Versatile Intelligent Portable Robot Platform Developed through Adaptive Neuro-Fuzzy Control

Luige Vladareanu, Victor Vladareanu, Hongbo Wang, Yongfei Feng, Mihai Radulescu, and Alexandra-Catalina Ciocîrlan

Abstract—**The paper presents a VIPRO versatile, intelligent and mobile latform for robots developed through adaptive networked control, using an original virtual projection method which involves the representation of modern mobile robots in a 3D virtual environment. The Cartesian robot workspace, which is learned using an adaptive neuro-fuzzy control for the prediction of desired references was generate. In correlation was used a strong robotic simulator, an open architecture system and adaptive networks over the classical control system of the robot.**

It was developed an intelligent control interfaces that apply advanced control technologies adapted to the robot environment such as control by artificial intelligence techniques using adaptive neuro-fuzzy inference systems, extended control (extenics), neutrosophic control, human adaptive mechatronics. The results lead to a high level real-time simulation platform as a new component, alongside the existing ones on the IT market, for modelling the interactions the robots in hazardous or challenging environments.

Index Terms—**Intelligent control interfaces, virtual projection method, adaptive networked control, tracking trajectory control, contradictory problems, extenics control.**

I. Introduction

Robots can be considered an intelligent system that interacts with the environment through effector sensors [1]-[4]. To model the surrounding world, it is necessary for a robot to collect data through the sensors over a period of time. Any type of sensor can generate errors. From the point of view of this definition, one might say that man is also a robot.

Man "interacts" with the environment through sensors and effectors, represented in the biological world by nerve endings, respectively muscles.

Starting in the 20th Century, from automatic industrial lines to the daily use of electronic devices, the mobile robot has been continuously in the spotlight on robotics research. The premise into the use of robots was that robots' performances have been greatly improved in recent years [5], [6].

It is known that robots have become of great help in the industry, where they have begun to replace people in activities involving heavy work or major life-threatening dangers, such as for example, fires, terrorist actions, earthquakes [7], [8]. In this context, even if fire detection is executed by aerial robots, drone, the terrestrial robots are used to acquisition data from the proximity of the event and to process the local images [9]-[12].

All Terrain Robots (ATR) are the category of mobile robots capable of delivering excellent performance on any kind of land [13], [14]. They are able to navigate on any kind of on rough and heavy terrain. They mainly have wheels or tracks for locomotion. The ATRs have different mechanisms to overcome different obstacles with variable sizes. It is always desirable for ATRs to be autonomous, to feel the environment with their own sensors and make decisions on their own by applying intelligent algorithms, based on the information received.

The goal was to conceive and build a mobile robot with good running capabilities, good adhesion on flooded or harsh terrain, will have the ability to avoid the obstacles with variable dimensions, will be able climb / descend the stairs, the ability to traverse trenches / crevices and generate stable motion on a rough surface. A large number of researchers have attempted to design certain ATRs using computer simulations, but because of the huge complexity involved in building them, the creation of real ATRs has been limited [14]-[16].

In this context, the Virtual, Intelligent, Portable research environment applied to Robots (VIPRo), is developed as a new component on the IT market, which allows researchers in robotics, IT, electronics, mechatronics, social science and humanities etc. to design, test, and experiment intelligent, real time control methods integrating classical control system in robot modelling and simulation [17]-[19].

Intelligent heterogeneous robot networks, remotely controlled by humans, do have an increasingly important role in hazardous and challenging environments, where human lives might be at risk. This is in fact the challenge of developing autonomous systems perceptive to human requirements and having the ability of continuous learning, adapting and improving in "real world" complex environments, so as to provide support in natural disasters, fires, or other calamities [20], [21]. The paper presents a VIPRO versatile, intelligent and mobile platform for robots, using an original virtual projection method which involves the representation of modern mobile robots in a 3D virtual

Manuscript received May 15, 2019; revised July 13, 2019. This work was supported in part by the Romanian Ministry of Research and Innovation, CCCDI-UEFISCDI, MULTIMOND2 project number PN-III-P1-1.2-PCCDI2017-0637/33 PCCDI/01.03.2018, and by KEYTHROB project, number PN-III-P3-3.1-PM-RO-CN-2018-0144 / 2 BM / 2018, within PNCDI III, and by the European Commission Marie Skłodowska-Curie SMOOTH project, Smart Robots for Fire-Fighting, H2020-MSCA-RISE-2016-734875. The authors gratefully acknowledge the support of the Robotics and Mechatronics Department, Insitute of Solid Mechanics of the Romanian Academy.

