Neutrosophic Theory Applied in the Multi Objectives Optimization of the Robot's Joints Accelerations with the Virtual LabVIEW Instrumentation

A. Olaru, S. Olaru, N. Mihai, and N. Smidova

***Abstract*—One of the most important problem to solve in the robots Kinematics and Dynamics is analyze of the joint's angular and linear accelerations. Because the movements of the robot's bodies going in the 3D space, the mathematical algorithm must be written in the complex matrix form. The paper show how some cases of the trapezoidal relatives' velocities characteristics in a joints determine the variation of the acceleration's vectors in the 3D space. The maximal values of these variations of the angular and linear accelerations influence the variation of the moments and forces. The analyze was made by using the Neutrosophic theory and vitual LabVIEW instrumentation. In a literature are described some methods of the assisted analyze of the acceleration without show the used mathematical model, without one critical analyze of the cases that must be avoid and finally without some conclusions for the researchers. The paper shown all LabVIEW virtual instruments (*VI*) used for this assisted research. By solving the assisted research of the acceleration will be open the way to the assisted research of the robots' dynamic behavior, to choose the optimal constructive and functional parameters (dimensions of the bodies, simultaneously, successive or complex configurations of the movements in the robot's joints, optimal values of the constant relative joint's velocities, etc.) of the robots to obtain the minimum variation of the forces and moments. The method that was shown in the paper solves one small part of the complex problems of the robot's kinematics and dynamics.**

***Index Terms*—Assisted research, Joint's accelerations, Neutrosophic theory, Virtual instrumentation, Multi objectives optimization.**

I. Introduction

The assisted analyze of accelerations in Robotics is one of the most important problem to be solved that will be assured one good choose of the robots parameters with the final goal –find the optimal dynamic behavior of the robot joints movements. Without the assisted research with the LabVIEW software will be not possible to study the kinematic and dynamic behavior. In [1] Ran Zhao show one synthesis about the trajectory generation for manipulators and cooperation robots. This subject have been discussed in numerous other books and papers, among can find [Brady 2], [Khalil 3] and [Biagiotti 4]. Kroger, in his book [Kroger 5], gives a detailed review on on-line and off-line trajectory generation and propose to reach a goal defined by constraints (position, velocity, acceleration, jerk,…) while respecting bounds ($V_{\max}$, $A_{\max}$, $J_{\max}$, $D_{\max}$) where: $V_{\max}$ is the maximum velocity, $A_{\max}$ is the maximum acceleration, $J_{\max}$ is the maximum jerk, $D_{\max}$ is the maximum first derivative of jerk. The first reason is that the trajectory can be adapted in order to improve the path accuracy. [Dahl 6] proposed to use one-dimensional parameterized acceleration profiles along the path in joint space instead of adapted splines. [Cao 7, Cao 8] used cubic splines to generate smooth paths in joint space with time-optimal trajectories. In this work, a cost function was used to define an optimization problem considering the execution time and the smoothness. [Constantinescu 9] suggested a further improvement of the approach of [Shiller 10] by leading to a limitation of the jerk in joint space, considering the limitation of the derivative of actuator force/torques. [MacFarlane 11] presented a jerk-bounded, near time-optimal, one-dimensional trajectory planner that uses quantic splines, which are computed online. Owen published a work on online trajectory planning [Owen 12]. Here, an off-line planned trajectory was adapted online to maintain the desired path. The work of Kim in [Kim 13] took

robot's dynamics into account. The other one is the robotic system must react to unforeseen events based on the sensor singles when the robot works in an unknown and dynamic environment. [Castain 14] proposed a transition window technique to perform transitions between two different path segments. [Liu 15] presented a one-dimensional method that computes linear acceleration progressions online by parameterizing the classic seven-segment acceleration profile. [Ahn 16] used sixth-order polynomials to represent trajectories, which is named **A**rbitrary **S**tates **PO**lynomial-like **T**rajectory (ASPOT). In [Chwa 17], Chwa presented an advanced visual servo control system using an online trajectory planner considering the system dynamics of a two-link planar robot. An algorithm proposed in [Haschke 18] is able to generate jerk-limited trajectories from arbitrary state with zero velocity. Broquere proposed in [Broquere 19] an online trajectory planner for an arbitrary numbers of independent DOFs. The Motion Conditions (MC) in Cartesian and Joints equations are shown in (1):

TABLE I: The Robot Movements Limits in Jerk, Acceleration and Velocities [1]

Jerk	Acceleration	Velocity
$5*A_{max}\ rad/s^3$	$2.5*V_{max}\ rad/s^2$	$V_{max}\ rad/s$

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$$M(t)=(X(t),\ V(t),\ A(t))=(Q(t),\ Q(t),\ Q(t)) \qquad (1)$$

where: $X(t)$, $V(t)$, $A(t)$ are the position, velocity and acceleration that describe the Cartesian MC, $Q(t)$, $Q^{'}(t)$, $Q^{''}(t)$ are the relatives position, velocity and acceleration that describe the Joints MC.

