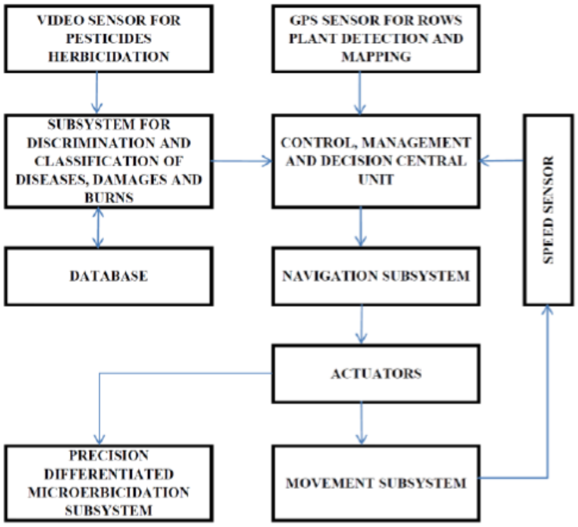

Figure 6: Spraying subsystem of ARoPWeC.

3.2. Control of Mobile Robots

The proposed control includes phases with temporal evolution [19], with the following sequence:

- Goal / task;

- Request for information, including resources;

- Analysis / scientific solution / method / algorithm, including possible risks;

- Evaluation of the result obtained in the virtual and real environment;

- Corrections / adjustments.

For example, the dynamic control algorithm of anthropomorphic walking robots (AWRs) is present in Figure **7**.

The control is carried out on hierarchical levels and distributed according to certain criteria within the robot subsystems. For a given situation, hierarchical levels can be defined, for example, by the descending order of the weights of the influence factors of control, determined with the triplet the Pareto principle - Gerbner method - Ishikawa diagram. There may be several hierarchical pyramids depending on the context. Tasks are planned successively, the analysis being multi-objective. The defined assembly is gathered in the robot's global control block, which is called central unit C.

The proposed system for MAR control (see Figure **8**) has an open architecture and is based on the VIPRO platform. With this platform it is designed, tested and experimented real-time control methods. The existence of a multitude of intelligent control interfaces ensures improved modelling and simulation results [20]. The VIPRO platform is based on the results of the module triplet (Pareto principle, Gerbner's method and Ishikawa diagram) in model development.

Although the mechanical system does not physically exist and the robot command and control subsystem is not modified, the method of virtual projection (Vladareanu-Munteanu method) performs online the design, testing and experimentation of the control methods on a classical mechatronic system [18].

4. CONCLUSIONS

The Earth's ecosphere needs to be urgently protected by intelligent policies and measures, so that our descendants can enjoy a good life.

The article reflects the needs of a smart farm space. The proposed concept can be improved, but can be used to carry out agricultural tasks.

Our paper proposes the concept for an ambitious project in which elements of robotics and agriculture are linked in order to achieve an ARoPWeC. The solution is based on validated research and is improved by bringing together an automatic and precise guidance subsystem among predatory plant crops, a spectral analysis subsystem for differentiating