Luige Vladareanu, Victor Vladareanu, Mihai Radulescu, Alexandra-Catalina Ciocîrlan are with Romanian Academy, Institute of Solid Mechanics, Romanian (e-mail: vladareanuv@gmail.com).

Hongbo Wang is with Fudan University, China (e-mail: hongbo_w@ysu.edu.cn).

Yongfei Feng is with Ningbo University, China (e-mail: yf_feng@126.com).

DOI: 10.7763/IJMO.2019.V9.722

environment using a strong robotic simulator, an open architecture system and adaptive networks over the classical control system of the robot, developing intelligent control interfaces through Adaptive Neuro-Fuzzy control that use advanced control technologies adapted to the robot environment.

II. VIPRO Platform Architecture

The VIPRO platform presents a **new concept through approaches of applied solid mechanics in** mobile autonomous robots stability for adapting the robot movements to unstructured rough terrain.

The mobile robot is an agent endowed with autonomous motion in unfamiliar and unstructured environments that operate autonomously, communicate and explore its environment. Mobile robots are complex systems that work in real-world environments, requiring an adaptive control system to control real-time robots for action as they wish.

A robot can be considered as a mathematical relation of actuated joints which ensures coordinate transformation from one axis to the other connected as a serial link manipulator where the links sequence exists.

Intelligent strategy systems, such as fuzzy logic, neural networks and genetic algorithms, have been used to equip the robot with intelligence in order to navigate in an environment or autonomously. Different hybrids of these strategies have been successfully deployed on mobile robots [22]-[24].

The VIPRO method enables the design, testing and experimentation of new intelligent control interfaces on a classical mechatronic control system (SCMC) in the presence of the physical mechatronic system (SMF), with own control system and mechanics structure, or in the absence thereof, without the need to modify its hardware structure, and, from optimal decisions and information fusion between the intelligent control interfaces, resulting in a high degree of versatility and portability to a global communications network.

The control system architecture is presented in correlation with the control strategy which contains three real-time control loops: balance robot control, walking diagram control and predictable movement control.

The remote control and e-learning software with the possibility of access throughout the internet as a web application within an international academic network is developed

For the fusion of information received from various sensors, information that can be conflicting in a certain degree, the robot uses the fuzzy and neutrosophic logic or set.

In a real time it is used a neutrosophic dynamic fusion, so an mobile autonomous robot can take a decision at any moment.

Various methods / control strategies are known for dynamic walking of humanoid robots based on the generation of walking models taking into account the stable point trajectory of zero moment point (ZPM) and ensure robot's stability (balance) through real-time control loops (Fig. 1) [17], [18], [20], [22], [23].

Since actual ZPM trajectory is different from the desired ZPM trajectory due to disturbances such as surface irregularities, sensory errors and imperfect dynamic model of the humanoid robot, more control systems based on sensory feedback are required.

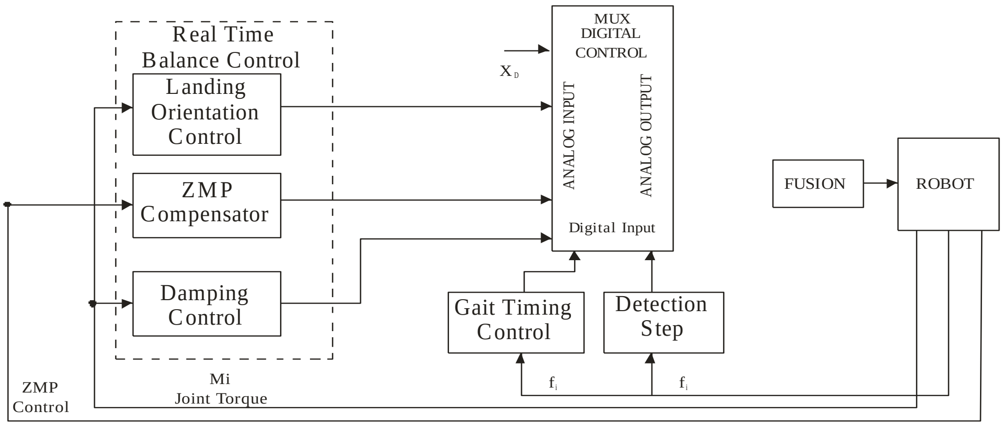

Fig. 1. Control strategies for dynamic walking of the humanoid robots.