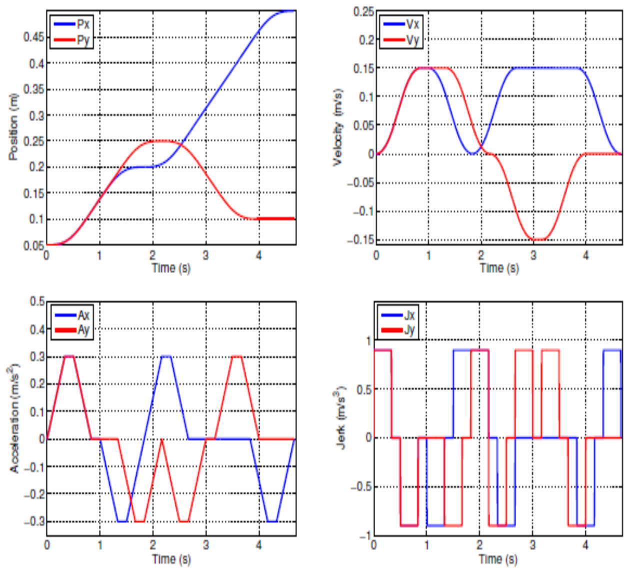


Fig. 1. Position, velocity, acceleration and jerk profile of unsynchronized 2D via- points motion [1].

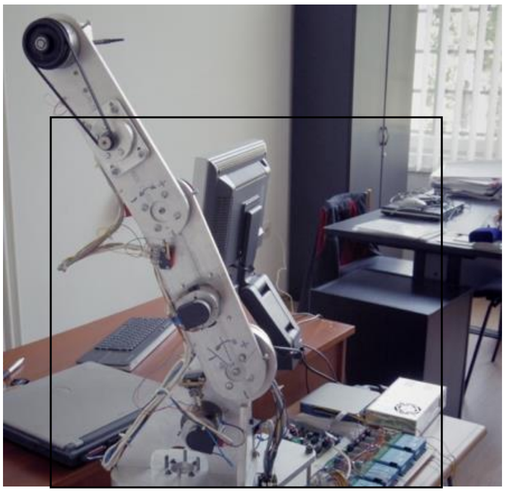


Fig. 2. The didactical arm type robot used in the assisted research.

After analysing the stat of art of the acceleration research we can do the followings remarks: (i) majority of the researchers analyse the acceleration like the first derivative of the velocity without using some matrix operators; (ii) the researchers didn't show the mathematical matrix form of the acceleration equations; (iii) the control of the robot's trajectory were do by controlling the positions, velocities, accelerations and jerks and by imposed some maximal values for each of them.

The paper propose to consider the analyse of robot's acceleration in one new manner: (a) by using the 6x6 matrix form of equations; (b) by transfer the equation in some LabView programs and show the characteristics in the different cases of the movements: simultaneously, successive, or combine both of them; (c) by analyse the characteristics that give us the possibility to establish what will be the cases where the acceleration have the maximum jerk that define the maximum of the force/moment variation and also define the non acceptable dynamic behavior of the movements; (d) for the assisted research was used one didactical arm type robot, acquisition board and LabView program from National Instruments, USA, for controlling the space trajectory, Fig. 2.

II. Modeling Simulation of the Robot's Joints Accelerations

For the assisted research of accelerations were needed firstly create the mathematical 6x6 matrix model, secondly construct some LabVIEW instruments that content this mathematical model, thirdly run these virtual instrumentations to obtain the accelerations characteristics versus time in some different cases of the robot's movements and with different body's length and finally analyze and chose the optimal values of the constructive and functional robot's parameters. Some of the proper results were obtained in the papers [20]-[25].

A. Mathematical 6x6 Matrix Model for Robot Joint's Accelerations

The dual matrix form of the accelerations equations assure the easily way for the assisted research of the kinematics and dynamics behaviour of robots. The matrix form of the dual absolute vector equations for accelerations are:

$$\begin{pmatrix}(\varepsilon_{i,0}^{i})\\(a_{i,0}^{i})\end{pmatrix}=[T_{i-1}^{i}]\begin{pmatrix}(\varepsilon_{i-1,0}^{i-1})\\(a_{i-1,0}^{i-1})\end{pmatrix}+(S''(i)) \qquad (2)$$

$$(S''(i))=\begin{pmatrix}(\varepsilon_{i,i-1}^{i})+(\widetilde{\omega}_{i-1,0}^{i})(\omega_{i,i-1}^{i})\\(a_{i,i-1}^{i})+(\widetilde{\omega}_{i-1,0}^{i})^{2}(r_{i,i-1}^{i})+2(\widetilde{\omega}_{i-1,0}^{i})(v_{i,i-1}^{i})\end{pmatrix} \qquad (3)$$

$$\begin{pmatrix}(\varepsilon_{i,0}^{0})\\(a_{i,0}^{0})\end{pmatrix}=\begin{bmatrix}[D_{i}^{0}] & [0]\\ [0] & [D_{i}^{0}]\end{bmatrix}\begin{pmatrix}(\varepsilon_{i,0}^{i})\\(a_{i,0}^{i})\end{pmatrix} \qquad (4)$$

$$\left[T_{i-1}^{i}\right]=\begin{bmatrix}\left[D_{i-1}^{i}\right] & 0\\ -\left[D_{i-1}^{i}\right]\left[\widetilde{r}_{i}^{i-1}\right] & \left[D_{i-1}^{i}\right]\end{bmatrix} \qquad (5)$$

