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Proper Jacobian Pseudo Inverse Neural Network Matrix Method Applied to Robot Inverse Kinematics Controlling

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Abstract—**These in the controlling of the space movement of the end effecter and the robot's joints one of the most important problem is to know with the extreme precision the joints relative displacement. Controlling this displacement must be done only by controlling with accuracy the movement of each motor in the joints by solving the forward and inverse kinematics problem. This problem could be solves on-line, but usually it is solved off line. One of the most precise method to solve the inverse kinematics problem in the robots with redundant chain is the complex coupled method, usually by coupling the neural network with Jacobian method. In this paper was proposed and used the proper coupled method Iterative Pseudo Inverse Jacobian Matrix Method (IPIJMM) with Sigmoid Bipolar Hyperbolic Tangent Neural Network with Time Delay and Recurrent Links (SBHTNN-TDRL). The solution of the inverse kinematics problem is very difficult to find when the degree of freedom increase and in many cases this is impossible because there are the redundant solutions. In all these cases must be used the numerical iterative approximation, like the proposed method, with artificial intelligence algorithm. The paper describe all virtual LabVIEW instrumentation, the needed steps in one case study, to obtain the space curves in different planes by using one arm type robot and the proposed algorithm. The errors of the space movement of the robot end-effecter, after applying the proposed method, was less than 0,001. The presented method and the Virtual Instrumentation (VI) are generally and they can be used in all other robots type application and for all other conventional and unconventional space curves.**

Index Terms—**iterative matrix method, forward and inverse kinematics, jacobianmatrix, pseudo inverse matrix, assisted research, neural network, LabVIEW instrumentation, gekodrivesystem**

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I. Introduction

The paper shown one new method applied to one arm type robot, by using the Iterative Pseudo Inverse Jacobian Matrix method coupled with proper Neural Network with the goal to establish with extreme precision the internal robot joints coordinates to control the end- effecter robots space trajectory. The proper neural network was established after the assisted numerical research of the neural network parameters, by proving some known networks types and to show all dependences between the network parameters and the convergence process. The better solution of the neural network design, to solve the inverse kinematics with the final goal to obtain quickly the convergence process of the space trajectory with the minimum of the errors, was established by using the own LabVIEW instrumentation. The Sigmoid Bipolar Hyperbolic Tangent Neural Network with Time Delay and Recurrent Links (SBHTNN-TDRL) coupled with Iterative Pseudo Inverse Jacobian Matrix Method (IPIJMM) was finally choose and used. All obtained results were verified by applying the file with internal coordinates changed in to the pulses number for each DC motor. For experimental prove where used the arm type robot with open chain, with 4 Degree of Freedom (DOF),with DC motor and Gekodrive GK330 in each joints.

Solving the inverse kinematics problem is much more difficult problem than forward kinematics. Sometimes no analytical solution is possible, and an iterative search is required by using the analytical, numerical or neuronal network methods like Gradient Method (GM), Jacobian Matrix Method (JMM), Pseudo Inverse Jacobian Matrix Method (PIJMM), Gradient Projection Method (GPM), Inverse Jacobian Inertia Matrix Method (IJIMM), Neural Network Coupled Method with some other numerical methods (NNCM) or many other coupled methods [1]-

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[12]. The solution of the inverse kinematics problem is computationally expansive and generally takes a very long time (Kucuk & Bingul, 2004) [1], (De Wit & Siciliano,1996) [2], (Jingguo Wang, Yangmin Li, Xinhua Zhao, 2010) [3], (P. J. Alsina & N. S. Gehlot, 1994) [4], (Manseur & Keith,1998) [5], (Li-Chun Wang & Chih Cheng Chen,1991) [6], (Welman,1989) [7], (Gorinevsky & Connoly,2001) [8], or some complex coupled method with neural networks (Lee, Schittenkopf, Olaru) [9]-[12]. The neural network method to obtain the real solutions of the inverse kinematics can offers the minimum of the errors, but is not easily to obtain the convergence process (Lee, 1997) [9], (Schittenkopf, Deco & Brauner, 1997) [10]. In the paper was proposed and used the proper coupled method of Iterative Pseudo Inverse Jacobian Matrix Method with Sigmoid Bipolar Hyperbolic Tangent Neural Network with Time Delay and Recurrent Links Method (IPIJMM-SBHTNN-TDRLM). By using the proposed method will be possible, very easily, to obtain the internal relative coordinates which should be applied in all robot joints with precision before 0,001.