Fuzzy logic controllers have been proven to be robust, relatively easy to design and, although a unified algorithm for parameter selection and optimization is still sought after, leading to various algorithms for the optimization of fuzzy inference systems' parameters, such as genetic algorithms and neural networks. This approach has led to a new direction relevant to the development of intelligent control techniques for rehabilitation robots through Neuro-fuzzy modelling and is a very convenient tool for simulating systems whose mathematical formulae are unknown or very complex specific to the top technologies of rehabilitation robots.

Relevant directions focused on the key technologies, specific for rehabilitation robots applied on the VIPRO platform, include:

- Research on upper limb rehabilitation 6-DOF robot control strategies, using a generalized shoulder joint that meets the large working space of human upper limb and multi-joint movement;
- Research on lower limb gait rehabilitation strategies using intelligent control methods for specialized rehabilitation robots;
- Research on ankle rehabilitation for strains and sprains using specialized and intelligent control methods;

Research using EEG and EMG to create an interface between the neurological respectively muscular functions of patients and rehabilitation robots, so that the rehabilitation robots will be improved and their efficiency increased.

VIPRO platform applications are focused on the development of a key technology using advanced rehabilitation techniques and cutting-edge equipment, through intelligent control strategies, advanced and cutting-edge theories by combining fuzzy logic for joint control and neural networks with genetic algorithms for the top level feedback loop control mechanisms [21], [23].

By this approach have been brought innovative solutions to the investigation of the upper limb rehabilitation robot with 6-DOF, mainly to control the large working space of human upper limb and multi-joint movement, using a generalized shoulder joint and advanced intelligent control strategies developed, and kinematics and mechanical structure of the rehabilitation robot (Fig. 2).

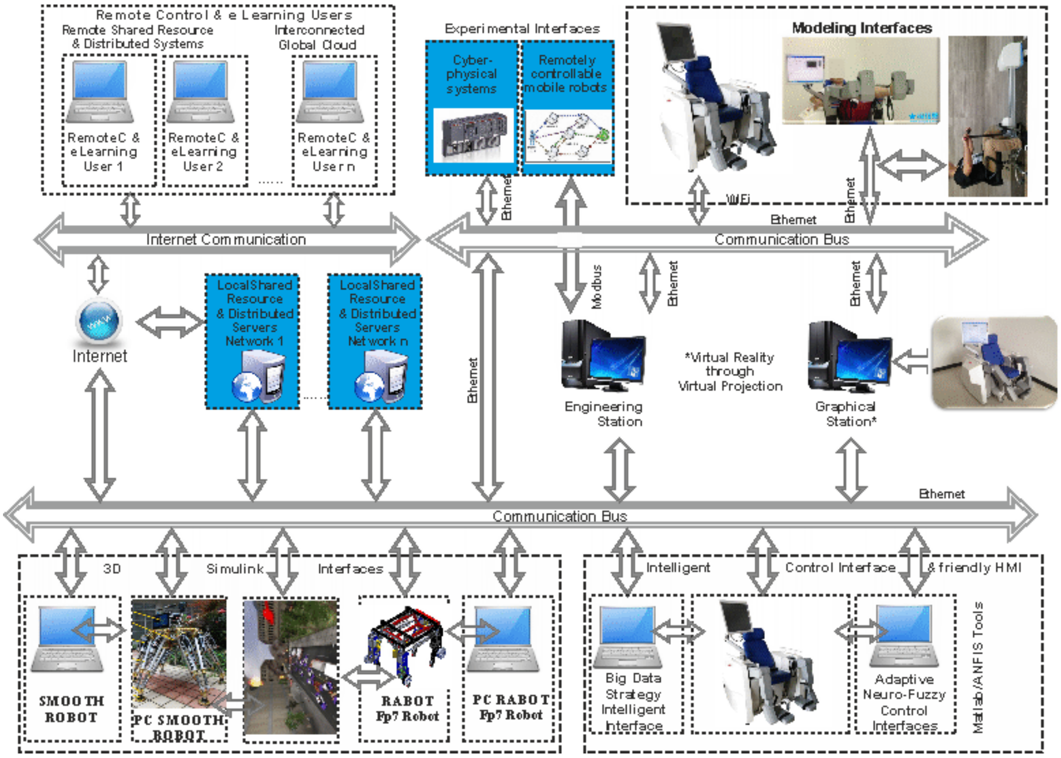

Fig. 2. VIPRO Platform for investigation of the upper limb rehabilitation robot.

