# Virtual LabVIEW$^{TM}$ Instrumentation for Simulation and Optimisation of the Robot Dynamic Behavior

Olaru Adrian
Machine and Manufacturing System Department
University Politehnica of Bucharest, Bucharest, Romania
Email: aolaru_51@ymail.com

Olaru Serban
Mechatronics Service Department, ROMSYS Company
Bucharest, Romania
Email: serban1978@gmail.com

***Abstract*—In the assisted researching of the dynamic behavior of industrial robots an important role plays modeling, simulation and optimization with virtual LabVIEW$^{TM}$ instrumentation. Virtual instrumentation easy provides comparison of theoretical and experimental results and the conditions to adjust and validate the mathematical models. The paper shows numerous virtual instruments and some case study to optimize the vibration and the motion of robots end-effecter by using the smart damper system and the assisted simulation and animation after solving the inverse kinematics.**

***Index Terms*—virtual instrumentation, modelling, simulation, inverse kinematics, dynamic behavior, animation**

## I. Introduction to Virtual Instrumentation

The transfer functions theory applied to the elements and the systems using the LabVIEW$^{TM}$ non linear components assure one very easily mode of the modeling, simulation and validation of the elements and systems, finally to obtain by sinthesys one integrated and intelligent system. In the paper will be presented one virtual LabVIEW propre library for the assisted research of the electrical and hydralic elements and systems with many results what will be possible to use in the curently research. In the optimising field was used some neural network and the on-line research of the network influences to the finally target of the servo driving system. With applied these virtual instrumentation together with other to solve with maximal precision the inverse kinematics was possible to design one proper smart system to decrease the vibration of the robot end-effector and optimise of the space trajectory. With designed LabVIEW$^{TM}$ *VI*-s will be possible to choose the optimal values of the constructive- functional parameters of the components of the system to obtain the required answer.

Recently, countries like Japan are facing a declining younger population and trying to attract students to science and engineering education to further technological advancement. In an effort to revitalize Japan's scientific research community, the government has allocated more funds to improve engineering education and research, as well as created more advanced degree programs [1], [2].

For more than a decade, educators have been exploring innovative ways to improve engineering education around the world. Engineering education has to adapt to the challenges of the future, particularly with respects to innovative new technologies, educational programs that integrate disciplines and engage students in the excitement of learning and ignite their passion for positive societal impact and develop leaders for the future. Although a number of systems and solutions have been developed over the past decade, new techniques and technologies are required for today’s students to practice key fundamental engineering concepts such as using computer based measurement and automation systems [3].

One of the key fundamental approaches to facilitate these requirements is Virtual Instrumentation (VI), which is the use of customizable software and modular hardware to create user- defined measurement systems. Over the past decade, a number of virtual instrumentation techniques and solutions have been reported based on specific applications or target audiences [4]-[11]. This paper addresses the impact of virtual instrumentation as an approach to multiple engineering disciplines through case studies for teaching and research using a numerical evaluation method.

## II. Dynamic Behavior of the Robot

The most important thing of one robot application in a manufacturing system is the dynamic behavior of the robot and what are the resonance frequencies determined by the acceleration time, compare with the frequency

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Fourier spectrum of the manufacturing system. The paper presents some proper virtual LabVIEW™ instruments (VI) for the assisted of the theoretical and experimental research of the industrial robots with DC motors. The virtual instruments were achieved in the LabVIEW™ soft 8.2 from National Instruments, USA. The *VI*-s simulates the open and closed loop of the DC servo systems, and the data acquisition of the Fourier spectrum of the acceleration, the acquisition of the velocity with the final goal to compare the simulate with the real results [12]-[25]. These methods will be possible to be used in the assisted research of the many other mechanical applications where it is necessary to know the dynamic behavior, the vibration spectrum and how the constructive and functional parameters of the DC servo systems and the movements cases (the equilibrium of the robot's arm and the up or down movements) determine the major changes of the spectrum and of the dynamic behavior. Now, in the world, all the dynamic determination of the dynamic behavior, of the vibration spectrum has made with some complex apparatus with the expensive cost not like were proposed in this research.

The proper mathematical matrix model of the dynamic behavior in the movement time it is presented below [19].

$$\begin{pmatrix} F^0 \\ M^0 \end{pmatrix} = \begin{bmatrix} z_u & 0 \\ 0 & z_u \end{bmatrix} \begin{pmatrix} D_{0,i}F_R^i \\ D_{0,i}M_R^i \end{pmatrix} - diag\begin{bmatrix} sign\frac{v_u^i}{|v_u^i|}m_{u_i} & sign\frac{\omega_u^i}{|\omega_u^i|}J_{g_i} \end{bmatrix} \cdot \begin{pmatrix} (a_{i,0}^i)+[\hat{\omega}_{i,0}^i]^2(r_{g_i}^i) \\ (\varepsilon_{i,i-1}^i)+[\omega_{i-1,0}^i](\omega_{i,i-1}^i) \end{pmatrix} +$$

$$+\begin{bmatrix} z_u & 0 \\ 0 & z_u \end{bmatrix} \cdot \begin{pmatrix} (0) \\ [G_{i,k}](\hat{b}_{i,k})\left((D_{0,i}F_R^i) - diag\begin{bmatrix} sign\frac{v_u^i}{|v_u^i|}m_{u_i} \end{bmatrix} \cdot [D_{0,i}]((a_{i,0}^i)+[\hat{\omega}_{i,0}^i]^2(r_{g_i}^i))\right) \end{pmatrix},$$

$$(M^0) = [k_{m_i}](i_{a_i})$$

$$(U_i)-(e_i) = [R_{a_i}](i_{a_i}) + [L_{a_i}]\left(\frac{di_{a_i}}{dt}\right) \tag{1}$$