where: $\begin{pmatrix}(\varepsilon_{i,0}^{i})\\(a_{i,0}^{i})\end{pmatrix}$ is the dual matrix vector of the absolute acceleration of the i joint versus the i Cartesian system; $\begin{pmatrix}(\varepsilon_{i,0}^{0})\\(a_{i,0}^{0})\end{pmatrix}$- the dual matrix vector of the absolute acceleration of the i joint versus the base Cartesian system; $\begin{pmatrix}(\varepsilon_{i-1,0}^{i-1})\\(a_{i-1,0}^{i-1})\end{pmatrix}$- the dual matrix vector of the absolute acceleration of the i-1 joint versus the i-1 Cartesian system; $[T_{i-1}^{i}]$-the quadratic 6x6 transfer matrix from the i-1 to i system; $(S''(i))$- the dual matrix vector of the relative joint's acceleration between i and i-1 joints versus i Cartesian system; $(\varepsilon_{i,i-1}^{i})$- the column matrix vector of the relative angular acceleration between i and i-1 systems versus i Cartesian system; $(\widetilde{\omega}_{i-1,0}^{i})$ - antisimetrical absolute vector of the angular velocity of the i-1 joint versus i Cartesian system; $(\omega_{i,i-1}^{i})$- velocity angular relative column matrix vector between i and i-1 joints; $(a^{i}_{i,i-1})$ – linear relative acceleration column matrix form between i and i-1 joints versus i Cartesian system; $(\widetilde{\omega}^{i}_{i-1,0})^{2}(r^{i}_{i,i-1})$ - column matrix centrifuge relative acceleration between i and i-1 joints versus i Cartesian system; $2(\widetilde{\omega}^{i}_{i-1,0})(v^{i}_{i,i-1})$- column matrix form of the Coriolis relative acceleration between i and i-1 joints versus i Cartesian system; (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; i- the current robot's joint and have the 1-5 values.

Relation (2) is the 6×6 matrix equation of the dual matrix vector of the absolute accelerations by recursive calculus. Relation (3) describe the dual matrix vector of the relative acceleration using the transfer 6x6 matrix (5) between the Cartesian systems. With relation (4) will be possible to redefine all dual accelerations vectors vs. the robot's base.

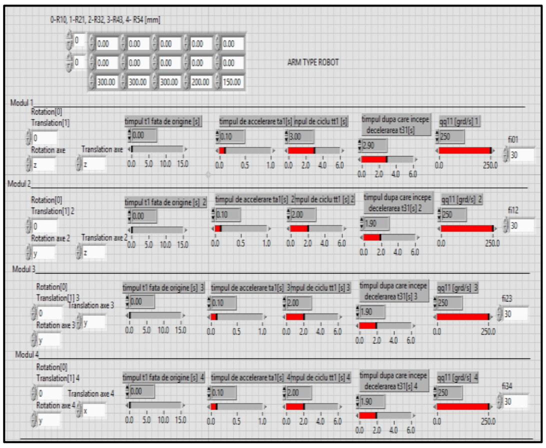


Fig. 3. The front panel of the LabVIEW program.

B. *Description of the used LabVIEW Programs*

The mathematical matrix model used in the assisted analyze of the robots joints accelerations was transposed in some virtual LabView instruments shown in Figs.3-6.

The front panel of the base program, Fig.3, and the icon, Fig.6, contents the part for the input data for each robot's module and the results of simulation, the linear and angular acceleration characteristics and also the angular variation of the linear and angular acceleration in the 3D space, Fig. 4.

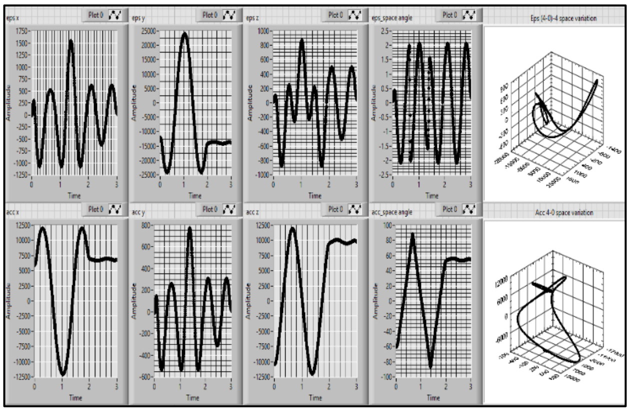


Fig.4. Front panel of the LabVIEW VI with some results after numerical simulation.

The base program, Fig. 5, contents some sub *VI*-s that could be used in many other LabVIEW programs. The base program used the sub *VI*-s for the following actions: to determine all dual absolute vector velocity, the sub *VI*-s to generate the translation matrices between all Cartesian systems, the sub *VI*-s to generate all relative dual vectors of acceleration and the sub *VI*-s to generate the trapezoidal characteristics of each joints movements.

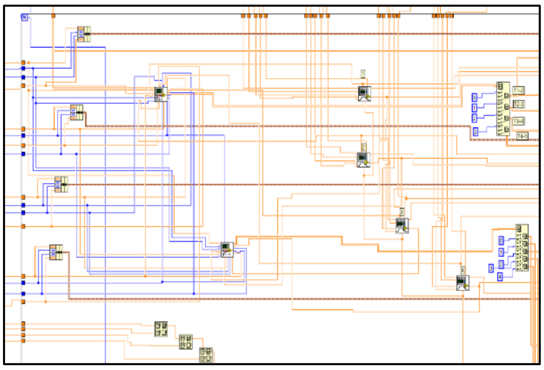


Fig. 5. Part of the block schema of the LabVIEW program.