Starting from previously applications using ANFIS to 2D model and 3D mechatronics systems, has been explored applications with encouraging results and adapted to a robotic system suited to the particular needs of this larger rehabilitation robot project, will bring a number of innovative control structures on the open architecture system, correlated with the implementation of the virtual projection method.

The VIPRO innovative platform is competitive with other similar virtual application platforms CDA, CAM, CAE, Solid Works or MatLab, Simulink, COMSOL, Lab View, but in addition to these platforms, it allows researchers to design, test, and experiment intelligent, real time control methods integrating classical control systems in robot modelling and simulation. The obtained results lead to the conclusion that the VIPRO platform is to be integrated on the IT market as a new component alongside the existing ones, allowing a correct evaluation of robot behaviours in hazardous or challenging environments and high level real-time simulation in order to correctly model interactions among the robots and between the robots and the environment.

In this context, it is necessary to simulate mechatronic systems and to choose their proper algorithms as well. Mobile robot's 3D simulation has to reproduce the real system dynamics and the environment, as accurate as possible.

Another aspect to be taken into account when the 3D model is created is the interaction between various mechatronic systems that can change the dynamic for the new resulted system.

III. Adaptive Neuro-Fuzzy Control Interfaces with Rehabilitation Robots Applications

Fuzzy logic is widely used worldwide as a landmark of artificial intelligence. Fuzzy logic is characterized by relative simplicity in design and implementation, the development of robust applications based on the emulation of the available expertise. To optimize the fuzzy deduction systems parameters many genetic algorithms and neural networks are developed.

The scientific relevance to develop a of a neuro-fuzzy control interface results of cutting-edge key technologies researches of the rehabilitation robots focused on improving the he mechatronic rehabilitation limbs device for the elderly with disabilities or dysfunctions. The end result will advance the state of the art by implementing intelligent algorithms, robotic environment virtualization and advanced control techniques.

The aging population problem is becoming increasingly serious, and the elderly are the main risk group for cerebrovascular disease, hemiplegia and paraplegia. These disorders often result in motor dysfunctions of the elderly, which highlights the urgency of the need for rehabilitation robots. The robotic systems have found application in rehabilitation due to their high accuracy, long-lasting resistance and a wide range of forces and movements.

Numerous lower limb rehabilitation robots have been developed. The current version of the mechatronic device can be improved by using artificial intelligence techniques, a concept already explored in published papers [22], [23]. Testing and validating these results in a laboratory-controlled environment would improve the current state of the art and facilitate the development and prototyping of a final product.

A relevant direction is the introduction of intelligent optimization methods for 9 degrees of freedom rehabilitation robots (DOFs), based on the medical condition of each patient. Manipulation of a large amount for processing data may be ineffective, as is the case of the Jacobi's matrix that requires high processing time and big physical memory. The paper aims to reduce the impact of this problem with optimizing data requirements by implementing an ANFIS interfaces.

Fuzzy logic is well established presence in artificial intelligence implementations due to its robust behavior and unclear event modeling capability. There is a wide range of intelligent algorithms that can be used to optimize the meta-parameters of a fuzzy or neutroscopic inference system. A promising research direction is the development of intelligent control techniques for neuro-fuzzy rehabilitation robots, very convenient for simulating systems for which the mathematical apparatus is unknown or very complex, such as the last generation rehabilitation robots.

Adaptive Neuro-Fuzzy Control Interfaces using the Versatile Intelligent Portable Robot Platform applies to 7 DOF rehabilitation robots.

Using the RoboAnalyzer software [25], we can visualize the modeling kinematic chain with the schematic in Figure 3. The same program offers the direct kinetics investigation and Denavit-Hartenberg equations as well as limited dynamic analysis capabilities.