where: $\boldsymbol{F^0}$ is the active forces matrix in a Cartesian fixed system; $\boldsymbol{M^0}$- the active moment matrix in a Cartesian fixed system; $\boldsymbol{z_u}$- joint-bodies matrix; $\boldsymbol{D_{i-1}}^{i}$- transfer matrix between *i*-1 and *i* body; $\boldsymbol{F_R}$- resistant forces matrix; $\boldsymbol{M_R}$ – resistant moments matrix; $\boldsymbol{m_i}$- mass matrix of bodies; $\boldsymbol{J_{gi}}^{0}$- inertial tensor matrix of bodies; $\boldsymbol{a_{i,o}}^{i}$- absolute dual acceleration matrix in a *i* body Cartesian system; $\boldsymbol{\omega^{\wedge}_{i,0}}^{i}$- non symmetric absolute angular velocity matrix in a *i* body Cartesian system; $\boldsymbol{\varepsilon_{i,i-1}}^{i}$- angular relative acceleration matrix in a *i* body Cartesian system; $\boldsymbol{\omega_{i,i-1}}^{i}$- angular relative velocity in a *i* body Cartesian system; $\boldsymbol{B}^{\wedge}$- modified arm type matrix; $\boldsymbol{k_{mi}}$ – matrix of gradient moment- intensity of the DC motors; $\boldsymbol{i_{ai}}$- matrix of the current intensity of all DC motors; $\boldsymbol{U_i}$ – matrix of electrical tensions; $\boldsymbol{e_i}$ – matrix of DC intern tensions; $\boldsymbol{R_{ai}}$- matrix of rotor DC resistance; $\boldsymbol{L_{ai}}$ **–** matrix of the DC inductances.

In order to search and validate the mathematical model, in the laboratory of the Dynamic Behavior of the Industrial Robots of the faculty I.M.S.T.-U.P.B., there was designed and realized an arm type robot, with five degrees of freedom. In a research stand it can be distinguished the following elements: didactical arm type robot with DC servomotors and velocity transducers; stabilized source of continuous voltage; robot command amplifier; personal computer; power source; function generator of the type POF-1 from KABID Poland; amplifier for the generator of the type LV 102 from MMF Germany; two accelerometers of the type 601A01, SN 30710 from IMI USA; electronic amplifier for the accelerometers; the electromagnetic exciter of the type 11075 from RFT Germany; connector of the type CB- 68 LP from National Instruments USA; acquisition board of the type PCI 6224M from National Instruments USA and virtual proper LabVIEW™ instrumentation.

This paper tries to develop one general assisted methodology of the dynamic behavior in the real time and frequency domain of the articulated arm type robot. In the paper were solved the following problems: the theoretical and the experimental assisted research with data acquisition by using the proper theoretical and experimental LabVIEW *VI*; the optimization of the dynamic behavior with the virtual proper *VI*-s; the choice of the optimal DC and closed loop parameters to obtain one better dynamic results. The actual research in the world does not approach the assisted virtual instrumentation for the optimization of the dynamic behavior.

## III. Virtual LabVIEW™ Instrumentation

### A. Virtual Instrumentation for the Theoretical Research

The icons of the *VI*-s for the assisted research of the servo motor (DC) are shown in Fig. 1 and Fig. 2, and comparative simulation in Fig. 3 [20], [22], [25].

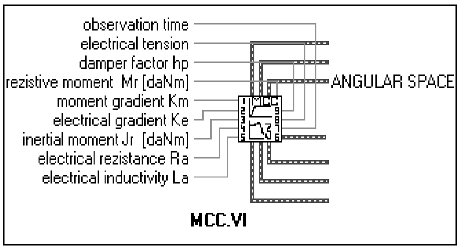


Figure 1. The icon of the *VI* for the assisted research of the DC motor

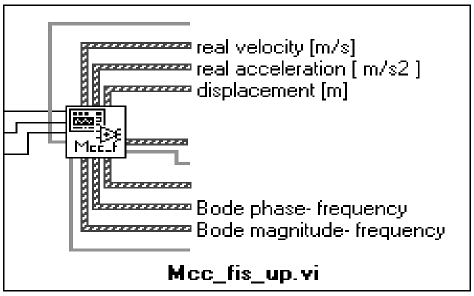


Figure 2. The icon of the DC motor *VI* for the comparative research

The *VI* for the assisted comparative analyzes use the input data from file, where was changed one parameter. The *VI*-S work on-line with the possibility to input some others rows of the input data file. The characteristics which were analyzed are the same. With this facility is possible to see, in a comparative way, what are some functional or constructive parameters of the DC motors or of the DC servo systems, and how changes the real and frequency characteristics and finally is possible to choose the optimum value of them to obtain the desired output for one typically robot application, when is necessary, for example, good precision, or good stability, or a good following capacity.

By changing some of the constructive or functional parameters of the DC motors we were obtained some results of the assisted comparative analyze, what is shown in the Fig. 3. The increases of the DC rotor resistance $R_a$ from 0.33 to 0.8Ω determine the damper of the output, the decrease of the resonance frequency, the Bode magnitude, the oscillation of the active moment and the electrical intensity, see front panel, Fig. 3 and part of the block diagram, Fig. 4.

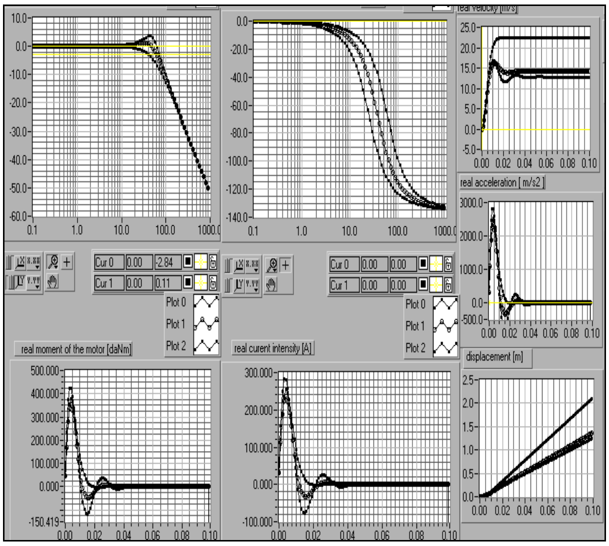

Figure 3. Front panel of the assisted theoretical analyze of the dynamic behavior of the DC motors.

