International Journal of Engineering & Technology, 7 (2.28) (2018) 134-137

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The walking robots critical position of the kinematics or dynamic systems applied on the environment model

Marcel Migdalovici[1] , L. Vladareanu[1]*, Hongnian Yu[2,3], N. Pop[1], M. Iliescu[1], V. Vladareanu[1], D. Baran[4], G. Vladeanu[1]

[1]*Romanian Academy, Institute of Solid Mechanics of the Romanian Academy, Bucharest, RO*
[2]*School of Computer Science and Network Security, Dongguan University of Technology, Dongguan 523808, China*
[3] *Faculty of Science and Technology, Bournemouth University, Poole BH125BB, UK*
[4]*National Institute of Aerospace Research "Elie Carafoli", Bucharest, RO*
**Corresponding author E-mail: luige.vladareanu@vipro.edu.ro , office@vtc.ro*

Abstract

The exposure is dedicated in the first to mathematical modeling of the environment where the aspects on the walking robots evolution models are described. The environment's mathematical model is defined through the models of kinematics or dynamic systems in the general case of systems that depend on parameters. The important property of the dynamic system evolution models that approach the phenomenon from the environment is property of separation between stable and unstable regions from the free parameters domain of the system. Some mathematical conditions that imply the separation of stable regions from the free parameters domain of the system are formulated. In the second part is described our idea on walking robot kinematics and dynamic models with aspects exemplified on walking robot leg. An inverse method for identification of possible critical positions of the walking robot leg is established.

Keywords: *environment's model, walking robot, kinematics/dynamic model, stability regions*

1. Introduction

The first part of the exposure is referred to mathematical modeling of the environment where the walking robots evolution models are assumed. The models of kinematics or dynamic system in the general case of systems that depend on parameters assure, by its properties, the mathematical characterization of the environment. Any system is expressed in terms of relevant parameters as geometrical parameters, physical parameters (in particular mechanical parameters), possible chemical, biological, economical, etc, [1-6, 10-12].

The important property of the dynamic system evolution models that approach the phenomenon from the environment is property of separation between stable and unstable regions from the free parameters domain of the system. This property is proposed that define the environment's mathematical model.

The mathematical conditions on the linear dynamic system matrix components that assure the separation between stable and unstable regions from the free parameters domain of the system are formulated [7-9].

In the second part of the exposure is described our walking robot evolution kinematics model and corresponding dynamic model with application on particular case of walking robot leg.

An inverse method for identification of possible critical positions of the walking robot is established. The link between mathematical model of the dynamic system walking robot and corresponding kinematics system mathematical model is emphasized [1-3, 13-16].

The problem analyzed by kinematics walking robot model that can be analyzed as problem in dynamic walking robot model having similar results, is also underlined.

2. On the environment's mathematical model

The mathematical property that one can remark on all dynamic systems models from the literature, which approaches the environment phenomena, is separation property between stable and unstable regions on the free parameters domain [2, 3, 9]. We have formulated, for the first time, the sufficient conditions needed on the functions that defined the dynamic system, which assure the separation between stable and unstable regions on the free parameters domain [9].

In the following we mention the extended our conditions on the matrix of functions that defines the autonomous linear dynamic system or "first approximation" of nonlinear dynamic system that allow the separation of the stable regions on the parameters domain.

Theorem on separation:

If the autonomous linear dynamic system defined by the matrix A, has the continuous on piecewise components of the matrix as functions on dynamic system free parameters and is assured that the eigenvalue functions of the matrix A are also continuous on piecewise, then these conditions allow the separation between stable and unstable regions of the dynamic system in the parameters domain [17-20].

Remark:

For the kinematics models of systems that depend on parameters, the property of separation is formulated on existence and inexistence regions in the domain on free parameters. This case is analyzed through our application on walking robot leg model.

3. Physical and mathematical models of the walking robot leg

In the following we firstly describe our physical and mathematical model on the kinematics of walking robot leg, with physical model of the robot leg defined by a "pivot point" attached to the robot body and two components and jointed in point denoted "knee joint" of the leg and the point , denoted "base point" of the leg, which are moved in vertical plane (Fig. 1).

The point P, in the case of fixed pivot point, describes a circle arc route in a cycled evolution of the robot leg and the base point Q is assumed that describes a close route compounded from the superior ellipse arc Q_BQ_A with semi axes length a, b and with point O_E centre of the ellipse, and closure of the leg evolution cycle by horizontal segment Q_AQ_B traversed by the base point Q.

