ANNALS OF FACULTY ENGINEERING HUNEDOARA
- INTERNATIONAL JOURNAL OF ENGINEERING
Tome IX (Year 2011). Fascicule 1. (ISSN 1584 - 2665)

Gyula MESTER[1], Aleksandar RODIC[2]

CONTRIBUTION TO THE SIMULATION OF HUMANOID KONDO ROBOT

[1]UNIVERSITY OF SZEGED, DEPARTMENT OF INFORMATICS, ROBOTICS LABORATORY, ÁRPÁD TÉR 2, SZEGED, HUNGARY
[2]UNIVERSITY OF BELGRADE, INSTITUTE MIHAILO PUPIN, ROBOTICS LABORATORY, VOLGINA 15, BELGRADE, SERBIA

ABSTRACT: This paper presents contribution to the simulation of biped robot Kondo robot KHR-1HV using 19-DOF. Studies in the area of humanoid robotics have recently made a remarkable progress. The modeling of the Kondo KHR-1HV humanoid robot motion is analyzed. A kinematic scheme of a 19-DOF biped locomotion system is used in simulation. The simulation results in the Matlab /Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method.
KEYWORDS: Modeling, dynamic model, Lagrangian dynamics simulation, biped locomotion, humanoid robot motion, Kondo robot KHR-1HV, 19-DOF, rigid segments, joints, bipedal walking, locomotion mechanism.

❖ INTRODUCTION

In recent years, there has been a growing interest in modeling, simulation and control of the humanoid robot motion. Currently many researches in robotics are dealing with different problems of humanoid robot motion. This paper deals with the simulation of biped robot Kondo robot KHR-1HV using 19-DOF.

The modeling of the Kondo humanoid robot motion is analyzed. The problem of bipedal motion is a very complex task. Studies in the area of humanoid robotics have recently made a remarkable progress.

The considered humanoid locomotion in this paper has 19-DOF. The simulation results in the Matlab/Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method. The paper is organized as follows:

The paper is organized as follows:

- Section 1: Introduction.
- In Section 2 modeling of the Kondo robot motion is proposed.
- In Section 3 the simulation results of the Kondo humanoid robot motion are illustrated.
- Conclusions are given in Section 4.

❖ MODELING OF THE KONDO ROBOT MOTION

The Kondo KHR-1HV humanoid robot's body consists of a number of rigid segments interconnected with joints. During the bipedal walking, some kinematic chains in their interaction with the unknown environment transform from open to closed type of kinematic chain. The dynamic model of the locomotion mechanism of the robot in a vector form is:

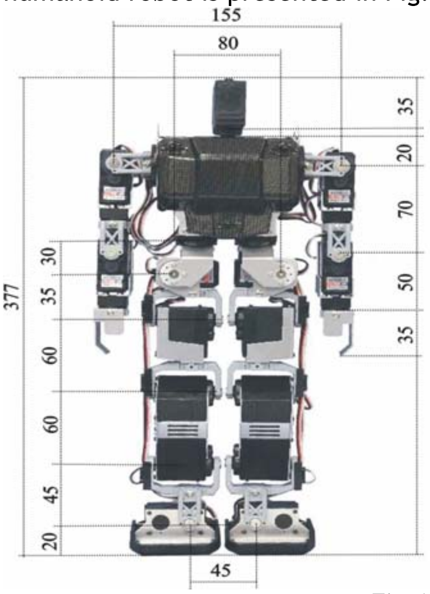
$$\mathbf{H}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{h}(\mathbf{q},\dot{\mathbf{q}}) = \boldsymbol{\tau} + \mathbf{J}^T(\mathbf{q})\mathbf{F} \tag{1}$$

where: H(q) - is the inertia matrix of the mechanism,
h - is the vector of centrifugal, Coriolis and gravitational moments,
J(q) - is the Jacobian matrix of the system,
q - is the vector of the internal coordinates,
F - is the vector of external forces and moments,
τ - is the vector of the driving torques at the robot joints.