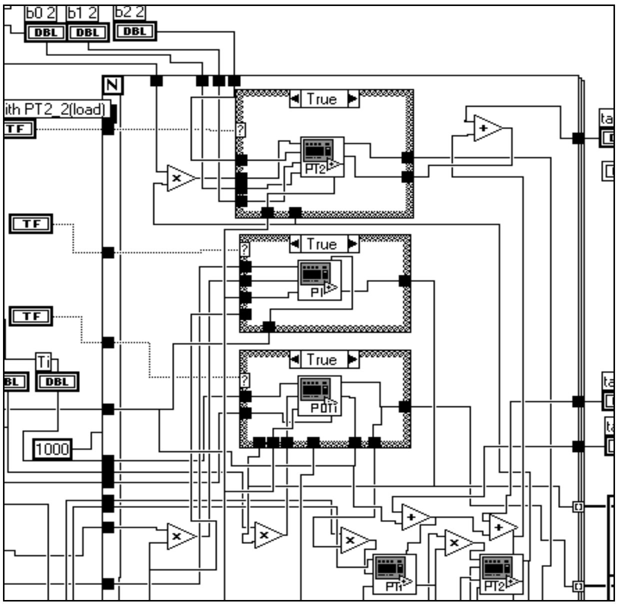

Figure 4. Part of the block diagram for the DC motor *VI*-s.

For analyzing what is happened in a complex closed loop block schema of the DC servo system, it was designed many virtual proper LabVIEW instruments [19]. With the elementary transfer functions it was created the complex block schema for driving modulus of industrial robot with some many closed loop type like proportional or double derivative control law. One of the simple schemas and the *VI*-s is presented in Fig. 5-Fig. 7. All these *VI*-s work on-line with the possibility to change some of the constructive and functional parameters and to say what are the results. This assisted activity open the way to choose the optimal values for the parameters to obtain the desired answer.

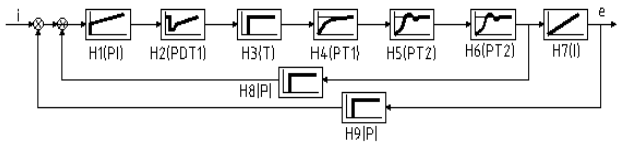


Figure 5. Automation block schema of the DC servo system

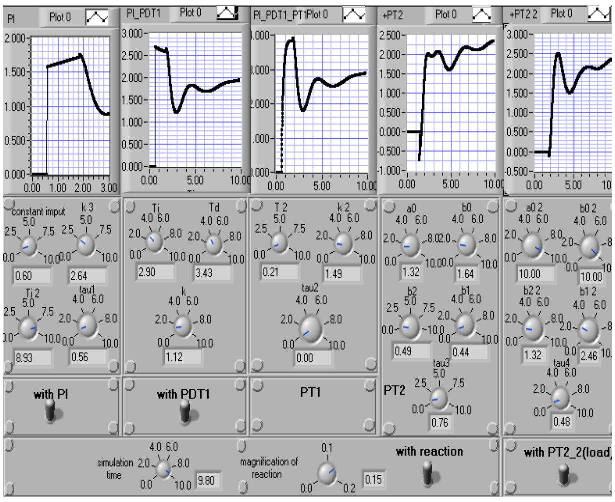

Figure 6. Front panel of the DC servo system simulation *VI*-s.

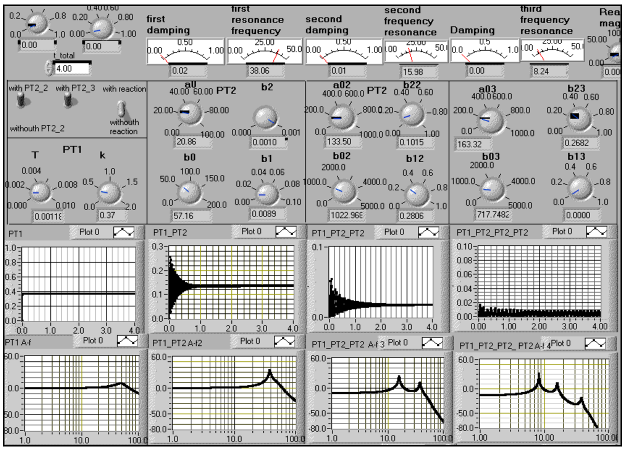

Figure 7. Front panel of the *VI*-s simulation with elementary transfer functions with real time and Bode characteristics.

The virtual proper LabVIEW™ instrumentation was created with the goal to assure the theoretical and experimental research to obtain and compare some teoretical and experimental results and assure one short time for the research and good results; LabVIEW™ *VI* for the theoretical research of the DC motor was created using the matrix mathematical model; the theoretical results obtained by changing some functional or constructive parameters of the DC motor or parameters of the system aids the designers to choose the optimal values for these; with the experimental research was possible to compare the theoretical and experimental results and to modify and ajust the mathematical model and validate them; by using the MRD was created the possibility to design in the future one intelligent assisted system. All creted LabVIEW$^{TM}$ *VI*-s and the research methode are generaly; they can be used in many other mechanical applications.

### A. Virtual Instrumentation for the Assisted Experimental Research

With the experimental assisted research will be possible to compare the theoretical and experimental results and to modify the mathematical model. We can observe that the experimental results, figure 8 are similarly with the theoretical one for common system's parameters, Fig. 6.

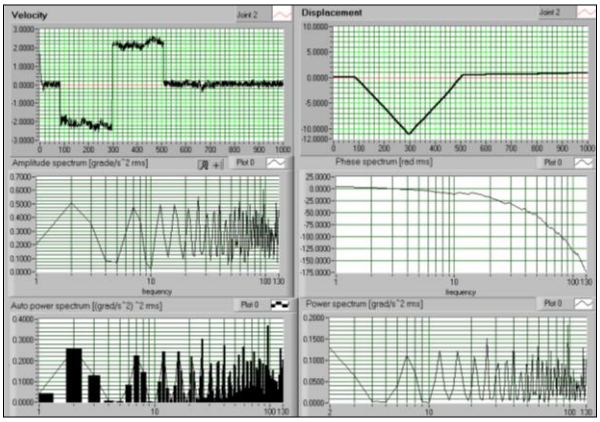

Figure 8. The results of the data acquisition of the velocity, space and Fourier spectrum of the DC servo system in two senses without dampers and time delay