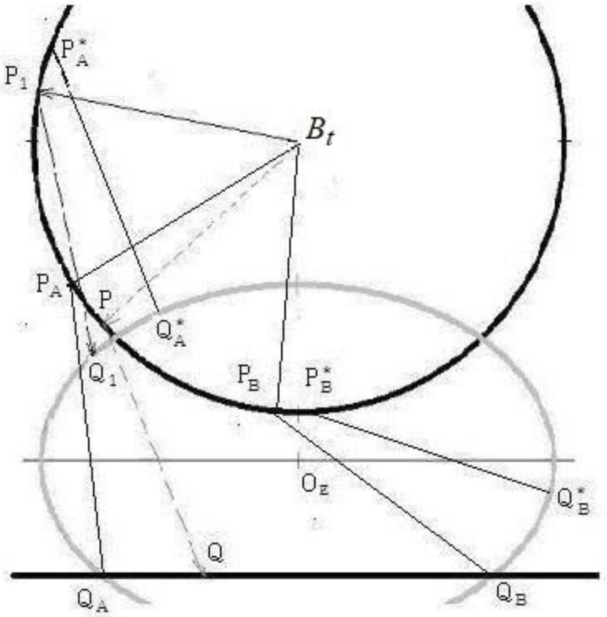

Fig.1. Physical model of the walking robot leg

The orthogonal system of coordinates and parameters signification are identified from the coordinates on the figure points: $B_t(a,h)$, $O_E(a,b_1)$, $P(x_P,y_P)$, $Q(x_Q,y_Q)$, $Q_A(x_A,0)$, , $Q_B(x_B,0)$.

The points P_A^* and P_B^* define the extremities of the maximal domain on circle arc where the knee joint P is moving because in these points, geometrical identified by the property that the segments $P_A^*Q_A^*$ and $P_B^*Q_B^*$ are normally on the ellipse arc, the direction of movement is changed.

The positions P_A^* and P_B^* of the knee joint, identified by us on the particular case of figure 1, are named by us the critical points from the leg evolution.

In other cases of robot leg with fixed pivot point, defined by the values of the geometrical parameters or in cases where the pivot point is moved in the walking robot evolution, is important to search the possible existence of the knee joint critical positions where the direction of movement is changed and where the speed of the knee joint must to be zero for the continuous evolution of the knee joint [8].

$$(x-a)^2+(y_P-h)^2-a^2=0.\;;\;(x-a)^2/a^2+(y_Q-b_1)^2/b^2=1. \quad \textbf{(1)}$$

The mathematical model deduced from the physical model, suggested by the particular case represented in figure 1, is defined through two formulas described by the equations (1).

Between the parameters' values, are assumed condtions $a>b>b_1>0;\ 2a>h$ where a and b are semi axes of the ellipse.

Explicit functions generated by (1) are presented in equations (2).

$$y_P=h\mp(2ax-x^2)^{1/2}\;;\;y_Q=\pm\, b/a\;(2ax-x^2)^{1/2}+b_1 \quad \textbf{(2)}$$

Let $P(x_P,y_P)$ and $Q(x_Q,y_Q)$ be points on the circle arc respectively on the ellipse arc for one leg position from the evolution. The condition on the distance PQ, namely the relation $(x_P-x_Q)^2+(y_P-y_Q)^2-a^2=0.$ is imposed. The uniform linear evolution of the variable x between 0 and $2a$, excepting a neighbourhood around possible critical points, in the case of fixed pivot point of the leg, is assumed as below, where the constant speed v_0 and initial condition x_0 are selected in equation (3).

$$x(t) = v_0\ t + x_0 \quad (3)$$

One cycle for the robot leg evolution can start from the position of base point Q_B, traversing the superior ellipse arc up to the point Q_A, using the evolution law (3), and returns by the linear uniform displacement on the horizontal axle, in the point Q_B, excepting a selected neighbourhood around each position $Q_A^*,\ Q_B^*$, where is defined a proper evolution.