Biped locomotion of humanoid robots is a very complex process to modeling. The bipedal walking of the robot consists of several phases that are periodically repeated: single-support phases and double-support phases.

The dynamics of the locomotion mechanism can be expressed by the Lagrangian dynamics. Computed Torque Control method is applied for control of the humanoid robot motion. The widely-known method to generate a stable trajectory for a biped robot is based on the Zero-Moment-Point (ZMP) equation. The concept of Zero-Moment-Point was first introduced by Miomir Vukobratovic and has an essential role both in scientific research and practical applications of bipedal motion of humanoid robots. The Zero-Moment-Point is the center of pressure at the feet on the ground, and the moment applied by the ground about the ZMP is zero.

The considered humanoid locomotion mechanism used in simulation in this paper has 19-DOF. The scheme of a 19-DOF biped locomotion system, masses and dimensions of the biped Kondo KHR-1HV humanoid robot is presented in Fig. 1.



Part	Body measures length [m]	mass [kg]
head	0.035	0.052
torso	0.11	0.678
single leg	0.22	0.264
single arm	0.155	0.126
whole body	0.377	1.51

Link	mass [kg]	Moments of inertia [kg m^2]		
		sagital axis (Ix)	lateral axis (Iy)	vertical axis (Iz)
head	0.052	0.0704X10^(-4)	0.1224X10^(-4)	0.0867X10^(-4)
torso	0.678	0.0007	0.0005	0.0011
upper arm	0.062	0.1244X10^(-4)	0.1764X10^(-4)	0.0867X10^(-4)
forearm	0.06	0.0704X10^(-4)	0.1224X10^(-4)	0.0867X10^(-4)
hand	0.004	0.1225X10^(-5)	0.1225X10^(-5)	0.0100X10^(-5)
thigh	0.07	0.4164X10^(-4)	0.3807X10^(-4)	0.0704X10^(-4)
shank	0.116	0.5178X10^(-4)	0.4983X10^(-4)	0.2448X10^(-4)
foot	0.078	0.1395X10^(-4)	0.3473X10^(-4)	0.3142X10^(-4)

Fig.1. The Kondo KHR-1HV humanoid robot

❖ SIMULATION RESULTS OF THE KONDO HUMANOID ROBOT MOTION

Simulation experiments are commonly used for the initial system analysis and control design while the experimental scalable test bed system has to be used in the final phase of system evaluation and control verification. The obtained results and control architecture can be afterwards adapted to the different application of mobile robots. Based on this, the important task in system development is accurate and valuable modeling of the observed system.

Simulation of the humanoid robot motion was performed using Matlab/Simulink and Robotics toolbox for Matlab/Simulink. In the simulation the biped robot walks on a flat horizontal plane. The simulation time is 3 s. The results of the simulation of Kondo robot motion are shown in Fig. **2-7.**