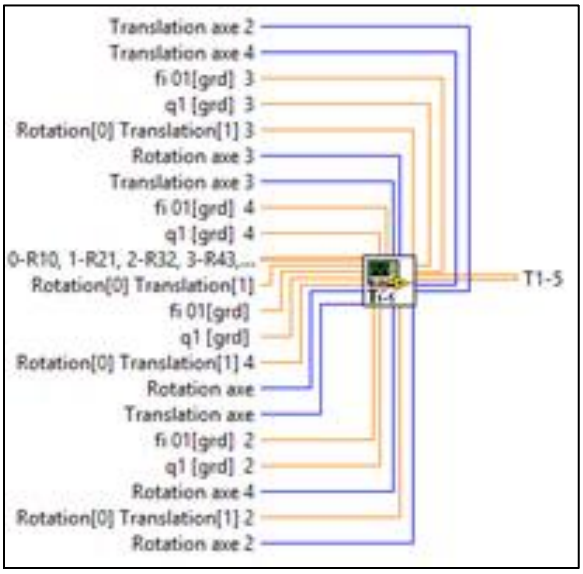


Fig. 6. Icon of the LabVIEW VI-s to determine the transfer matrices between the Cartesian robot's joints.

C. *The Results of the Assisted Research*

The theoretical assisted research with the proper LabView VI-s to determine the joint's acceleration was done by using different velocities characteristics like: with simultaneously movements of all joints, with successive movements or simultaneously and successive after the acceleration time, or combine two movements to be simultaneously and other successive. All these results are shown in the Tables II and III. In the simulation activities, to be obtained good results, we used the trapezoidal characteristics of relative joint's velocities in some different cases: simultaneously, successive, some successive and some simultaneously after acceleration time, some successive and some simultaneously after the constant velocity period, successive after the deceleration time, simultaneously with the same or different velocities values and also simulation with different measure of each robot's body.

In all studied cases were shown the maximal variation of the linear and angular velocities, the space angle between the base robot Cartesian system and the angular and linear acceleration of the end-effecter. All these could be influence the dynamic behavior of the robot in different types of applications. The maximum variation of the angular or linear acceleration, the increasing of the frequencies variation, influence the force and moment in the joints and determine the same variation of the dynamic behavior.

III. Neutrosophic Theory Applied in Multi Objectives Optimization of the Robot's Joints Accelerations

The steps to optimize some of the functional parameters of the robot must be the followings: - chose the objective and if the action will be with only one objective function (*f*) or with multi objective function (*mof*); -define these objective functions; -define all constraints for the constructive and functional parameters imposed by the robot's design of the structure and by physical application; -construct one complex algorithm in a iterative manner and apply them together with Neutrosophic theory because in other case the results must be nul; -adjust the algorithm before will be touched the convergence process and will be obtained the results of the multi objective functions and apply the pounders and calculate the current pounders; - determine the values of the variable parameters of the (*mof*).

A. Generality of Optimization of the Acceleration's Variation

The optimization of the acceleration contents the following steps:

1) We defined the mof vs. the following parameters, where p is the case study: from the relative velocity characteristics: t- time to origin; t_{di}- time delay between the joint's movements; q_i'- relative constant velocity in each joint; from the robot: -lengh L_i of each robot's body.

$$mof(t_i, t_{di}, q_i, L_i) \stackrel{\text{def}}{=} \big(\{p\ of\ min\ range\ A_x\} \cap \{p\ of\ min\ range\ A_y\} \cap \{p\ of\ min\ range\ A_z\} \cap \{p\ of\ min\ range\ \varepsilon_x\} \cap \{p\ of\ min\ range\ \varepsilon_y\} \cap \{p\ of\ min\ range\ \varepsilon_z\} \cap \{p\ of\ min\ range\ A_{angle}\} \cap \{p\ of\ min\ range\ \varepsilon_{angle}\} \cap \{p\ of\ min\ range\ v_{A\,x,y,z}\}\big) \quad (6)$$

Define the constraints

$$\begin{gathered} A_{x\,min} \le A_x \le A_{x\,max} \\ A_{y\,min} \le A_y \le A_{max} \\ A_{z\,min} \le A_z \le A_{z\,max} \\ \varepsilon_{x\,min} \le \varepsilon_x \le \varepsilon_{x\,max} \\ \varepsilon_{y\,min} \le \varepsilon_y \le \varepsilon_{y\,max} \\ \varepsilon_{z\,min} \le \varepsilon_z \le \varepsilon_{z\,max} \\ \dot{q}_{imin\,x,y,z} \le \dot{q}_{i\,x,y,z} \le \dot{q}_{imax\,x,y,z} \\ q_{imin\,x,y,z} \le q_{i\,x,y,z} \le q_{imax\,x,y,z} \\ angle_{Amin} \le angle_A \le angle_{Amax} \\ angle_{\varepsilon min} \le angle_\varepsilon \le angle_{\varepsilon max} \end{gathered} \quad (7)$$