The mathematical model of the walking robot leg, near of the critical point P_A^*, which have abscise denoted x_{PA*}, using physical model from the figure 1 and abscise $x \in (\ x_{PA*},\ 2a/3)$, where x is assumed decreasing convergent to abscise x_{PA*}, is analyzed in equation (4).

$$y_P = h + (2ax - x^2)^{1/2}\ ;\ y_Q = b/a\ (2ax - x^2)^{1/2} + b_1\ ; \quad x(t) = -v_0\ t + 2a/3 \quad (4)$$

The value of abscise $x(t)$, in our hypothesis, respect the condition $x_{PA*} < x(t)$ that implies $x_{PA*} < -v_0 t + 2a/3$ such that $v_0\ t\ <\ 2a/3 - x_{PA*}$. The corresponding expression of $y_P(t)$ is $y_P(t) = h + (2a\ x(t) - (x(t))^2)^{1/2}$. The value of time parameter, in assumption that $x(t)$ is decreasing convergent to abscise x_{PA*}, for which is verified the equation $\mathrm{d}(y_P(t))/\mathrm{d}t = 0$, using admissible value of parameter v_0, is of interest for us because identifies critical position of knee joint P, if it exists.

We remark that the domain of parameters' values $x,\ y_P,\ y_Q,\ h,\ b_1,\ v_0,\ x_0,\ t$ with fixed values of positive parameters $a,\ b,\ b_1$, in this analyzed case, for which described evolution exists, is an interval for one free parameter. The domain of existence coincides, in these formulated cases, with the domain of stability, such that we can affirm that there is a separation between stable (existence) and unstable (inexistence) regions of the free parameters values of the robot leg model. We can intuitively conclude that the analysis is true and for robot leg with uniform distributed mass on the leg.

The following judgment on kinematics and dynamic model of walking robot leg, describe its link. The dynamic model is assumed that consists from two pipes of mass decreasing convergent to zero. The contribution of mass for leg dynamic model is negligible in the case of mass sufficient close of zero. We can affirm that the kinematics model of leg is a particular case of dynamic model. Evolution of the leg dynamic model can be described using also our study on Bernoulli – Euler beam model. The problem that arises in kinematics walking robot model can be transferred as problem in dynamic walking robot model with similar solution. The problem of critical positions is an example.

4. Conclusion

The property of separation in the free parameters domain on the dynamic systems that approach the phenomena on the environment permits us to characterize the environment mathematical model. This notion includes dynamic and kinematics models. The link between dynamic and kinematics walking robot model applied on walking robot leg model is not exhausted our analysis but a promising way of research is opened.

Acknowledgement

This work was partially supported by European Commission Marie Skłodowska-Curie SMOOTH project (H2020-MSCA-RISE-2016-734875/2016-2020, Romanian Academy and "Joint Laboratory of Intelligent Rehabilitation Robot" collaborative research agreement between Institute of Solid Mechanics of the Romanian Academy by IMSAR, RO and Yanshan University, CN, project KY201501009/2016.

References

[1] Hirsch M W, Smale S, Devaney R L. Differential equations, dynamical systems, and an introduction to chaos, Academic Press, 2004

[2] Halanay A, Rasvan V. Applications of Liapunov methods in stability, Kluwer Academic Publishers, 1993, http://dx.doi.org/101007/978-94-011-1600-8

[3] Teodorescu P P, Stanescu N D, Pandrea N. Numerical analysis with applications in mechanics and engineering, John Wiley & Sons, Hoboken, USA, 2013, doi: 10.102/9781118614563

[4] Migdalovici M, Baran D. On a stability analysis method of dynamical systems with numerical tests, Proceedings of the Int. Conf. of Diff. Geom. and Dynamical Systems (DGDS-2008), Geometry Balkan Press, 2009, 99–107

[5] Vladareanu L, Tont G, Ion I, Munteanu M S, Mitroi D. Walking robots dynamic control systems on an uneven terrain, Advances in Electrical and Computer Engineering, 10, 2, 2010, 146–153

[6] Vladareanu V, Tont G, Vladareanu L, Smarandache F. The navigation of mobile robots in non-stationary and non-structured environments, Int. J. Advanced Mechatronic Sys., 5, 4, 2013, 232–243

[7] Pop N, Vladareanu L, Popescu I.N, Ghita C, Gal A, Cang S, Yu H, Bratu V, Deng M. A numerical dynamic behaviour model for 3D contact problems with friction, Computational Materials Science, 94, 2014, 285–291