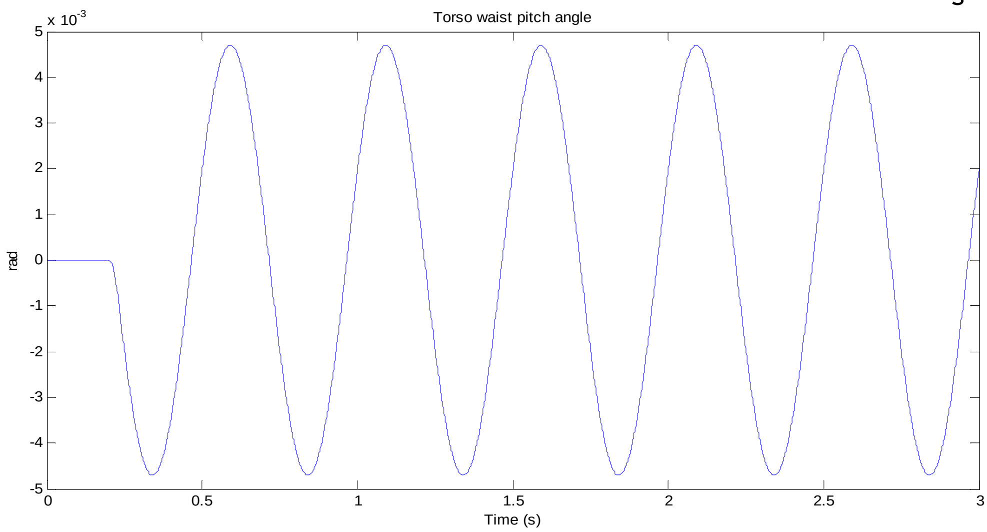


Fig.2. Torso waist pitch angle

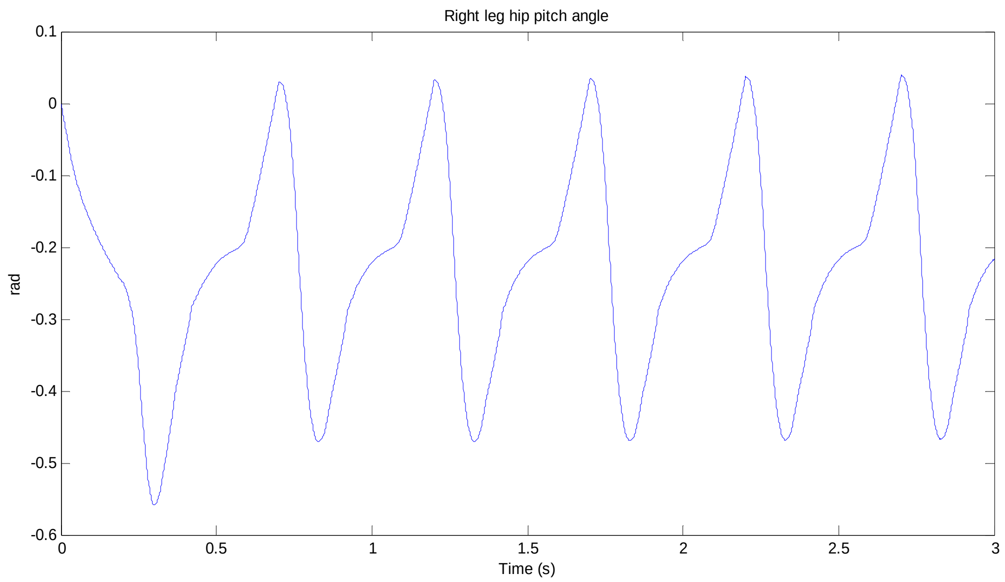


Fig.3. Right leg hip pitch angle

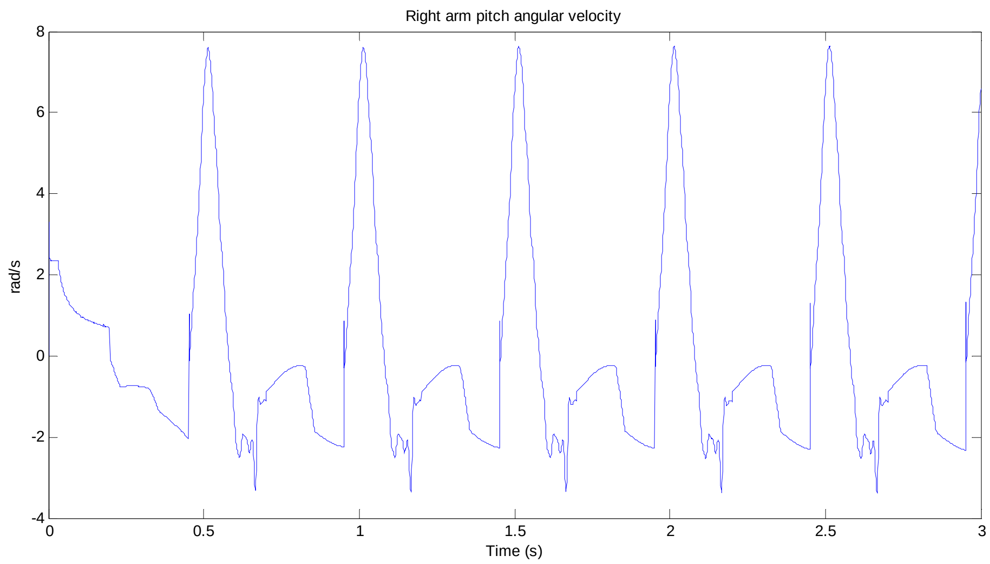


Fig.4. Right arm pitch angular velocity

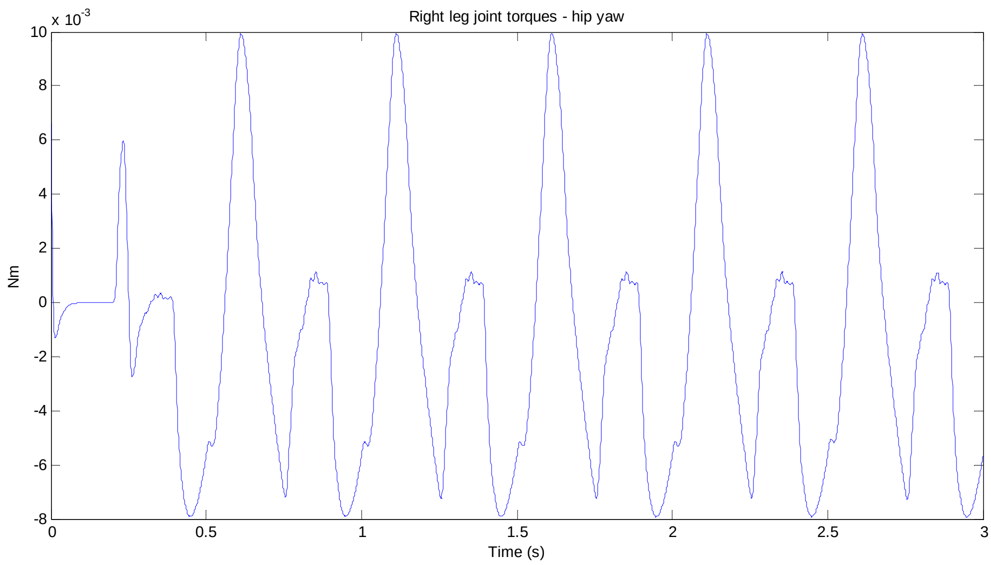


Fig.5. Right leg joint torques – hip yaw

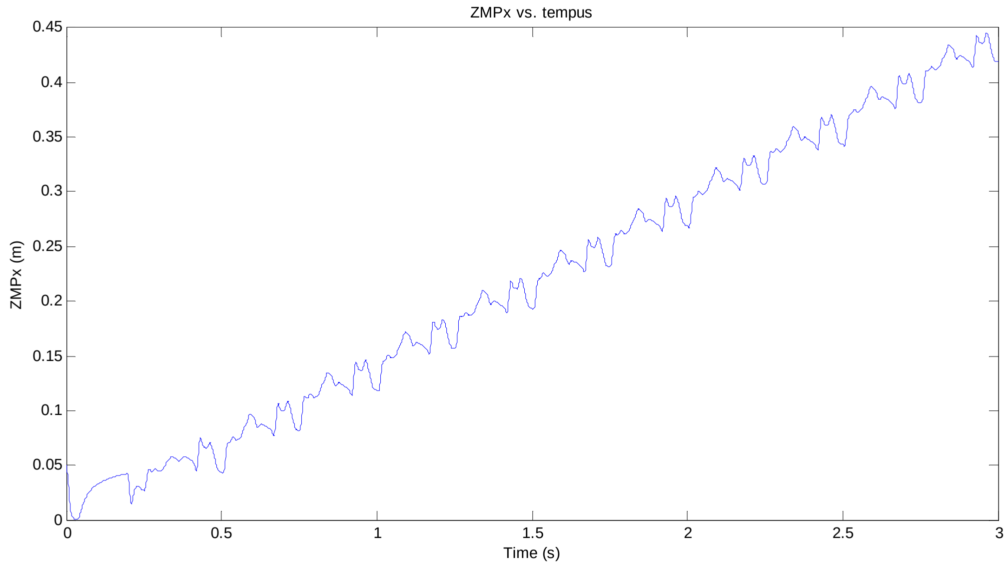


Fig.6. ZMP x trajectory

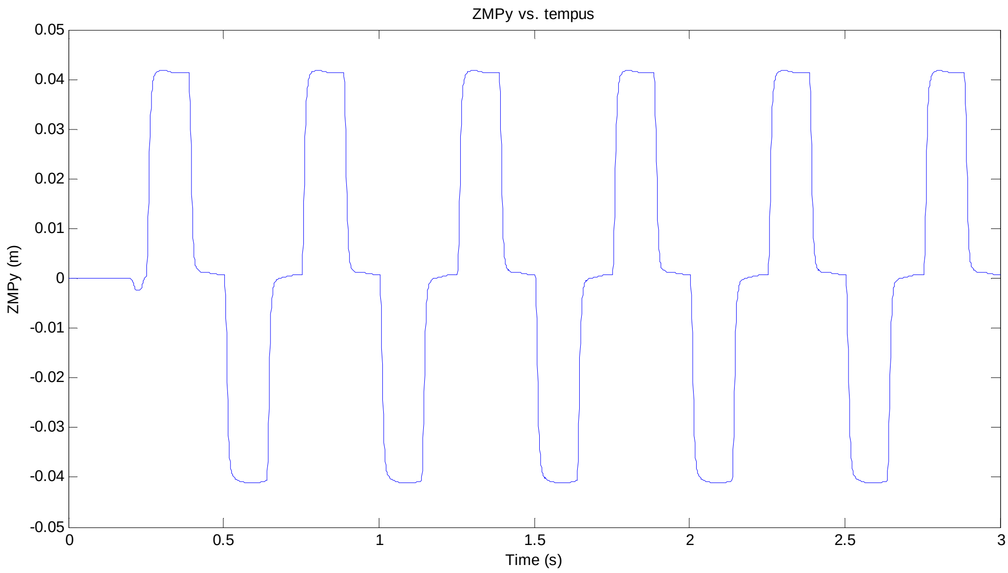


Fig.7. ZMP y trajectory

❖ CONCLUSION

This paper will deal with the modeling and simulation of the autonomous motion of KONDO KHR-1HV humanoid robots. A scheme of a 19-DOF biped locomotion mechanism of the anthropomorphic structure is used. The simulation results in the Matlab/Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method.

❖ ACKNOWLEDGEMENT

The results in the paper are partially supported by the TÁMOP-4.2.2/08/1/2008-0008 program of the Hungarian National Development Agency. Part of this paper is published in the International Symposium on Advanced Engineering & Applied Management 40th Anniversary in Higher Education, Hunedoara, Romania, 4-5 November, 2010. Gyula Mester is with the Department of Informatics, Robotics Laboratory, University of Szeged, Hungary

❖ REFERENCES

[1.] Vukobratović M. et al., Biped Locomotion-Dynamics, Stability, Control and Application, Springer Verlag, Berlin, Germany, 1990.

[2.] S. Kajita, K. Tani, Experimental study of biped dynamic walking in the linear inverted pendulum mode. Proceedings of the IEEE International Conference on Robotics and Automation, pp. 2885-289,1Nagoya, Japan, 1995.