2) Define the algorithm to obtain the best solution of the robot's joints movements (mof):
3) Impose one time to origin t_i and time delay between each of joints, t_d the cycle time t_t and calculate all internal coordinates of each joints $q_i(t)$, $q'_I(t)$, $q''_I(t)$;
4) Determine *all relative velocity characteristics* $q_i(t_i, t_d)$, $q_i'(t_i, t_d)$, $q_i''(t_i, t_d)$;
5) Determine the characteristics of all absolute angular and linear accelerations:

$$\begin{gathered} f_1 = acc_x[q_i(t_i,t_d);\ \dot{q}_i(t_i,t_d), \ddot{q}_i(t_i,t_d)] \\ f_2 = acc_y[q_i(t_i,t_d);\ \dot{q}_i(t_i,t_d), \ddot{q}_i(t_i,t_d)] \\ f_3 = acc_z[q_i(t_i,t_d);\ \dot{q}_i(t_i,t_d), \ddot{q}_i(t_i,t_d)] \\ f_4 = arctg\frac{acc_z}{\sqrt{acc_x^2 + acc_y^2}} \end{gathered} \quad (8)$$

$$\begin{gathered} f_5 = eps_x[q_i(t_i,t_d);\ \dot{q}_i(t_i,t_d), \ddot{q}_i(t_i,t_d)] \\ f_6 = eps_y[q_i(t_i,t_d);\ \dot{q}_i(t_i,t_d), \ddot{q}_i(t_i,t_d)] \\ f_7 = eps_z[q_i(t_i,t_d);\ \dot{q}_i(t_i,t_d), \ddot{q}_i(t_i,t_d)] \\ f_8 = arctg\frac{eps_z}{\sqrt{eps_x^2 + eps_y^2}}; \end{gathered} \quad (9)$$

6) Determine *the range of angular and linear accelerations:*

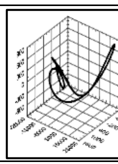
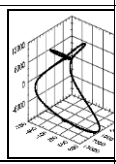
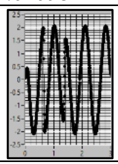
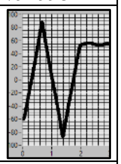
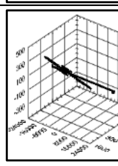
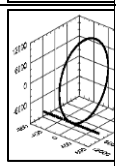
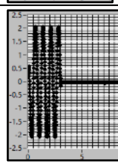
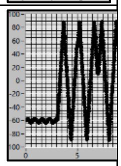
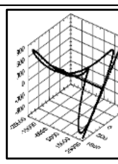
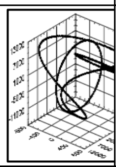
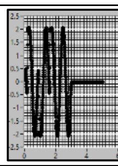
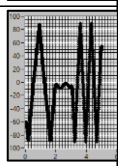
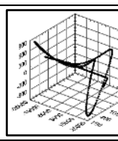
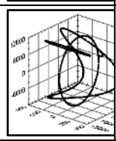
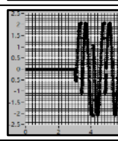
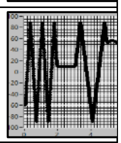
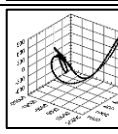
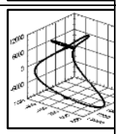
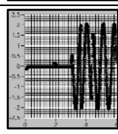
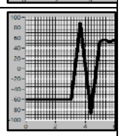
$$R_{acc\,x}, R_{acc\,y}, R_{acc\,z}, R_{acc\,angle}, R_{eps\,x}, R_{eps\,y}, R_{eps\,z}, R_{eps\,angle};$$

7) Determine *the times* t_i *and* t_d *what will be obtained the minimum of each range;*
8) Apply the (mof), or partial of complex function and determine the optimal values of the analyzed parameters t_i, t_d, L_i, q'_I.

B. Case Study of the Robot Arm Type

The analyse will be done after study of the synthetic report presented in the Tables II and III.

TABLE II: The Synthetic Report of the Studied Cases- 3D Variation of the Eps., Acc., Angle eps., Angle acc

Case study	Eps. space variation	Acc. space variation	Eps. angle space variation	Acc. angle space variation
0-0-0-0				
0-2-4-6				
0-3-3-0				
3-0-0-3				
3-3-0-0				