The direct kinematics, necessary to determine the end-effector position in the three-dimensional Cartesian space, knowing totally or partially the variables values in the robotic space, is determined with the relation:

$$X \in R^3,\ \Theta \in R^n,\ f_{DK}(\Theta) = X \qquad (1).$$

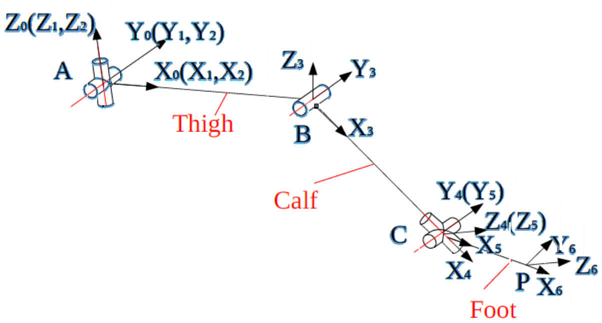

Fig. 3. Kinematic chain scheme modelled by robot analyser.

Because of the relatively large number of variables the step was chosen to generate numeric values for each larger variable. Practically, a limited number of values are used for each variable, because the number of points generated by generating any possible combinations between them can make it difficult to run the algorithm under the available processing power.

For the model with seven degrees of freedom, the variables are modeled within the limits:

Θ_1 = -30 ... 45;
Θ_2 = -140 ... 15;
Θ_3 = -40 ... 50;
Θ_4 = -10 ... 150;
Θ_5 = -10 ... 20;
Θ_6 = -30 ... 50;
Θ_7 = -50 ... 10;

Relationships for modeling the direct kinematics chain are shown in Fig. 4.

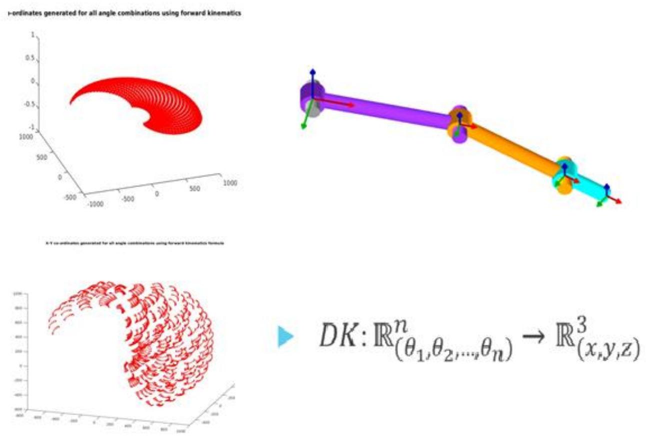

Fig. 4. The robot's direct kinematics chain modelling.

Since the calculation of the robot inverse kinetics, determined by the relationship (2):

$$X \in R^3,\ \Theta \in R^n,\ f_{IK}(X) = \Theta \qquad (2).$$

Which identifies the actual margins on the robot axes at a known effector position in the three-dimensional Cartesian space are laborious, requiring large resources on the computer and high execution time, it was necessary to use artificial intelligence methods.

The inference system was constructed using the basic values for the initialization meta-parameters, with the most important meta-parameters presented below:

1) number of membership functions for each variable (base value: 4)
2) Type of membership functions for each variable (base value: Gaussian)
3) How to generate the initial inference system (base value: grid partitioning)

Three options for how to generate the inference system were analyzed:

4) Grid partitioning (GP)
5) Subtractive clustering (SC)
6) Fuzzy c-means clustering (FCM)

Using the direct kinematics equation with all possible combinations resulting from the values generated for the actuated variables of degrees of freedom, the robotic workspace of Fig. 4 was obtained.

There are notable differences between the first option (GP), which produces partitioning of the input space, thus being more susceptible to the exponential growth problem of dimensionality, while SC and FCM use clustering methods to obtain a distributed partition.

The fuzzy inference system obtained was iteratively optimized to improve the ability to emulate the learned system's behavior. The algorithm allows to specify a number of rolling options, such as the maximum number of iterations ("epochs"), the initial step processing value, optimization method (hybrid or reverse propagation, classical for neural networks), and specification of a data set for validation.

Relationships for inverse kinematics involving the ANFIS inference system are shown in Fig. 5.