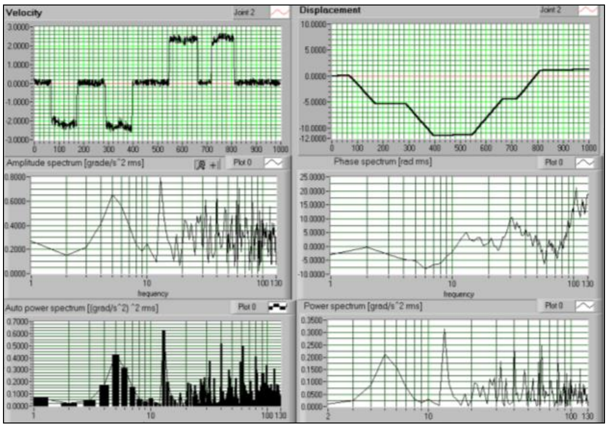

Figure 9. The results of the data acquisition of the velocity, space and Fourier spectrum of the DC servo system in two senses with damper, spring and time delay

From the Bode theoretical characteristics of the didactical arm type robot we can remark that not all application of the proportional reaction is good, or the value of the proportional reaction was good determined. With the created *VI* will be possible to choose the optimal values for this reaction's parameters to obtain the desired answer, Fig. 8 and Fig. 9.

One good information we can obtain from the experimental research with the proper virtual Fourier analyzer in a movement of the robot's arm. The study cases were: the movement in two directions with of without time delay between the movement senses, or the time delay inside of one movement, Fig. 8 and Fig. 9. The delay, between the senses or inside of the movement, transfer the Fourier spectrum to the high frequency the first frequencies from the Fourier spectrum were moved to the 6-7Hz; the frequency domain is bigger, 8Hz and with delay was 0-8Hz and 12-80Hz, that mince the component with the delay work like one slow stop band filter in a slow frequency and open band filter in the high, and the component without delay work like slow stop band filter; in the Fig. 8 and Fig. 9 are shown the results of the data acquisition of the robot arm velocity in the two cases with and without magneto rheological damper MRD. We can remark that in a movement with MRD the vibration of the velocity was attenuated.

With the special virtual LabVIEWTM instrumentation for the assisted research of the systems will be possible to determine the parameters of the mathematical model of the system to obtain the velocity characteristic with the better errors to the theoretical one. After compare the theoretical results with the real one we can remark that the errors are in the 1% field.

## IV. Study Case of the Optimisation of the Fourier Spectrum

In the robots research one of the most important thinks is the kinematics and dynamics research. Knowing these results will be possible to control and optimize the 3D space trajectory of the robot's end- effecter. Now, in the world, many of actual research used some complex mathematical models but without virtual instrumentation, without the possibility to obtain some different velocities characteristics assisted results and without trying some control lows and to say the influences [21]-[27]. The forward kinematics of a robot determines the configuration of the end-effector (the gripper or tool mounted on the end of the robot) given the relative configurations of each pair of adjacent links of the robot [28]-[47], but without virtual on-line instrumentation will be very hard to decide about the modeling, the optimal values of some body dimensions or masses and about the optimal control velocity characteristics. For the purpose of modeling, searching and validating the mathematical model of the kinematics and dynamics robots behavior, in the laboratory of the Dynamic of Industrial Robots of the faculty I.M.S.T.-U.P.B., was designed and made one arm type robot with five DOF, what used at these research.

The optimization Fourier will be possible to obtain by applying the smart schema of controlling using the Fourier generator, smart magneto rheological damper and accelerometers. In this case the damper spectrum will be the same with the robot spectrum with the goal to decrease them.

### B. Instrumentation to Solve the Forward, Inverse Kinematics and Dynamics

The mathematical model of the kinematics and dynamics behavior has been made with respect the structure of robot Fig. 1 and Newton-Euler equations. For the cinematic iterative equation it used the vector space sum and the quadratic transfer matrix from one layout to another. Matrix iterative vector equation for position is given by: [17]

$$\left(r_i^0\right)=\left(r_{i-1}^0\right)+\left[D_{i-1}^0\right]\left(r_i^{i-1}\right) \tag{2}$$

where: $(r^0{}_i)$ is the column matrix vector for absolute position $i$ joint versus the zero point; $(r^0{}_{i-1})$- column matrix vector for absolute position $i$-1 joint; $[D^0{}_{i-1}]$- quadratic matrix for transfer vector from $i$-1 to base system. Matrix iterative vector equation for dual velocity vector is given by:

$$\begin{pmatrix}\left(\omega_{i,0}^i\right)\\ \left(v_{i,0}^i\right)\end{pmatrix}=\left[T_{i-1}^i\right]\begin{pmatrix}\left(\omega_{i-1,0}^{i-1}\right)\\ \left(v_{i-1,0}^{i-1}\right)\end{pmatrix}+\begin{pmatrix}\left(\omega_{i,i-1}^i\right)\\ \left(v_{i-1,i}^i\right)\end{pmatrix} \tag{3}$$

symmetric matrix angular absolute velocity vector from $i$-1 joint reduced to the $i$ Cartesian system; $(a^i{}_{i,i-1})$ matrix vector for relative linear acceleration between joint $i$ and $i$-1, reduced to the $i$ Cartesian system.

where: $\begin{pmatrix}\left(\omega_{i,0}^i\right)\\ \left(v_{i,0}^i\right)\end{pmatrix}$ is the dual matrix vector for absolute velocity $i$ joint reduced to the $i$ Cartesian System; $\begin{pmatrix}\left(\omega_{i-1,0}^{i-1}\right)\\ \left(v_{i-1,0}^{i-1}\right)\end{pmatrix}$ - dual matrix vector for absolute velocity $i$-1 joint reduced to the $i$-1 Cartesian system; $[T^i{}_{i-1}]$- quadratic matrix 6x6 for transferdual velocity vector from $i$-1 to $i$ Cartesian system; $\begin{pmatrix}\left(\omega_{i,i-1}^i\right)\\ \left(v_{i,i-1}^i\right)\end{pmatrix}$ - dual matrix vector for relative velocity between $i$ joint and $i$-1, reduced to $i$ Cartesian system.