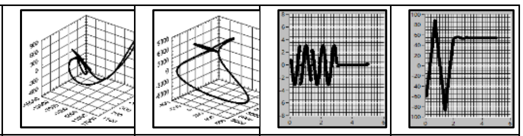
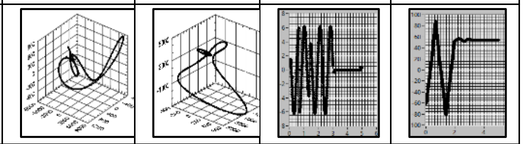
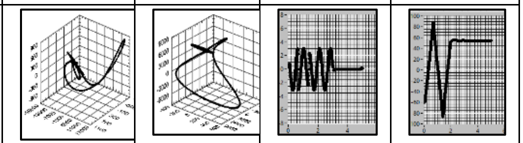
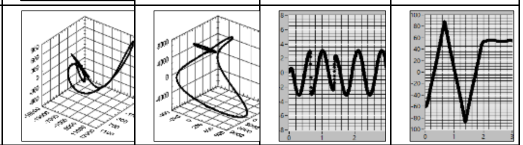
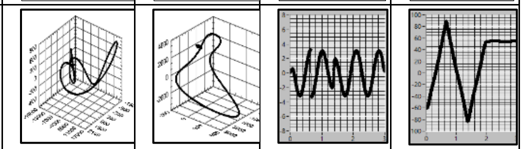
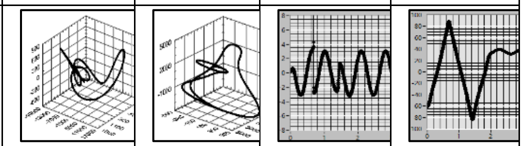
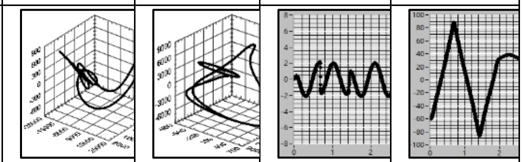
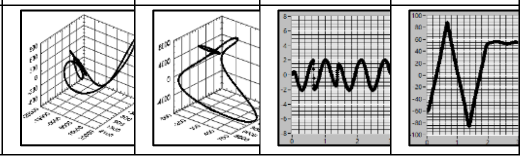
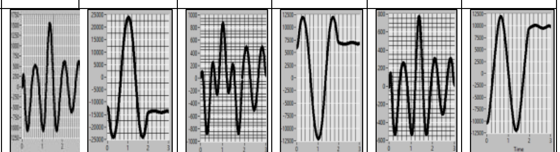
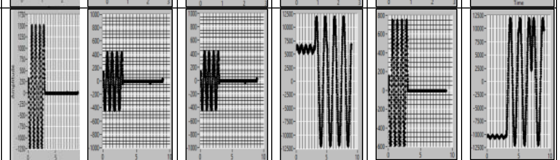
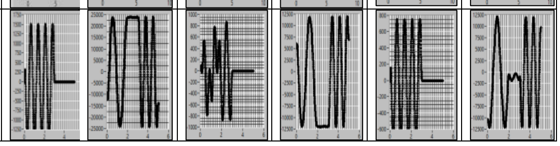
Case	
0-0-3-3 L_i=300	
0-0-3-3 L_1=100	
0-0-3-3 L_i=200	
0-0-0-0 L_i=200 v_i=200	
0-0-0-0 L_i=100 200, 300, 400,100 v_i=200	
0-0-0-0 L_i=100, 200, 300, 400,100 v_i=250, 220,200,80	
0-0-0-0 L_i=200, 300,300, 300,200 v_i=250, 220,200, 180	
0-0-0-0 L_i=200, 300,300, 300,200 v_i=250	

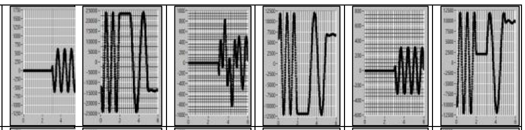
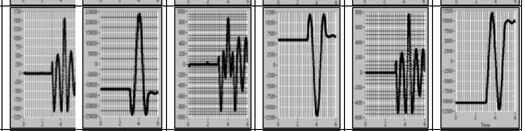
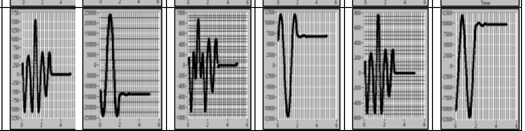
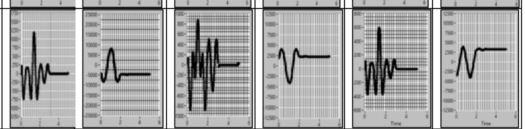
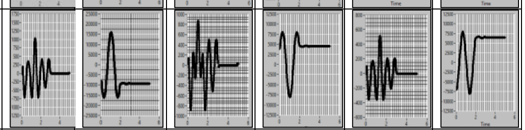
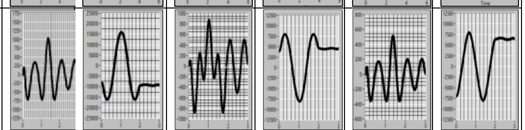
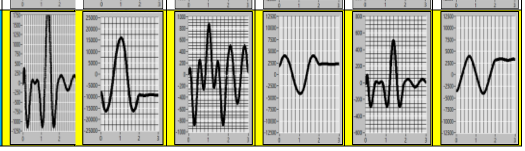
TABLE III: THE SYNTHETIC REPORT OF THE STUDIED CASES- VARIATION OF THE EPS., ACC., ANGLE EPS., ANGLE ACC

Case study	Eps.x / Eps.y / Eps.z / Acc.x / Acc.y / Acc.z
0-0-0-0	
0-2-4-6	
0-3-3-0	

To be analysed and to be compared between them, the synthetic results could be put in the form of the Table IV.

TABLE IV: THE SYNTHETIC RESULTS

Case Ponders p_i	Alure Eps. in the space (100)	Alure Acc. in the space (100)	Eps. angle min-max (100)	Acc. angle min-max (100)	Eps. x min-max (100)	Eps. y min-max (100)	Eps. z min-max (100)	Acc. x min-max (100)	Acc. y min-max (100)	Acc. z min-max (100)
0-0-0-0	2 loops	1 loop	4	170	2500	50000	1750	25000	1350	25000
0-2-4-6	1 loop	1 loop	4.2	175	2750	900	900	25000	1350	25000
0-3-3-0	2 loop	4 loops	4	180	2750	49000	1800	25000	1350	25000
3-0-0-3	1 loop	3 loops	4	175	1200	49000	1600	24000	1200	24000
3-3-0-0	2 loops	2 loops	4	170	2500	49000	1800	24000	1350	24000
0-0-3-3 L_i=300	2 loops	2 loops	6	180	2000	19000	1800	24000	1000	8000
0-0-3-3 L_1=100	2 loops	2 loops	12	170	2000	15000	1800	8000	1000	8000
0-0-3-3 L_i=200	2 loops	2 loops	6	180	1750	35000	1800	15200	800	15000
0-0-0-0 L_i=200 v_i=200	3 loops	2 loops	6	180	1750	30000	1700	15500	850	15000
0-0-0-0 L_i=100… v_i=200	3 loops	2 loops	6.5	170	1950	29500	1750	8000	800	7850
0-0-0-0 L_i=100… v_i=250…	3 loops	3 loops	7.5	175	3000	35000	1800	9000	950	8000
0-0-0-0 L_i=200… v_i=250…	3 loops	3 loops	4.5	175	3000	50000	1850	16000	1250	15500
0-0-0-0 L_i=200… v_i=250	3 loops	2 loops	4	175	3000	50000	1750	16000	1150	15300