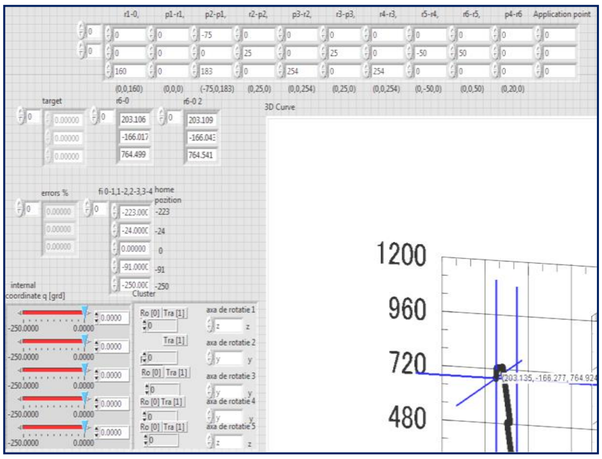

Figure 1.The front panel of the LabVIEW*VI*–s for animation of the robot's joints by using the internal coordinates- with joints in the home position

Figure 2. The didactical arm type robot used in the assisted research

II. Generality of the Used Arm Type Robot with Gekodrive DC Motors and LabVIEW VI-s

The complex program of the controlling the movement in all robot's joints contents some VI-s to generate the space curve points, animation of the robot's joints according with the internal coordinate and forward kinematics, generation of the internal coordinate for one know point, generation of the internal coordinates for all know external coordinates of space curve and generation of the file with internal coordinates transposed in to the relative and absolute pulses number for each of motors. The first VI is for animation of the robot's joints movement according with internal coordinates, Fig. 1 for the didactical robot that used in the research, Fig. 2.

With this program can be determined the internal coordinates for one know external position of the end-effecter. The program is generally; we have the possibility to construct other arm type robot with other dimensions and rotation axes, because for forward kinematics on used the following matrix method.

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

where: (r_i^0) - matrix of the current position vector; (r_{i-1}^0) - matrix of the position vector of the previous point; $[D_{i-1}^0]$ - matrix of transfer from *i*-1 to base plane; (r_i^{i-1}) - matrix of relative position between *i* and *i*-1 points. The general front panel of the complex *VI* of the forward kinematics are shown in Fig. 3.

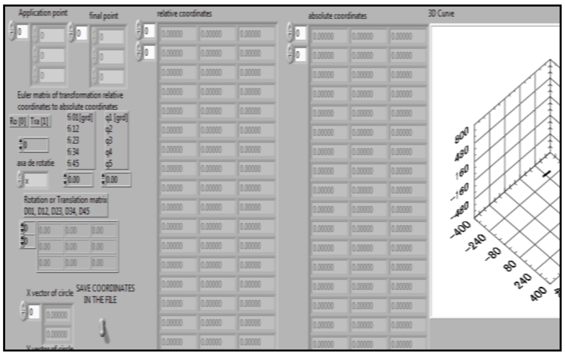

Figure 3. Front panel of the complex *VI*-s for generate the internal coordinates for controlling the motors from the joints, using the external coordinates

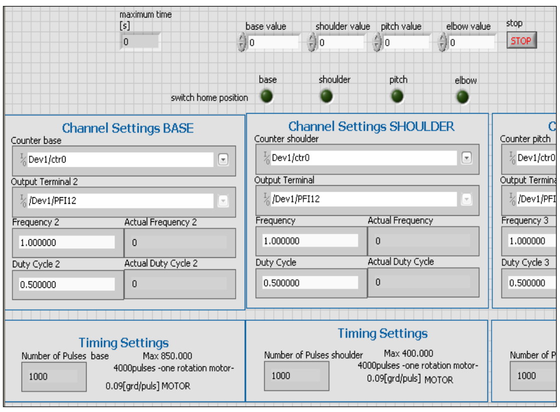

Figure 4. Front panel of the controlling movement of the motors

The controlling front panel of the complex program is shown in Fig. 4.

III. The Mathematical Model of the Proposed Iterative Algorithm to Determine the Internal Coordinate with Extreme Precision (less than 0.001)

The proper Neural Network (NN) used four layers (4-12-4-3), many time delay blocks and recurrent links, coupled with the Forward Kinematics (FK) and Iterative Pseudo Inverse Jacobian Matrix Method proper algorithm (IPIJMM). All used layers are sensitive sigmoid bipolar hyperbolic tangent functions type to take in consideration the influences of the input data to the internal coordinates q_i in all movement direction, positive or negative.

$$\begin{aligned}(dq_i) &= \alpha[(T_i)-(FK(q_i))][J(q_i)]^T\{[J(q_i)][J(q_i)]^T\}^{-1} \\ (q_j) &= (q_i)+(dq_i)\end{aligned} \qquad (2)$$

$$(n)_1 = [\underset{p_1}{[w]^1} + \underset{p_2}{(tcg_1)}\cdot(\varepsilon_1)][((p)-(a_2)((t)-(p_3)+1))+((b_1)+(\varepsilon_1));$$

$$(a_1) = \frac{(p_4)(1-e^{-n_1})}{1+e^{-n_1}};(\varepsilon_1)=(t_1)-(a_1)$$

$$n_2 = [w^2 + \underset{p5}{tcg_2}\cdot\varepsilon_2](a_1(t-p_6+1))+(b_2+\varepsilon_2);$$