The quadratic 6x6 transfer matrix has the following expression:

$$\left[T_{i-1}^i\right]=\begin{bmatrix}\left[D_{i-1}^i\right] & 0\\ -\left[D_{i-1}^i\right]\left[\hat{r}_i^{i-1}\right] & \left[D_{i-1}^i\right]\end{bmatrix} \tag{4}$$

Matrix iterative equation for dual acceleration vector is given by:

$$\begin{pmatrix}\left(\varepsilon_{i,0}^i\right)\\ \left(a_{i,0}^i\right)\end{pmatrix}=\left[T_{i-1}^i\right]\begin{pmatrix}\left(\varepsilon_{i-1,0}^{i-1}\right)\\ \left(a_{i-1,0}^{i-1}\right)\end{pmatrix}+\begin{pmatrix}\left(\varepsilon_{i,i-1}^i\right)+\left[\widehat{\omega}_{i-1,0}^i\right]\left(\omega_{i,i-1}^i\right)\\ \left(a_{i,i-1}^i\right)+\left[\widehat{\omega}_{i-1,0}^i\right]^2\left(r_i^0\right)+2\left[\widehat{\omega}_{i-1,0}^i\right]\left(v_{i,i-1}^i\right)\end{pmatrix} \tag{5}$$

where: $(\varepsilon^i{}_{i,0})$ is the matrix vector for absolute angular acceleration joint $i$ reduced to Cartesian system $i$; $(a^i{}_{i,0})$- is the matrix vector for absolute linear acceleration joint $i$ reduced to the Cartesian system $i$; $(\varepsilon^i{}_{i,i-1})$ is the matrix vector for relative angular acceleration between joint $i$ and $i$-1, reduced to the $i$ Cartesian system; $\left[\widehat{\omega}_{i-1,0}^i\right]$ anti symmetric matrix angular absolute velocity vector from $i$-1 joint reduced to the $i$ Cartesian system; $(a^i{}_{i,i-1})$ matrix vector for relative linear acceleration between joint $i$ and $i$-1, reduced to the $i$ Cartesian system (Fig. 10-Fig. 15).

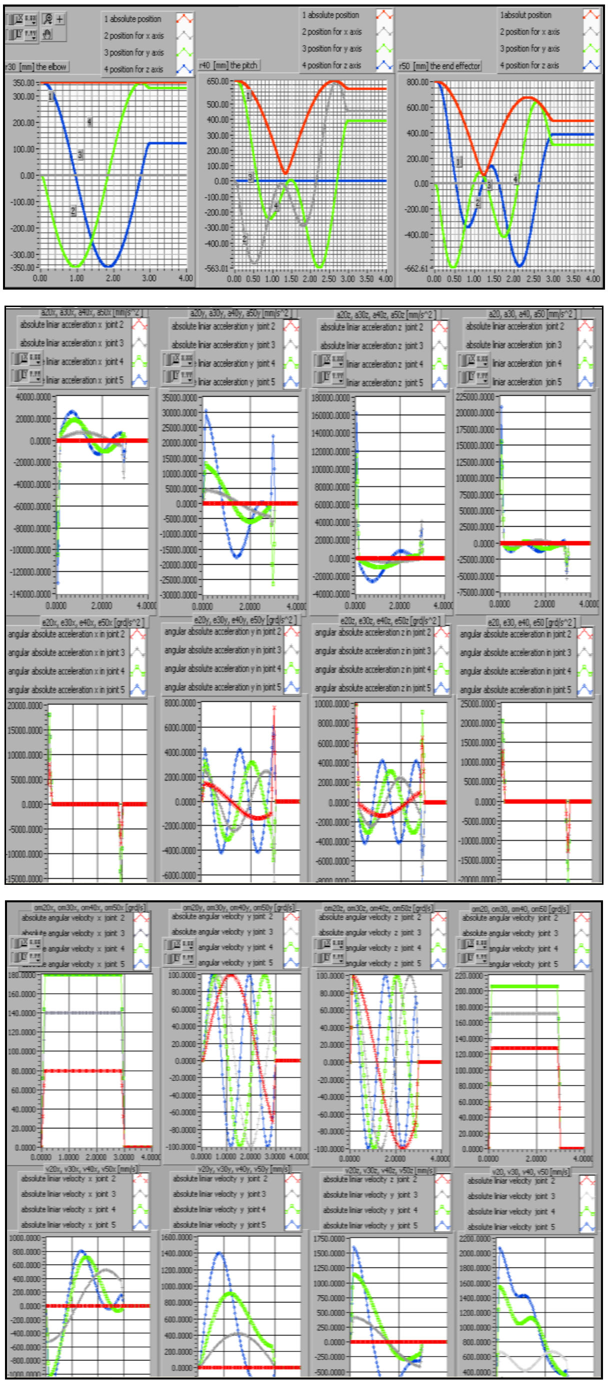

Figure 10. Positions, velocities and accelerations characteristiques for the simultaneously mouvements