Case	
3-0-0-3	
3-3-0-0	
0-0-3-3 L_i=300	
0-0-3-3 L_i=100	
0-0-3-3 L_i=200	
0-0-0-0 L_i=200 v_i=200	
0-0-0-0 L_i=100, 200, 300, 400,100 v_i=200	

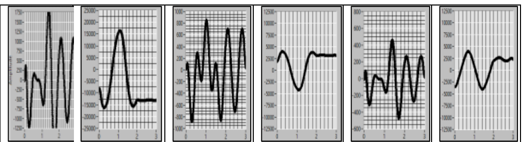
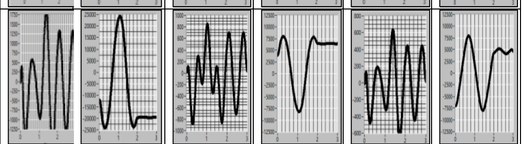
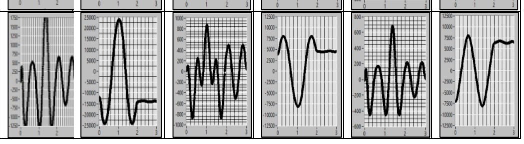
Case	
0-0-0-0 L_i=100, 200,300, 400,100 v_i=250, 220,200, 80	
0-0-0-0 L_i=200, 300,300, 300,200 v_i=250, 220,200, 180	
0-0-0-0 L_i=200, 300,300, 300,200 v_i=250	

TABLE V: THE RESULTS AFTER WERE DETERMINED THE POUNDER WITH NEUTROSOPHIC THEORY

Case	Alure Eps. in the space	Alure Acc. in the space	Eps. angle	Acc. angle	Eps. x	Eps. y	Eps. z	Acc. x	Acc. y	Acc. z	Rezults
p_i	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	
0-0-0-0	50	100	100	100	48	1,8	51,42	32	59,25	32	574,48
0-2-4-6	100	100	95,23	97,14	43,63	100	100	32	59,25	32	759,27
0-3-3-0	50	25	100	94,44	43,63	1,83	50	32	59,25	32	488,17
3-0-0-3	100	33	100	97,14	100	1,83	56,25	33,33	66,66	33,33	621,56
3-3-0-0	50	50	100	100	48	1,83	50	33,33	59,25	33,33	525,76
0-0-3-3	50	50	66,66	94,44	60	4,73	50	33,33	80	100	589,18
0-0-3-3	50	50	33,33	100	60	6	50	100	80	100	629,33
0-0-3-3	50	50	66,66	94,44	68,57	2,57	50	52,63	100	53,33	588,21
0-0-0-0	33	50	66,66	94,44	68,57	3	52,94	51,61	94,11	53,33	567,68
0-0-0-0	**33**	**50**	**61,53**	**100**	**61,53**	**3,05**	**51,42**	**100**	**100**	**101,91**	**662,46**
0-0-0-0	33	33	53,33	97,14	40	2,57	50	88,88	84,21	100	582,14
0-0-0-0	33	33	88,88	97,14	40	1,8	48,64	50	64	51,61	508,09
0-0-0-0	33	50	100	97,14	40	1,8	51,42	50	69,56	52,63	545,56

The values of the Table V will be calculate using the values from the Table IV with the maximal ranges of angular and linear space angle, space loops and values versus each Cartesian axes. The maximal value of the ponder is when the range variation is minimum and also the number of loops of the space vector of angular and linear acceleration is minimum. All others will be calculate by compare them with the minimum value and the maximal value of the ponder equal with 100. Consider that, all analyzed parameters are the same importance in a dynamic behavior of the robot and for that all parameters will have the same maximal ponders p_i=100. The best solution that obtained after applied the *mof* was the case when the movements were simultaneously (0-0-0-0) and the lengths of the bodies were are different 100, 200, 300, 400, 100 (in inch) and the relative velocity is the same 200grd/s (bold case -the Table V).

IV. CONCLUSION

The assisted research, proposed by this paper, with original contribution in modelling by 6x6 matrix form, and in the simulation with proper virtual LabVIEW instrumentation for the assisted research of the acceleration, open the way to the optimal assisted research in the future of the Kinematics and Dynamics for the different type of robots and for different robot's applications in singular, multi robot application, or in the cooperation manner of the action. The analyse of the acceleration is one of the most important problem that must be solved in the robot's kinematics. Positions, velocities, accelerations and jerks are the most important components in the dynamic behaviour equations and by known these will be possible to optimal choose the kinematic robot's parameters to obtain finally the goals in robotics: the reduction of the space errors of the end-effecter. The presented matrix equations to determine the linear and angular accelerations, the used mathematical algorithm, the virtual LabView instrumentation are generally and they could be applying in many other robotic applications.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

AO conducted the research and all mathematical model, algorithm and wrote the paper; SO analyzed the data and the English grammar; NM assured the experimental stand; NS work in the research of actual stage. All authors had approved the final version.