$$a_2 = \frac{p_7(1-e^{-n_2})}{1+e^{-n_2}};(\varepsilon_2)=(t_2)-(a_2)$$

$$(q_i)=(p_8)((a_2)-(\varepsilon_f));(\varepsilon_{pos})=(t_3)-(r_i);$$

$$(n_3)=[[w^3]+\underbrace{(tcg_2)\cdot(\varepsilon_{pos})}_{p_5}](q_i)+((b_3)+(\varepsilon_{pos}));$$

$$(a_3)=\frac{(p_9)(1-e^{-n_3})}{1+e^{-n_3}};(\varepsilon_f)=(t_2)-(a_3).$$

where(q_i) – internal relative coordinates matrix; (t_i)-column matrix of the targetdata of each layer; (*FK*)-column matrix of the forward kinematics results; $[J(q_i)]^T\{[J(q_i)][J(q_i)]^T\}^{-1}$- pseudo inverse matrix of the Jacobian; α - convergence step of the iteration (teaching gain); (a_i) - matrix of output data of the sensitive sigmoid function; (n_i) - matrix of inputof the sensitive sigmoid function;(ε_i)- matrixerror after each layer; *t* – step delay; (p_i)- parameterof the neuralnetwork what can be changed for optimizing the results; [w^i]- weight matrix what can be on-line changed; (b_i)- biases matrixwhat can be on-line changed.

The block schema of the results after applying the proper IPIJMM-SBHTNN-TDRL method can be see in Fig. 5.

IV. Discussion of the Results

Finally, the paper will shown the animation of the robot's TCP on the ***Γ*** target known curve (the circle in some different Euller space planes) and the movement of all his joints.After analyzing the obtained results after the assisted simulation and experimental research with proper *VI*-s, Fig. 1-Fig. 5, we can do the following remarks: the final errors after application of the proposed complex algorithm IPIJMM-SBHTNN-TDRLM, for all points of the Euller space circle curve was before 0,001; the change of the amplifier and the teaching gains of the used neural network, assured the decreasing of the errors from 18% to 1% after 132 iterations; one substantial decreasing of the errors and the decreasing of the number of iterations was obtained by on-line changing of the weight, biases and sensitive functions parameters and also the target of the hidden layer, 18% to 1% for 32 iterations; the errors can be decreasing by impose in the while loop structure of the used *VI*-s one limit value to 0,001.The animation and the experimental model using LabVIEW instrumentation open the way to the off-line analyze and optimization of the movement motor's controlling.

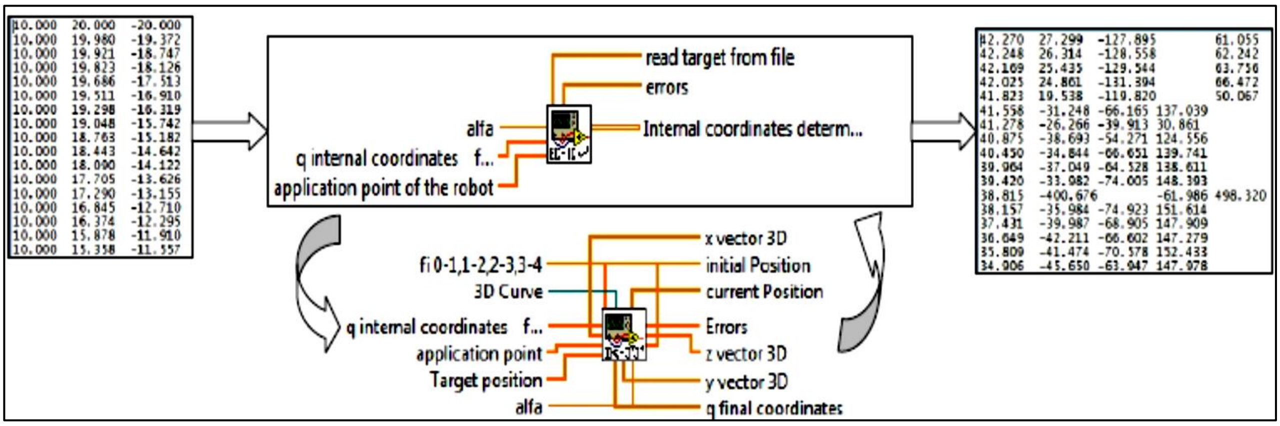

Figure 5. The iterative method applied for space curve in Euller plane.

V. Conclusion

With this method, by applying the control of the inverse kinematics problem by using the proposed algorithm IPIJMM-SBHTNN-TDRL will be possible to obtain one optimization of the robot end- effecter position in the space. The applying method, the proposed algorithm, the assisted research with the virtual LabVIEW instrumentation opens the way to apply the intelligent systems in to the robot control.The future work will be the applying the proposed method to the multi robot application with multiple tasks like exoskeleton, or complex compound space trajectory.

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