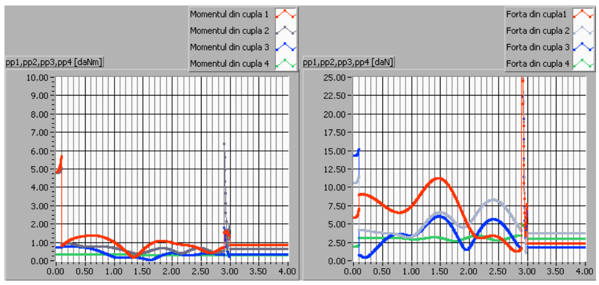


Figure 11. The moments and forces in all robots joints for successive movements

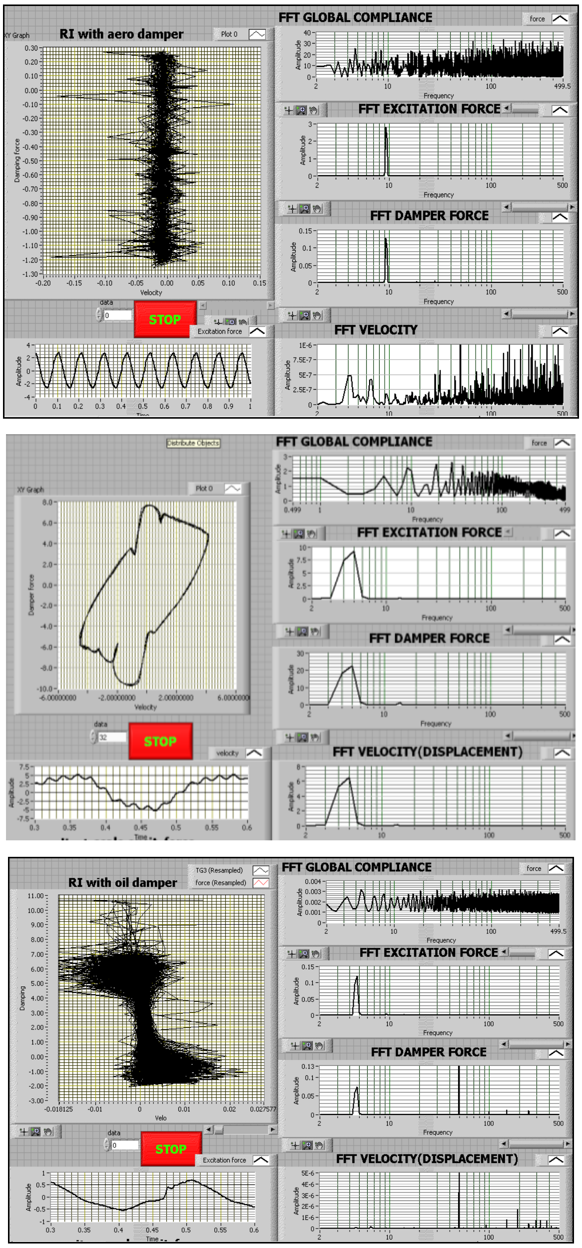


Figure 12. The front panel after excitation with 5 Hz of the robot base modulus with the results characteristics of damper force vs.displacements in the cases: without damper; with aero damper; with magneto rheological damper

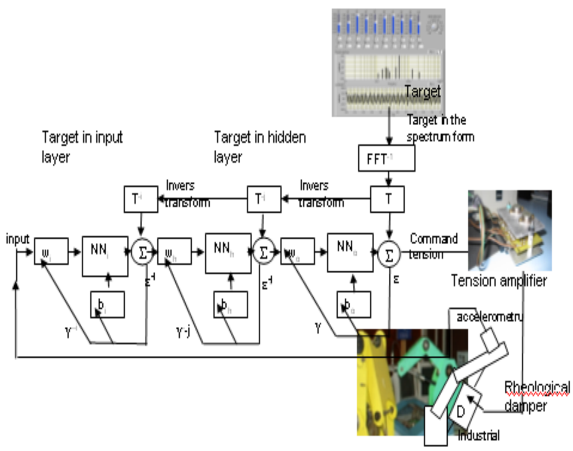


Figure 13. The block schema of the smart damped system.

After analyze of the experimental characteristics we can remark the followings: the real hystheresis characteristic have many damper force oscillations because the oscillations of the didactical structures; the increase of the curent intensity determine the increase of the VGDDEC and the moving of the frequencies of the Fourier spectrum in the high field; with one command law in the closed loop schema it is possible to determine the increasing of the VGDDEC only when and where will be necessary, for each resonance frequencies of the Fourier spectrum; by using this application it is possible to decrease all magnitude of the all frequencies of the Fourier spectrum or move them in to the attenuation field or reduce the magnitude of them.

## *C. Instrumentation for the Smart Systems*

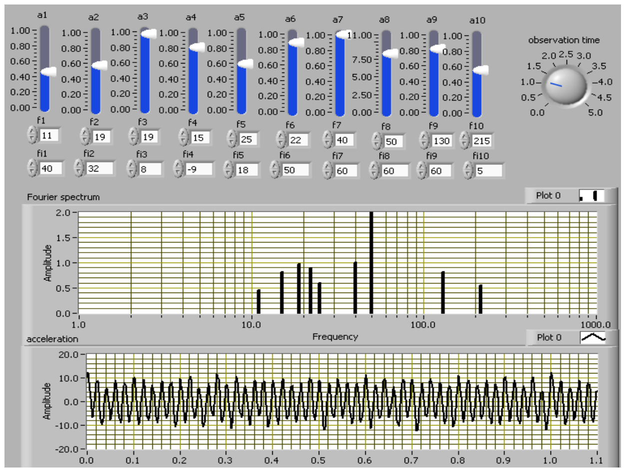


Figure 14. Front panel of the LabVIEW$^{TM}$ *VI*-s with proper Fourier generator of the desired vibration spectrum

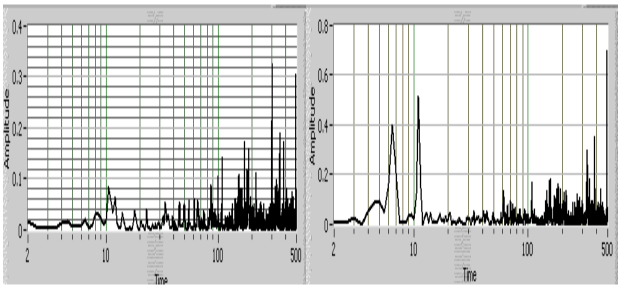

Figure 15. The results of the vibration Fourier spectrum without and with the smart damper system

For the smart systems were designed some virtual instruments: Fourier generator, proper neural network Bipolar Sigmoid Hyperbolic Tangent Neural Network with Time Delay and Recurrent Links (BSHTNN-TDRL) and proper smart damper schema that used the MRD, NN, accelerometers.

The assisted research of some dynamic behavior parameters and the influences to the MRD parameters opens the way to optimize the vibration Fourier spectrum in all resonance frequencies. By applying the MRD we can move on- line, by applying the proposed controller with three neural networks, the bad frequencies in to the attenuation bandwidth. The established MRD parameters with LabVIEW$^{TM}$ instrumentation assures the reducing of the errors between the numerical model and the real one and assures the optimization of the dynamic behavior of all mechanical structures by established of one precise mathematical model.

The proposed neural network (NN) type (BSHTNN-TDRL) was established after assisted research of many other types and all his parameters. The proposed and used in this research of this complex neural network schema was established after assisted research of this proposed type with many changes of some components or include others. The place of the time delay, the number of the recurrent links and his applied places, the amplifier gain and the hidden layer target data are the more important parameters to according and teaching the neural network.

The complex schema of the controller was established after using other NN types. The complex controlling with kinematics, dynamics and vibration are more efficiently in to the optimizing the TCP space trajectory without big magnitude of the vibrations, without increasing of the moment in all joints.