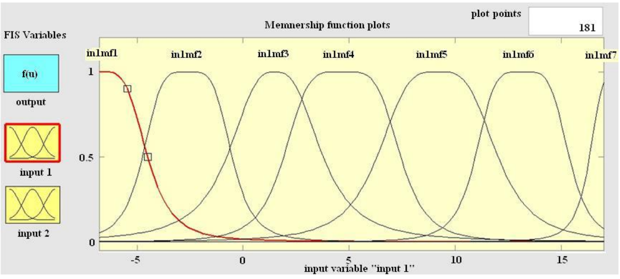

Fig. 5. Inverse kinematics of the ANFIS system.

In order to validate the model, the program with the structure of Fig. 6 was applied:

- Run ANFIS, get FIS
- Check in Cartesian space
- Generate test field $(x, y, z)_i$ across workspace
- Use FIS to estimate $(\widehat{\theta_{i1}}, \widehat{\theta_{i2}}, \ldots, \widehat{\theta_{in}})$
- Run DK with $(\widehat{\theta_{i1}}, \widehat{\theta_{i2}}, \ldots, \widehat{\theta_{in}})$, get $(\widehat{x_i}, \widehat{y_i}, \widehat{z_i})$
- Compare

$$e = \sum_i \sum_j (|x_{ij} - \widehat{x_{ij}}| + |y_{ij} - \widehat{y_{ij}}| + |z_{ij} - \widehat{z_{ij}}|)$$

Fig. 6. Validation program structure of the ANFIS system.

In technical terms, validation prevents the over-optimization trend present in any learning algorithm with an extended parameter space. In the context of the current application, this option will increase the learning error because the algorithm will run on a giant data set that will be harder to approximate correctly.

The virtual application for optimizing Adaptive Neuro-Fuzzy Control Interfaces using the Versatile Intelligent Portable Robot Platform is shown in Figure 7. The implementation of the application has led to the following steps: user-friendly visual environment, learning opportunity, workspace visualization, FIS visualization, parameterization, example run, learned model (FIS) export.

We can see the resolution at which this space is generated, compared to those generated for the other models considered. This space will be learn by the ANFIS algorithm for each variable in the robotic space. The optimization problem has a learning set up to 20.000 data points that will be divided between the learning set (70%), the validation set (20%) and the test set (10) %).

By this approach to the investigation of the upper limb rehabilitation robot with 7-DOF, mainly to control the large working space of human upper limb and multi-joint movement, have developed a generalized shoulder joint and advanced intelligent control strategies.

IV. Conclusions

Robotic systems have found their way into the rehabilitation robot field. They are highly accurate, can be sustained for very long periods of time, can automatically feedback the progress, and perform a wide range of forces and motions, and several lower limb rehabilitation robots could have been developed.

The Adaptive Neuro-Fuzzy Control Interfaces using Versatile Intelligent Portable Robot Platform aims to reduce this issue by optimizing the numerical amount of data applying ANFIS algorithm. Fuzzy Logic has long been used in academia and in industry and is one of the more palpable staples of artificial intelligence in use in the world today.

Based on the variable workspace, trajectory planning of the arbitrary curve, the largest linear motion and the largest circle motion methods has been investigated. All the training trajectories can make the hip joint and knee joint motion ranges the same with those of unaffected people.

The VIPRO interface is a software application that allows the user to access and develop various real time control programs in simulation environment, combining the virtual environment and/or the real environment.

Acknowledgment

This work was supported by a grant of the Romanian Ministry of Research and Innovation (MCI), CCCDI-UEFISCDI, MULTIMOND2 project number PN-III-P1-1.2- PCCDI2017-0637/33PCCDI/01.03.2018, and by KEYTHROB project, within PNCDI III, MCI and MFE by Competitiveness Operational Program (COP) / (POC), TOP MetEco AMBIENT project, ID P_39_383, contract107/09.09.2016, and by the European Commission Marie Skłodowska-Curie SMOOTH project, Smart Robots for Fire-Fighting, H2020-MSCA-RISE-2016-734875. The authors gratefully acknowledge the support of the Robotics and Mechatronics Department, Institute of Solid Mechanics of the Romanian Academy.

References

[1] X. Q. Chen, Y. Q. Chen, and J. G. Chase, "Mobiles robots – Past present and future," *Mobile Robots - State of the Art in Land*, Sea, Air, and Collaborative Missions, In Tech, pp. 1-32, 2009.