[3.] J. H. Park, K. D. Kim (1998) Biped robot walking using gravity-compensated inverted pendulum mode and computed torque control. Proceedings of the IEEE International Conference on Robotics and Automation, Leuven, Belgium, 1998.
[4.] T. Furuta et al., Design and construction of a series of compact humanoid robots and development of biped walk control strategies. Robotics and Autonomous Systems, pp. 81-100, 2001.
[5.] A.Rodić, D.Katić, M.Vukobratović," The Connectionist Compensator for Advanced Integrated Road Vehicle Controller", International Journal Engineering & Automation Problems, vol..2, no.1, pp.27-39, 2001.
[6.] A.Rodić, D.Katić, M.Vukobratović,"The Connectionist Compensator for Advanced Integrated Vehicle", Proceedings of the IEEE International Conference on Control Applications, Mexico City, Mexico, September 2001.
[7.] A.Rodić, D.Katić, M.Vukobratović, "The Neural Compensator for Advanced Vehicle Controller", Proceedings of the 6. Workshop Application of Neural Networks in Electrotehnics - NEUREL'02, Belgrade, Yugoslavia, September 2002.
[8.] D.Katić, A.Rodić, "Neural Control Techniques For Humanoid Robots", Proceedings of the 47. ETRAN Conference, Herceg-Novi , Serbia & Montenegro , June 2003, vol. 4, pp..386-389.
[9.] A.Rodić, M. Vukobratović, M. Filipović, D. Katić, " Modellling and Simulation of Locomotion Mechnanisms of Antropomorphic Structure Using Contemporary software tools", ", Proceedings of the 47. ETRAN Conference, Herceg-Novi, Serbia & Montenegro, June 2003, Vol.4, pp.347-350.
[10.] A.Rodić, D.Katić, M.Vukobratović," The Advanced Vehicle Control Algorithm Using Neural Networks", Proceedings of the European Control Conference ECC 2003., Cambridge,UK, September 2003.
[11.] J. H. Park, Fuzzy-Logic Zero-Moment-Point Trajectory Generation for Reduced Trunk Motions of Biped Robots. Fuzzy Sets and Systems 134, pp. 189-203, 2003.
[12.] Vukobratović M., Rodić A.: Contribution to the Integrated Control of Artifical Human Gait. Proceedings of the SISY 2004, Symposium on Intelligent Systems, Subotica, Serbia, pp. 59-70, 2004.
[13.] Vukobratović M, Potkonjak V, Rodić A (2004) Contribution to the Dynamic Study of Humanoid Robots Interacting with Dynamic Environment. Robotica. Vol. 22, pp. 439-447
[14.] M.Filipović, A.Rodić, D.Katić, " An Analysis of Movement of Elastic Robotic System under the influence of environment dynamics", Proceedings of 29. HIPNEF 2004, Vranjačka Banja, Serbia & Montenegro, May 2004.pp.385-390.
[15.] M.Filipović, D.Katić, A.Rodić, " An Analysis of Movement of the Flexible Robotic System in Horizontal Plane", Proceedings of the 7th DQM-2002 Dependability and Quality Management, Belgrade, Serbia & Montenegro, June 2004.
[16.] M. Vukobratovic, V. Potkonjak, A. Rodic, "Contribution to the Dynamic Study of Humanoid Robots Interacting with Dynamic Environment", Robotica, CAMBRIDGE university press, United Kingdom, Vol. 22, pp. 439-447, 2004
[17.] A. Rodić, D. Katić, "Intelligent Control of Road Vehicles by Implementation of Artificial neural Networks", Technics-Mechanic Engineering, No. 5/04, pp. 1-12, in Serbian, 2004
[18.] M. Filipović, A. Rodić, D. Katić, "Motion Analysis of Elastic Robotic Systems Under Influence of Dynamic Environment", Proceedings of 29th szmposium HIPNEF 2004, pp.385-390, Vrnjačka Banja, Serbia, May, 2004