After the analyze of the results, we can do the following remarks: the used complex mathematical model for control kinematics and dynamics behavior open the way to the more accurate and precise robotic systems; the assisted research of the MRD, robot structure, neuronal networks open the way to optimize the global dynamic behavior of the industrial robots by on-line application of the smart systems; by changing, on-line, the intensity of the current, $i$ will be possible to change the characteristics of the damper and finally the dynamic behavior; by using the proposed controller with three neural networks will be very easily to decrease or moving the undesired frequencies from the Fourier spectrum in to the bandwidth.

The assisted method, the virtual LabVIEW$^{TM}$ proper instrumentation, the proposed controller with three controlling ways can be applying in many other mechanical applications.

## V. Conclusion

In Conclusion, in this paper we addressed the impact of virtual instrumentation approach through case studies both for teaching and research. Several assessments were introduced based on the master or Ph.D. student, or researchers surveys and review of the master or Ph.D. student research papers. The results shows that the *VI*-s based approach, significantly increased the efficiency of teaching and research in terms of master or Ph.D. student, or researchers motivation, ease of programming, hardware connectivity with real world, ease of customization as well as less development time and lower system cost. With these results, overall master or Ph.D. student, or researchers motivation increased and course evaluation was higher than the average value of the graduate school courses. In research, master or Ph.D. students, or researchers emphasized that the *VI*-s approach shortens the automation time significantly and decreases the overall system cost, then increases the efficiency of research as compared with traditional methods or conventional instruments. Besides, LabVIEW's graphical environment is easy to learn, customize and debug the *VI*-s applications as compared with text based programming languages. This enables master or Ph.D. students, or the researchers to focus on the research project, and then finally accelerate the research. In teaching, the *VI*-s concept is very convenient for classroom use, especially its intuitive and graphical programming, graphical user interface and hardware-software. Without the *VI*-s were not be possible to obtain the dynamic behavior of the robots, were not be possible to adjust and validate the complex matrix- mathematical model and compare the theoretical results with experimental.

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## References

[1] Ministry of Education, Culture, Sports, Science and Technology Website. [Online]. Available: http://www.mext.go.jp

[2] L. D. Hayes, "Higher education in Japan," *The Social Science Journal*, vol. 34, no. 3, pp. 297-310, 1997.

[3] D. Schaefer, J. H. Panhai, S. K. Choi, and F. Mistree, "Strategic design of engineering education for the flat world," *Engng Ed*., vol. 24, no. 2, pp. 274-282, 2008.

[4] N. Ertugrul, "Towards virtual laboratories: A survey of LabVIEW-based teaching/learning tools and future trends," *International Journal of Engineering Education*, vol. 16, no. 3, 2000.

[5] K. N. Whitley and A. F. Blackwell, "Visual programming in the wild: A survey of LabVIEW programmers," *Journal of Visual Languages & Computing*, vol. 12, no. 4, pp. 435-472, August 2001.

[6] H. M. G. Ramos, P. S. Girao, A. C. Serra, "Impact of virtual instrumentation in teaching automated measurement systems," *IEEE Africon*, vol. 2, pp. 978-981, 1996.

[7] J. Jovitha, "Virtual instrumentation using LabVIEW," PHI Learning, 2010.

[8] Z. Yi, J. Jian-Jun, and F. Shao-Chun, "A LabVIEW-Based, interactive virtual laboratory for electronic engineering education," *International Journal of Engineering Education*, vol. 21, no. 1, pp. 94-102, 2005.

[9] O. Gol, J. Machotka, and Z. Nedic, "Project-Based virtual instrumentation in engineering education," in *Proc. International Multi-Conference on Society, Cybernetics and Informatics*, 2007, p. 223-227.

[10] Y. Ugurlu, The role of Graphical System Design (GSD) in engineering education – Case Study: Introduction of NI Application Contest –, The Japanese Society of Engineering Educational, Annual Symposium, 2010, pp. 322- 323.

[11] National Instruments Japan, Application contest website (Japanese). [Online]. Available: http://www.ni.com/jp/apcon

[12] R. Murphy, *Introduction to Obotics*, The MIT Press, Cambridge, Massachusetts, 2000.

[13] M. Niţulescu, "Sisteme robotice cu capacitate de navigaţie," Edit. Universitaria Craiova, 2002.

[14] PROJET Centaure, Réalisation d'un Robot Mobil Autonome. Ecole Polytechnique de Lille, 2005.

[15] D. Pănescu, "Sisteme de conducere a roboţilor industriali," Univ. Tehnică, Gheorghe Asachi din Iaşi, 1996 PAC-MAN, EECE 474 Project.

[16] H. Borenstein and H. R. Enerett, "Sensors and methods for mobile robot positioning," The University of Michigan, 1996.

[17] E. J. Nicolson, *Tactile Sensing and Control of Planar Manipulator*, Berkely, 1994.

[18] P. Popescu, I. Negrean, I. Vuşcan, and N. Haiduc, "Mecanica manipulatoarelor şi roboţilor," EDP, Bucureşti, 1994.