[2] E. Garcia and M. Jimenez, "The evolution of robotics research," *Robotics & Automation Magazine*, vol. 14, pp. 90-103, 2007.

[3] R. A. Brooks, *Cambrian Intelligence: The Early History of the New Artificial Intelligence*, The MIT Press, Cambridge, Massachusetts, 1999.

[4] *Robotics. Intern. Conf. on Humanoid Robots*, pp. 557-562, 2003.

[5] I. Pearson, *The Future of Robots in Sports: A Futurizon Report Commissioned by BETBRIGHT*."

[6] *Bot Soon the Field: The Future of Sports and Robotics*, 2018.

[7] R. C. Luo and K. L. Su, "Autonomous fire-detection system using adaptive sensory fusion for intelligent security robot," *IEEE/ASME Transactions on Mechatronics*, vol. 12, no. 3, pp. 274–281, 2007.

[8] J. H. Kim and B. Y. Lattimer, "Real-time probabilistic classification of fire and smoke using thermal imagery for intelligent firefighting robot," *Fire Safety Journal*, vol. 72, pp. 40–49, 2015.

[9] W. Zhenkuang, C. Shi, J. Li, and L. Y. Jiu, "Study on the fire source localization method based on machine vision," 2012.

[10] L. Vladareanu, "Istoria și filosofia roboților umanoizi," *Studii şi Comunicări*, 2016.

[11] G. H. Kun, C. W. Ping, and L. X. Fang, "Study on fire locating based on image processing," *Journal of East China Jiaotong University*, vol. 4, no. 22, 2005.

[12] D. J. Pack and R. Avanzato, "Firefighting mobile robots and interdisciplinary design comparative perspectives," *IEEE Transactions on Education*, vol. 47, no. 3, 2004.

[13] T. Thueer and R. Siegwart, "Mobility evaluation of wheeled all-terrain robots," *Robotics and Autonomous Systems*, vol. 58, pp. 508-519, 2010

[14] D. Pradhan, J. S. Sen, N. B. Hui, "Design and development of an automated all-terrain wheeled robot," *Advances in Robotics Research*, vol. 1, no. 1, pp. 21-39, 2014.

[15] A. Krebs, F. Risch, and T. Thueer, "Rover control based on an optimal torque distribution, application to 6 motorized wheels passive rover," in *Proc. IEEE/RSJ, IC on Intelligent Robots and Systems*, 2010

[16] T. Thueer, P. Lamon, and A. Krebs, "CRAB-exploration rover with advanced obstacle negotiation capabilities," Dissertation. Swiss Federal Institute of Technology (ETHZ), Switzerland, 2006.

[17] L. Vladareanu, L. M. Velea, R. I. Munteanu, A. Curaj, S. Cononovici, T. Sireteanu, L. Capitanu, and M. S. Munteanu, *Real Time Control Method and Device for Robots in Virtual Projection*, 2009.

[18] V. Vlădăreanu, P. Schiopu, M. Deng, and H. Yu, "Intelligent extended control of the walking robot motion," in *Proc. the 2014 International Conference on Advanced Mechatronic Systems*, Kumamoto, Japan, August10-12, 2014, pg. 489-495, 2014.

[19] M. Pandelea, L. Vladareanu, M. Iliescu, R. I. Munteanu, and M. Radulescu, "Intelligent advanced control strategies for mobile autonomous robots' stability through versatile, intelligent, portable vipro platform," in *Proc. the 42th International Conference on ICMSAV*, 2018.

[20] L. Vladareanu, O. Melinte, A. Bruja, H. B. Wang, X. Wang, and S. Can, "Haptic interfaces for the rescue walking robots motion in the disaster areas," in *Proc. the UKACC International Conference on Control*, 2014.

[21] V. Victor and M. I. Radu, "The optimization of intelligent control interfaces using versatile intelligent portable robot platform," *Procedia Computer Science*, vol. 65, 2015.

[22] T. Gu, C. J. Li, and Q. Zhan, "Advances in application of rehabilitation robots for upper limb dysfunction in patients with stroke," *J Neurol Neurorehabil*, vol. 13, no. 1, pp. 44-50, 2017.