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REFERENCES

[1] R. Zhao, *Trajectory Planning and Control for Robot Manipulations Robotics*, Université Paul Sabatier - Toulouse III. English NNT: 2015.

[2] M. Brady, J. Hollerbach, T. Johnson, and T. Lozano-Perez, *Robot Motion, Planning and Control*, *The MIT Press*, Cambridge, Massachusetts.

[3] W. Khalil and E. Dombre, "Modelisation, identification et commande des robots," *Hermes*, vol. 56, 1999.

[4] L. Biagiotti and C. Melchiorri, "Trajectory planning for automatic machines and robots," *Springer Science & Business Media*, 2008.

[5] T. Kroger and F. M. Wahl, "Online trajectory generation: Basic concepts for instantaneous reactions to unforeseen events," *Robotics IEEE*, no. 1 94–111, 2010.

[6] O. Dahl and L. Nielsen, "Torque-limited path following by online trajectory time scaling," *Robotics and Automation IEEE Transactions*, no. 5, pp. 554–561.

[7] B. L. Cao and G. I. Dodds, "Time-optimal and smooth joint path generation for robot manipulators," in *Proc. Control '94 International Conference*, vol. 2, pp. 1122–1127, 1994.

[8] B. Cao, G. I. Dodds, and G. W. Irwin, "Constrained time-efficient and smooth cubic spline trajectory generation for industrial robots," *Control Theory and Applications IEEE Proceedings*, vol. 144, no. 5, pp. 467– 475, 1997.

[9] D. Constantinescu and E. A. Croft, "Smooth and time-optimal trajectory planning for industrial manipulators along specified paths," *Journal of Robotic Systems*, vol. 17, no. 5, pp. 233–249, 2000.

[10] Z. Shiller, "Time-energy optimal control of articulated systems with geometric path constraints," *Robotics and Automation IEEE Proceedings*, vol. 4, pp. 2680–2685, 1994.

[11] S. Macfarlane and E. A. Croft, "Jerk-bounded manipulator trajectory planning: design for real- time applications," *Robotics and Automation IEEE Transactions*, vol. 19, no. 1, pp. 42–52, 2003.

[12] W. S. Owen, E. A. Croft, and B. Benhabib, "Real-time trajectory resolution for dual robot machining," in *Proc. ICR'04 IEEE International Conference on Robotics and Automation*, vol. 5, pp. 4332–4337, 2004.

[13] J. Y. Kim, D. H. Kim, and S. R. Kim, "On-line minimum time trajectory planning for industrial manipulators," in *Proc. International Conference on Control, Automation and Systems*, pp. 36–40, 2007.

[14] R. H. Castain and Ri. P. Paul, "An on-line dynamic Trajectory Generator," *Journal of Robotics Research*, vol. 3, no. 1 68–72, 1984.

[15] S. Liu, "An on-line reference-trajectory generator for smooth motion of impulse- controlled industrial manipulator," in *Proc. Advanced Motion Control 7th International Workshop*, pp. 365–370, 2002.

[16] K. Ahn, W. K. Chung, and Y. Yourn, "Arbitrary states polynomial like trajectory (ASPOT) generation," in *Proc. Industrial Electronics Society 30th Annual Conference of IEEE IECON*, 2004.

[17] D. Y. Chwa, J. Kang, and J. Y. Choi, "Online trajectory planning of robot arms for interception of fast maneuvering object under torque and velocity constraints," *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions*, no. 6, pp. 831–843, 2005.

[18] R. Haschke, E. Weitnauer, and H. Ritter, "On-line planning of time-optimal, jerk-limited trajectories," in *Proc. Intelligent Robots and Systems IROS 2008-IEEE/RSJ International Conference*, pp. 3248–3253, 2008.

[19] X. Broquere, D. Sidobre, and I. Herrera-Aguilar, "Soft motion trajectory planner for service manipulator robot," in *Proc. Intelligent Robots and Systems IROS - IEEE/RSJ International Conference*, 2008.

[20] A. Olaru, S. Olaru, and N. Mihai, "Proper assisted research method solving of the robots inverse kinematics problem," *Applied Mechanics and Materials*, vol. 555, pp. 135-147, 2014.

[21] A. Olaru, S. Olaru, and L. Ciupitu, "Assisted research of the neural network by back propagation algorithm," in *Proc. OPTIROB 2010 International Conference Research Publishing Services Singapore Book*, pp. 194-200, 2010.

[22] S. Olaru, A. Oprean, and A. Olaru, "Assisted research of the new Bouc-Wen rheological damper," in *Proc. OPTIROB 2008*, pp. 143- 152, 2008.

[23] A. Olaru *et al*., "Optimizing the global dynamic compliance by using the smart damper and LabVIEW instrumentation," *Applied Mechanics and Materials*, vol. 186, pp. 26-34, 2010.

[24] A. Olaru and S. Olaru, "Research of the industrial robot's viscose global dynamic damper coefficient with LabVIEW instrumentation," 2006.

[25] A. Olaru, "Theoretical and experimental research of cinematic and dynamic behaviour of industrial robots," in *Proc. Annals of DAAAM for 2001,* pp. 333-334, 2001.

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