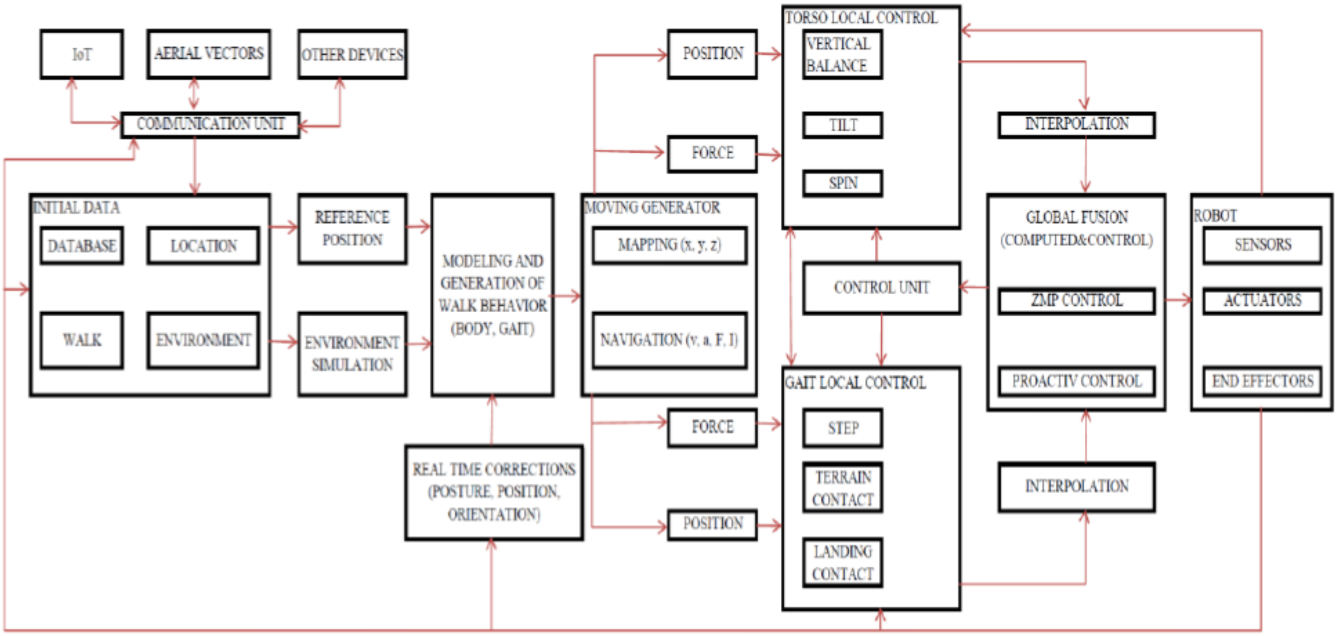

Figure 7: Dynamic control algorithm of AWRs.

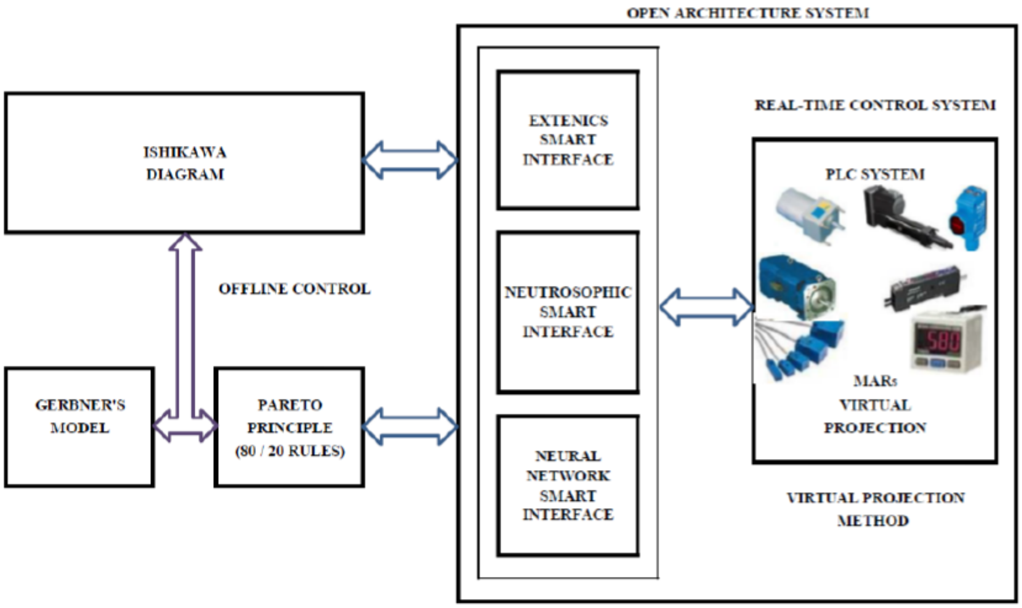

Figure 8: Dynamic control algorithm of MARs.

and classifying weeds, a subsystem of navigation and control of the behaviour of robots on unstructured terrain, a multi-purpose control attached to the Drop-on-Demand spray subsystem.

Designing and developing of ARoPWeC for hoeing crops is a must for smart farms, part of Agriculture 4.0.

The method of virtual projection within the VIPRO platform is based on the data of the triplet (Pareto principle, Gerbner's method and Ishikawa diagram) and on the real-time control. Tasks are planned successively, the analysis being multi-objective.

Other advantages of ARoPWeC are the identification of the deformed surfaces or objects near the platform, repositioning in the direction of the rows of plants and identification, differentiation and classification of the weeds.

The further development of the research will aim to increase the database, to add new criteria for refining it, in order to achieve the most accurate results through the Deep Learning process.

Robots are of great importance in the evolution of society only in terms of the existence of the human being and their environment.

This is only the first step, following that in the future, our team to realize and to validate the solution described both in the virtual and in the real environment.

REFERENCES

[1] Amend S, Brandt D, Di Marco D. *et al.*, 2019. Weed Management of the Future. Künstliche Intelligenz (2019) 33: 411-415. https://doi.org/10.1007/s13218-019-00617-x

[2] Azimi Mahmud MS, Zainal Abidin MS, Mohamed, Z. *et al.* 2019. Multi-Objective Path Planner for an Agricultural Mobile Robot in a Virtual Greenhouse Environment. Computers and Electronics in Agriculture. 157. 488-499. https://doi.org/10.1016/j.compag.2019.01.016

[3] McAllister W, Osipychev D, Davis A, Chowdhary G. 2019.Agbots: Weeding a field with a team of autonomous robots. Computers and Electronics in Agriculture. 163. 104827. https://doi.org/10.1016/j.compag.2019.05.036

[4] Liu Y, Zhang W, Pan S, Li Y, Chen Y.2020. Analyzing the robotic behavior in a smart city with deep enforcement and imitation learning using IoRT. Computer Communications 150 (2020) 346-356. https://doi.org/10.1016/j.comcom.2019.11.031