[23] V. Vladareanu, I. Dumitrache, L. Vladareanu, I. S. Sacală, G. Tonţ, and M. A. Moisescu, "Versatile intelligent portable robot control platform based on cyber physical systems principles," *Studies in Informatics and Control*, vol. 24, no. 4, pp. 409-418, 2015.

[24] L. Pignolo, G. Dolce *et al*., "Upper limb rehabilitation after stroke: ARAMIS a "robo-mechatronic, innovative approach and prototype," in *Proc. IEEE Ras & Embs International Conference on Biomedical Robotics and Biomechatronics*, 2012.

[25] R. Analyzer. [Online]. Available: http://www.roboanalyzer.com/.

Luige Vlădăreanu received his Ph.D. degree in electronics field. He is the director of Robotics and Mechatronics Department. He is a PhD advisor in the field of mechanical engineering at the Romanian Academy and corresponding member of the American-Romanian Academy, Member of the International Institute of Acoustics and Vibration, Auburn University, USA. He has published over 35 books and book chapters, 11 edited books, over 200 papers in journals, proceedings and conferences in the areas. Director and coordinator of over 15 grants of international and national research – development programs in the last 5 years, 15 invention patents, developing 17 advanced work methods resulting from applicative research activities and more than 60 research projects. His scientific work is focused on real time control in solid mechanics applied in robotics, mechatronics, complex industrial automations in distributed and decentralized structure.

Victor Vlădăreanu is a scientific researcher at the Institute of Solid Mechanics of the Romanian Academy. He has published 5 book chapters, 20 papers in national and international journals, over 30 papers in national and international conferences and is a co-author for international and 6 national patents. Dr. Vlădăreanu has also participated in 3 international and 6 national research grants, and is the legal representative of IMSAR in the „MASIM" project, financed within the national program PN II. He has received his PhD from the Faculty of Electronics, with the thesis „Contributions to the intelligent control of autonomous robots using multi-sensor systems" and his master's thesis, from the University of Newcastle, UK, is a comparative study of evolutionary optimization algorithms for the control of autonomous robots. His main research interests are in the field of robotics and artificial intelligence, focusing on fuzzy systems, artificial neural networks, evolutionary algorithms, Extenics, Neutrosophy and analytical statistics.

Alexandra Catalina Ciocirlan is a scientific researcher, graduated the Faculty of Engineering and Management of Technological Systems at Politehnica University of Bucharest, master in European Cultural Studies at Politehnica University of Bucharest, PhD student in robotics and mechatronics. Her interest researches are intelligent control systems for autonomous mobile robots, autonomous robot navigation through deep learning and optimization and also point-cloud based on detection and tracking.

Hongbo Wang received his BS and MS degrees from Institute of Northeast Heavy Machinery, Qiqihar, China in 1982 and 1986. He received his PhD degree from Nagasaki University, Nagasaki, Japan in 1997. He studied as a Visiting Scholar in the Institute of Robotics, ETH Zuerich, Switzerland from 1992 to 1993. After that, he moved to Nagasaki University as a Researcher. From 1998, he worked in DAIHEN Corporation as a deputy manager, Osaka, Japan. Since 2009, he has been working with Yanshan University, Qinhuangdao, China as a Professor. He published about 150 papers in Journal and International Conference. Since 2012, he presided over The National High Technology Research and Development Program of China, National Key Technology Research and Development Program of China, International Science and Technology Cooperation Program of China. His current research interests are in rehabilitation robot and assisting robot for the disabled and the elderly.

Yongfei Feng was born in 1988. He is currently a joint doctoral-student at Yanshan University, China, and Institute of Solid Mechanics of Romanian Academy, Romania (2016.9-). Once he obtained his master degree at Yanshan University, China, 2015 and the major is mechatronics. His research interests include mechatronics and rehabilitation robot. Dr. Feng is a reviewer of International Journal of Advanced Robotic Systems &ACTA Automatica Sinica, and so on. He has published more than 8 papers and owned 3 China patents.

Mihai Radulescu is research assistant at IMSAR. He graduated from Faculty of Mechanical Engineering and Mechatronics, with the master in biotechnology at Politehnica University of Bucharest, the PhD student in robotics and mechatronics. Her interest researches are on development of a versatile, intelligent, portable robot platform VIPRO with real-time control systems for mobile robots, techniques that use image analysis, image formation, image operations, sampling & quantization to improve robotic navigation for intelligent robot vectors used in special missions.