[19.] M. Filipović, D. Katić, A. Rodić, " Motion Analysis of Elastic Robotic Systems in Horizontal plane", Proceedings of the 7th DQM-2004 Dependability and Quality Management, Belgrade, Serbia & Montenegro, June, 2004
[20.] M. Vukobratović, A. Rodić, "Contribution to the Integrated Control of Artificial Human Gait", Proceedings of 2nd Serbian-Hungarian Joint Symposium on Intelligent Systems, SISY 2004, pp. 59-70, Subotica, Serbia & Montenegro, 2004
[21.] Metta G, Sandini G, et. all (2005) The RobotCub Project – an open framework for research in embodied cognition. Proc. of the 2005 IEEE-RAS Int. Conf. On Humanoid Robots
[22.] K. Addi, D. Goeleven, A. Rodic, "Nonsmooth Mathematical Modelling and Numerical Simulation of a Spatial Vehicle Dynamics", *Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM)*, Wiley-VCH Verlag GmbH & Co. KGaA - Weinheim, DOI 10.1002/zamm.200410235, pp. 1-25 (2005)
[23.] A. Rodić, D. Katić, M. Filipović, "Control of Dynamic Balance and Trunk Posture of Humanoid Robots in Service Tasks", in Proceedings of 49th Conference on ETRAN, Vol. IV, pp. 347-350, Serbia & Montenegro, Budva, 2005
[24.] Rodić A, Vukobratović M (2006) Control of Dynamic Balance of Biped Locomotion Mechanisms in Service Tasks Requiring Appropriate Trunk Postures. Engineering & Automation Problems. ISSN 0234-6206, Vol. 5, No. 1, pp. 4-22.
[25.] D. Katić, A. Rodić, "Control Algorithm for Humanoid Robots Walking Based on Learning Structures", in Proceedings of 49th Conference on ETRAN, Vol. IV, pp. 355-358, Serbia & Montenegro, Budva, 2005
[26.] A. Rodić, M. Vukobratović, "Intelligent Integrated Control of Vehicle Stability Characteristics", in Proceedings of EAEC2005 European Automotive Congress, Serbia & Montenegro, Belgrade, June, 2005
[27.] A. Rodić, E. Schnieder, "Hybrid Model-Based – Knowledge-Based Control of Driver-Vehicle System Performances", in Proceedings of EAEC2005 European Automotive Congress, Serbia & Montenegro, Belgrade, 2005
[28.] A. Rodić, "User Oriented Software Toolbox for Advance Modeling, Control Synthesis and Simulation of Automotive Systems", in Proceedings of EAEC2005 European Automotive Congress, Serbia & Montenegro, Belgrade, June, 2005
[29.] A. Rodić, K. Addi, G. Dalleau, "Contribution to the Mathematical Modeling of Multi-point, Non-smooth Impact/Contact Dynamics of Human Gait", in Programe resume of the 6th International Conference AIMS 2006 "Dynamic Systems, Differential equations and Applications", pp. 101-102, University Poitiers, Poitiers, France, 2006
[30.] K. Addi, G. Dalleau, A. Rodic, "Linear Complementarity Problem Formulation Used for Modeling of Impact/Contact Dynamics of Byped Locomotion Mechanisms", in Proceedings of ETRAN 2006, Belgrade, Serbia, 2006
[31.] A. Rodic, M. Vukobratovic "Multi-feedback Dynamic Control of Byped Robots", in Proceedings of ETRAN 2006, Belgrade, Serbia, June, 2006
[32.] Katić D, Rodić A, Vukobratović M (2007) Reinforcement Learning Control Algorithm for Humanoid Robot Walking. International Journal of Information & Systems Sciences. Vol.4, No.2, pp.256-267
[33.] Vukobratović M, Rodić A (2007) Contribution to the Integrated Control of Biped Locomotion Mechanisms. International Journal of Humanoid Robotics. World Scientific Publishing Company. New Jersey, London, Singapore. Vol. 4, No. 1, pp. 49-95
[34.] Gyula Mester: „ Bipedal Walking in Robots", Proceedings of the IV. Európai kihivások nemzetközi konferencia, pp. 703-707, Szeged, Hungary, 2007.