[8] Migdalovici M, Vladareanu L, Baran D, Vladeanu G. Radulescu M. Stability Analysis of Walking Robot Motion, ICCMIT 2015, Elsevier: doi:10.1016/j.procs.2015.09.117

[9] Migdalovici M, Baran D, Vladeanu G. Stability control of linear and nonlinear dynamic systems, International Journal of Acoustics and Vibration, 21, 4, 2016, 440–444

[10] Luige Vladareanu, Octavian Melinte, Adrian Bruja, Shuang Cang , Hongnian Yu, Hongbo Wang, Xiaojie Wang, Zeng-Guang Hou, Xiao-Liang Xie, Haptic interfaces for the rescue walking robots motion in the disaster áreas, 2014 UKACC International Conference on Control (CONTROL 2014), Loughborough, U.K., 9-11 July 2014, pg. 498 - 503, IEEE, doi: 10.1109/CONTROL. 2014.6915189, ISBN 978-1-4799-2518-6

[11] N Pop, L Vladareanu, IN Popescu, C Ghiță, A Gal, S Cang, H Yu, V Bratu,M Deng, A numerical dynamic behaviour model for 3D contact problems with friction, Computational Materials Science 94, 2014, 285-291

[12] Luige Vladareanu, Daniel Mitroi, Radu Ioan Munteanu, Shuang Chang, Hongnian Yu, Hongbo Wang, Victor Vladareanu, Radu Adrian Munteanu. Hou z.g., Octavian Melinte, Radu Adrian Munteanu , Zeng-Guang Hou , Xiaojie Wang , Guibin Bia , Yongfei Feng and Eugen Albu, Improved Performance of Haptic Robot Through the VIPRO Platform, Acta Electrotehnica, vol. 57, 2016, ISSN 2344-5637.

[13] Pop N., Cioban H., Horvat-Marc A., Finite element method used in contact problems with dry friction, Computational Materials Science, Volume: 50, Issue: 4, 1283-1285, ISSN: 0927-0256 , (2011)

[14] Yongfei Feng, Hongbo Wang, Tingting Lu, Victor Vladareanu, Qi Li and Chaosheng Zhao. Teaching Training Method of a Lower Limb Rehabilitation Robot. Int J Adv Robot Syst, 2016,

[15] N. POP, An algorithm for solving nonsmooth variational inequalities arising in frictional quasistatic contact problems, Carpathian Journal of Mathematics, Vol. 24, No. 2, 110-119, ISSN:1584-2851, (2008)

[16] Vladareanu, V., Schiopu, P., & Deng, M. (2013, September). Robots extension control using fuzzy smoothing. In Advanced Mechatronic Systems (ICAMechS), 2013 International Conference on (pp. 511-516). IEEE.

[17] Ionel Alexandru Gal, Vladareanu L, Hongnian Yu, Hongbo Wang, Mingcong Deng, „Advanced intelligent walking robot control through sliding motion control and bond graphs methods", Advanced Mechatronic Systems (ICAMechS), 2015 International Conference on, 22-24 Aug. 2015, Beijing, China,, pg. 36 – 41, DOI: 10.1109/ICAMechS.2015.7287125, INSPEC Accession Number: 15489961, Publisher: IEEE.

[18] Ionel Alexandru Gal, Luige Vladareanu, Radu I Munteanu, Sliding Motion Control With Bond Graph Modeling Applied on a Robot Leg, Revue Roumaine Des Sciences Techniques-Serie Electrotechnique Et Energetique, Vol 60, Nr.2, pp 215-224, Ed. Romanian Academy, 2015, ISSN: 0035-4066.

[19] Victor Vladareanua, Radu I. Munteanub, Ali Mumtazc, Florentin Smarandachedand Luige Vladareanua *, "The optimization of intelligent control interfaces using Versatile Intelligent Portable Robot Platform", Procedia Computer Science 65 (2015): 225 – 232, ELSEVIER, www.sciencedirect.com, doi:10.1016 /j.procs.2015.09.115.

[20] Melinte Octavian, Luige Vladareanu, Radu A. Munteanu, and Hongnian Yu. "Haptic Interfaces for Compensating Dynamics of Rescue Walking Robots", Procedia Computer Science 65 (2015): 218-224. ELSEVIER, www.sciencedirect.com, doi:10.1016/j.procs.2015.09.11