[19] A. Olaru, "Virtual LabVIEW instrumentation in the technical research of the robots elements and the systems," Bren Publishing House, 2002, pp. 68-75
[20] A. Olaru, *Dynamic of the Industrial Robots*, vol. 2, Bren Publishing House, 2001, pp. 167-175.
[21] A. Olaru and N. Mihai, *Dynamic of the Industrial Robots*, vol. 1, Bren Publishing House, 1999, pp. 106-120.
[22] A. Oprean and A. Olaru, "Theoretical and experimental analyze of position and velocity at articulated arm industrial robot," in *Proc. Int. Conf. on Solid Mechanics*, Romanian Academy, 2001, pp. 230-238.
[23] A. Olaru, "Theoretical and experimental research of cinematic and dynamic behavior of industrial robots" in *Proc. 12th International DAAAM Symposium*, 2001, pp. 333-334.
[24] A. Olaru and S. Staicu, "Theoretical and experimental research dynamic behavior of industrial robots," *Mechanical Engineering*, vol. 63, no. 2, pp. 1-12, 2001.
[25] Olaru, A., "Research the dynamic behavior of the industrial robots in the frequency domain" in *Proc. Int. Conf. on Solid Mechanics, Romanian Academy*, 2002, pp. 233-240.
[26] J. Denavit and R. Hartenberg, "A kinematic notation for lower-pair mechanisms based on matrices," *ASME Journal of Applied Mechanics*, vol. 22, pp. 215–221, 1955.
[27] J. Luh, M. Walker, and R. Paul, "On-Line computational scheme for mechanical manipulators," *ASME Journal on Dynamic Systems, Measurment and Control*, vol. 104, pp. 69–76, 1980.
[28] R. Featherstone, *Robot Dynamics Algorithm*, Boston, MA: Kluwer Academic Publishers, 1987.
[29] J. Rasmussen, M. Damsgaard, E. Surma, S. Christensen, M. de Zee, and V. Vondrak, "AnyBody- a software system for ergonomic optimization," in *Proc. Fifth World Congress on Structural and Multidisciplinary Optimization*, 2003.
[30] S. Delp, F. Anderson, A. Arnold, P. Loan, A. Habib, C. John, E. Guendelman, and D. Thelen, "OpenSim: Open-source software to create and analyze dynamic simulations of movement," *IEEE Transactions on Biomedical Engineering*, 2007. (in Press).
[31] A. Kuo, "A least-squares estimation approach to improving the precision of inverse dynamics computations," *Journal of Biomechanical Engineering*, vol. 120, no. 1, pp. 148–159, 1998.
[32] W. Blajer, K. Dziewiecki, and Z. Mazur, "Multibody modeling of human body for theinverse dynamics analysis of sagittal plane movements," *Multibody System Dynamics*, vol. 18, no. 2, pp. 217–232, 2007.
[33] K. Yamane and Y. Nakamura, "O(N) forward dynamics computation of open kinematic chains based on the principle of virtual work," in *Proc. IEEE International Conference on Robotics and Automation*, 2001, pp. 2824–2831.
[34] R. M. Murray, Z. Li, and S. S. Sastry, "A mathematical introduction to robotic manipulation," University of California, Berkeley1994, CRC Press.
[35] P. J. Alsina and N. S. Gehlot, "Direct and inverse kinematics of robot manipulator based on modular neural networks," *ICARCV, IEEE*, pp. 1743-1747, 1994.
[36] R. Manseur and D. Keith, "A fast algorithm for reverse kinematics analysis of robot manipulator," *International Journal of Robotics Research*, vol. 7, no. 3, pp. 622-648, 1998.
[37] S. Staicu, "Dynamics analysis of the Star parallel manipulator," *Robotics and Autonomous Systems*, Elsevier, vol. 57, no. 11, pp. 1057-1064, 2009.
[38] S. Staicu, "Dynamics of the 6-6 Stewart parallel manipulator," *Robotics and Computer- Integrated Manufacturing*, Elsevier, vol. 27, no. 1, pp. 212-220, 2011.
[39] M. Hajduk, J. Semjon, and M. Vagaš, "Design of the welding fixture for the robotic station for spot weldind based on the modular concept," *Acta Mechanica Slovaca*, vol. 13, no. 3, pp. 30-35, 2009.
[40] L. Páchniková and M. Šalátová, "Ciele a efekty pružných výrob" *Acta Mechanica Slovaca*, vol. 12, no. 2-A, pp. 451-454, 2008.
[41] MacLean, Hunter. Satellite Communications Services Industry, A Satellite Out of Tune, Infotrack Magazine Index Plus. 8 April l996.
[42] A. Olaru, S. Olaru, and L. Ciupitu, "Assisted research of the neural network by bach propagation algorithm," in *Proc. International Conference, Calimanesti*, Romania, 2010, pp. 194-200.
[43] A. Olaru, S. Olaru, D. Paune, and A. Ghionea "Assisted research of the neural network," in *Proc. International Conference, Calimanesti*, Romania, 2010, pp. 189-194.
[44] A. Olaru and S. Olaru, "Assisted research of the neural network with LabVIEW instrumentation," *IEEE ICMENS-2010 Proceedings*, Changsha, China, pp. 1-8, 2010.
[45] A. Olaru, A. Oprean, S. Olaru, and D. Paune, "Optimization of the neural network by using the LabVIEW instrumentation," *IEEE ICMERA 2010 Proceedings*, 2010, pp. 40-44.
[46] S. Olaru, A. Oprean, and A. Olaru, "Assisted research of the new Bouc-Wen rheological damper," in *Proc. OPTIROB 2008*, Predeal, Bren, Bucharest, May 2008, pp. 143-152.
[47] A. Olaru and S. Olaru, "Research of the industrial robots viscose global dynamic damper coefficient with LabVIEW instrumentation," in *Proc. CAX'2006*, Akademia Techniczno-Rolnicza, Bydgoszcz, Nov. 2006, pp. 73-81.

**Adrian Olaru** finish the University Politehnica of Bucharest, the Faculty of Machine-Tools, Machine and Manufacturing Systems Department. Now, from 1998 I am a university full professor, and I teach the following courses: Industrial Robots Dynamics Behavior, LabVIEW application in modeling and simulation of the dynamic behavior of robots and Personal and social robots. I am a doctor from 1989. In the last ten years I have been leading the following research projects: computer aided research and design for the hydraulic amplifiers of pneumatic and hydraulic screwdrivers; computer aided research over the dynamic behavior of the forging manipulator orientation modulus; computer aided research over dynamic behavior of the charging manipulators tipping modulus; computer aided research over dynamic behavior of the charging manipulators translation modulus; experimental validation for mathematical models of hydraulic elements and servo system; methodological guide for dimensioning and optimizing electrohydraulic elements; design of the mobile robots; assisted research of the magneto rheological dampers; assisted research of the intelligent dampers; assisted research of the neural networks; optimizing of the robots dynamic behavior by using the Fourier proper analyzer; optimizing the dynamic compliance and global transmisibility by using the assisted research and proper LabVIEW instrumentation; optimize the dynamic behavior and the space trajectory by using the proper neural network.

**Serban Olaru** finish finished the University Politehnica of Bucharest, Faculty of Machines and Manufacturing Systems, Romania. From 2008 he become the Ph.D. Eng. in the field of mechatronics. Now, he works in RomSYS private company, from Bucharest, Romania, in the department of mechatronics. He write mote than 50 research papers in the fields of intelligent damper systems, mechatronic systems, simulation and modeling with LabVIEW instrumentation.