[35.] A. Rodić, "Towards Sustainable Transport and Active Traffic Safety – Synthesis of Hazard Prevention Control System based on Modeling of Cognitive Driver Behavior", UNESCO Program – Education for All by 2015, 11th Education and Training Workshop, Belgrade, Serbia, 22th – 28th October, 2007
[36.] Gyula Mester, „Lépegető humanoid robotok mozgástervezése", MTA, VMTT konferencia kiadvány, pp.267-273, Novi Sad, Serbia, 2007.
[37.] Gyula Mester, „Dynamic Modeling for a Walking Robot", Proceedings of the SIP 2008, 26th International Conference SCIENCE IN PRACTICE, pp.87-89, ISBN 978-953-6032-52-4, Osijek, Croatia, 2008.
[38.] Mester Gyula, „Kétlábon járó robot modellezése", Informatika a felsőoktatásban 2008, konferencia kiadvány, pp. 1-8, ISBN 978-963-473-129-0, Debrecen, 2008.
[39.] Gyula Mester, „Simulation of Humanoid Robot Motion", Proceedings of The KANDÓ CONFERENCE, pp. 1-8, ISBN 978-963-7154-74-4, Budapest, 2008.
[40.] Rodić A, Vukobratović M, Addi K, Dalleau G (2008) Contribution to the Modeling of Non-smooth, Multi-point Contact Dynamics of Biped Locomotion – Theory and Experiments., Robotica. CAMBRIDGE Univ. Press. Vol. 26, Issue, 02, pp. 157-175
[41.] Katić D, Rodić A, Vukobratović M (2008) Hybrid Dynamic Control Algorithm For Humanoid Robots Based On Reinforcement Learning. Springer Journal of Intelligent and Robotic Systems. No.1, pp.3-30
[42.] D. Katić, A. Rodić, "Intelligent Autonomous Locomotion of Humanoid Robots through Perception, Learning and Spatial Reasoning", in Proceedings of the ETRAN 2008, Subotica, Serbia, June, 2008
[43.] A. Rodić, V. Potkonjak, "Towards Advanced Personal Robot Platform – Concept of Intelligent Service Robot of High Performances", in Proceedings of the ETRAN 2008, Subotica, Serbia, June, 2008
[44.] A. Rodić, D. Katić, "Trajectory Prediction and Path Planning of Autonomous Biped Robots – Learning Locomotion and Fuzzy Reasoning", in Proceedings of the 9th Symposium on Netwotk Applications in Electrical Engineering, Electrotechnic Faculty, Belgrade, Serbia, September, 25-27, 2008
[45.] D.Katić, A.Rodić, "Dynamic Control Algorithm for Biped Walking Based on Policy Gradient Fuzzy Reinforcement Learning", in Prioceedings of the 17th IFAC World Congress, Seoul, Republic of Corea, July 2008.
[46.] D. Katić, A. Rodić, "Intelligent Autonomous Locomotion of Humanoid Robots through Perception, Learning and Spatial Reasoning", in Proceedings of the ETRAN 2008, Subotica, Serbia, June, 2008
[47.] D.Katic, A.Rodic, M.Vukobratovic," Reinforcement Learning Control Algorithm for Humanoid Robot Walking", International Journal of Information & Systems Sciences, Vol.4, No.2, pp.256-267, 2008.
[48.] Gyula Mester, Aleksandar Rodic, "Autonomous Locomotion of Humanoid Robots in Presence of Mobile and Immobile Obstacles", Studies in Computational Intelligence, Towards Intelligent Engineering and Information Technology, pp. 279-293, ISBN 978-1-642-03736-8, Library of Congress: 2009933683, DOI 10.1007/978-3-642-03737-5-_20, Springer, 2009.

ANNALS OF FACULTY ENGINEERING HUNEDOARA
– INTERNATIONAL JOURNAL OF ENGINEERING

Faculty of Engineering Hunedoara,
5, Revolutiei, 331128, Hunedoara,
ROMANIA
http://annals.fih.upt.ro