[5] Kostavelis I, Gasteratos A. 2015. Semantic mapping for mobile robotics tasks: A survey. Robotics and Autonomous Systems 66 (2015) 86-103. https://doi.org/10.1016/j.robot.2014.12.006

[6] Aliev K, Antonelli D, Bruno G. 2019. Task-based Programming and Sequence Planning for Human-Robot Collaborative Assembly. IFAC-Papers On Line. 52. 1638-1643. https://doi.org/10.1016/j.ifacol.2019.11.435

[7] Knoll F, Czymmek V, Harders L, Hussmann S. 2019.Real-time classification of weeds in organic carrot production using deep learning algorithms. Computers and Electronics in Agriculture. 167. 105097. https://doi.org/10.1016/j.compag.2019.105097

[8] Liu B, Bruch R. 2020. Weed Detection for Selective Spraying: A Review. Current Robotics Reports. https://doi.org/10.1007/s43154-020-00001-w

[9] Kamata T, Roshanianfard A, Noguchi N. 2018.Heavy-weight Crop Harvesting Robot - Controlling Algorithm. IFAC-PapersOnline. 51. 244-249. https://doi.org/10.1016/j.ifacol.2018.08.165

[10] Inoue K, Kaizu Y, Igarashi S, Imou K. 2019. The development of autonomous navigation and obstacle avoidance for a robotic mower using machine vision technique. IFAC-Papers On Line. 52. 173-177. https://doi.org/10.1016/j.ifacol.2019.12.517

[11] Fortunati L, Cavallo F, Sarrica M. 2018. Multiple Communication Roles in Human-Robot Interactions in Public Space. International Journal of Social Robotics. https://doi.org/10.1007/s12369-018-0509-0

[12] Tiddi I, Bastianelli E, Daga E, d'Aquin M, Motta E. 2019. Robot-City Interaction: Mapping the Research Landscape-A Survey of the Interactions Between Robots and Modern Cities. International Journal of Social Robotics. https://doi.org/10.1007/s12369-019-00534-x

[13] Raja R, Slaughter D, Fennimore S. *et al*. 2019. Crop signaling: A novel crop recognition technique for robotic weed control. Biosystems Engineering. 187. 278-291. https://doi.org/10.1016/j.biosystemseng.2019.09.011

[14] Utstumo T, Urdal F, Brevik A. *et al*. 2018.Robotic in-row weed control in vegetables. Computers and Electronics in Agriculture. 154. 36-45. https://doi.org/10.1016/j.compag.2018.08.043

[15] Pandelea M, Vladareanu L, Cretu D, Iliescu M. 2018. Study on the importance and role of artificial intelligence in precision agriculture. Scientific works. I/vol. IV. Agora Publishing. ISSN 2457-4449.

[16] Vladareanu V, Cononovici SB, Munteanu MS, Wang H, Moisescu M, Feng Y, Pandelea M. 2017. Modelling and simulation of humanoid robot walk with environment adaptive loads. Acta Electrotehnica, Vol. 58. no.1-2. pp 144-151. ISSN 2344-5637.

[17] Pandelea M, Vladareanu L, Iliescu M, Munteanu RI, Radulescu M. 2018.Intelligent Advanced Control Strategies for Mobile Autonomous Robots Stability Through Versatile, Intelligent, Portable VIPRO Platform. ICMSAV. COMAT. eMECH. Transilvania University Press of Brasov. ISSN 2457-8541.

[18] Vladareanu L, Pandelea M, Vladareanu V, *et al*. 2019. Improving anthropomorphic robot stability using advanced intelligent control interfaces. Periodicals of Engineering and Natural Sciences. Vol. 7, No. 1, June 2019. pp. 349-355. ISSN 2303-4521. https://doi.org/10.21533/pen.v7i1.339

[19] Pandelea M, Vladareanu L, Iliescu M, Frent Radu C. 2019. Anthropomorphic Walking Robots Integration in Smart Green Systems. SMARTGREENS 2019.8th International Conference on Smart Cities and Green ICT Systems.Conference Paper. Modelling Practical Paradigms of Green Manufacturing Systems - MoMa-GreenSys. https://doi.org/10.5220/0007828402260233

[20] Vladareanu L, Vladareanu V, Melinte O, Radulescu M, Pandelea M, *et al*. 2019. Mobile Robots Applied on Virtual and Real Environments. 22nd International Conference on Control Systems and Computer Science (CSCS). pp. 610-615. https://doi.org/10.1109/CSCS.2019.00111

[21] Gidea M, Constantinescu C, Trif A, Boasca A, Burcea M. Research into the use of image processing and automatic mapping of weeds within GIS systems. International Multidisciplinary Scientific Geo Conference Surveying Geology and Mining Ecology Management, SGEM 2017.Conference paper. 2017; 17(23): 641-648. https://doi.org/10.5593/sgem2017/23/S11.080

[22] Manea D, Gidea M, Marin E, Mateescu M. 2018.Simulation of mechanical parameters of sprayer boom. Engineering for Rural Development. Conference paper. 2048; 17: pp. 45-51. https://doi.org/10.22616/ERDev2018.17.N048

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