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- **Nov 19, 2013 News!** Vol.2, No.3 has been indexed by Crossref
- **Nov 15, 2013 News!** Vol.2, No.2 has been indexed by Crossref

General Information

- **ISSN:** 2010-3697
- **Frequency:** Bimonthly
- **DOI:** 10.7763/IJMO
- **Editor-in-Chief:** Prof. Adrian Olaru
- **Executive Editor:** Mr. Ron C. Wu
- **Abstracting/ Indexing:** Engineering & Technology Digital Library, ProQuest, Crossref, Electronic Journals Library, DOAJ, Google Scholar, EI (INSPEC, IET).

ISSN 2010-3697 IJMO International Journal of Modeling and Optimization Vol. 1, No. 1, April, 2011 www.ijmo.org IACSIT

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Proper Software Platform ROBO-PVAFM Applied in Robotics

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CONTENT

1. GENERALITY ABOUT THE EXISTING SOFTWARE PLATFORMS

- Was analysed the following software:

RoboNaut [1], WorkspaceLt [2], RoboticSimulation [3], SimRobot [4], NI-Robotics [5], Open Dynamics Engine [6], Bullet Physics [7], NVidia PhysX [8], DART [9], RoKiSim [10], RoboAnalyser [11] and ROS- Gazebo [12].

- After were analyzed these software platforms and some other papers from the same topics [13-29] we can do the following remarks:

(i) programs provide animation of various robotic applications without considering the cases what the variation of the forces and moment to be minimum;

(ii) researchers did not take into account the influence of the position of each joint of the robot on the dynamic behavior, respectively element-joint, or joint-element, Newton action-reaction forces;

(iii) researchers did not consider the influence of body size on inertia tensors and implicitly on dynamic behavior;

(iv) the velocity and acceleration analysis did not highlight both the angular and the linear velocities and accelerations for each joint of the robot as well as the way in which the parameters of the trapezoidal speed characteristics influence the speed variation;

(v) the influence of the movement mode respectively the simultaneous, successive or simultaneous- successive movement for various joints on the dynamic behavior was not taken into account;

(vi) the existing software platform did not include the study of the influence of the up or down movement, as well as of the robot movement with and without the manipulated object;

(vii) the influence of the bodies dimensions of the robots, as well as their material on the variation of the kinetic moment and implicitly on the dynamic behavior.

Compared with the analyzed software, the new proper platform **Robo-PVAFM introduce:**

- Used the highlights way in which show the structure of the robot with all Cartesian systems in each of the robot's joints;
- Used the bodies-joints and joints- bodies matrices to simplify the equilibrium of the action and reaction forces;
- Used the clusters, which define the type of movement, in various control options such as successive, simultaneous or their combinations, with the possibility of inserting break times in the programs;
- Used the calculus of the inertial tensors by define the dimensions, the material and the filling factor of each body;

By using the new proper **Robo-PVAFM** software platform will be relatively easy to determine the parameters of the speed characteristics to obtain the minimal variations of the forces and moments in the joints and also the optimal position of the joints.

2. PROPER MATRIX MATHEMATICAL MODEL IN POZITIONS, VELOCITIES, ACCELERATIONS, FORCES AND MOMENTS ANALYSE

that was transposed in the Labview proper software platform

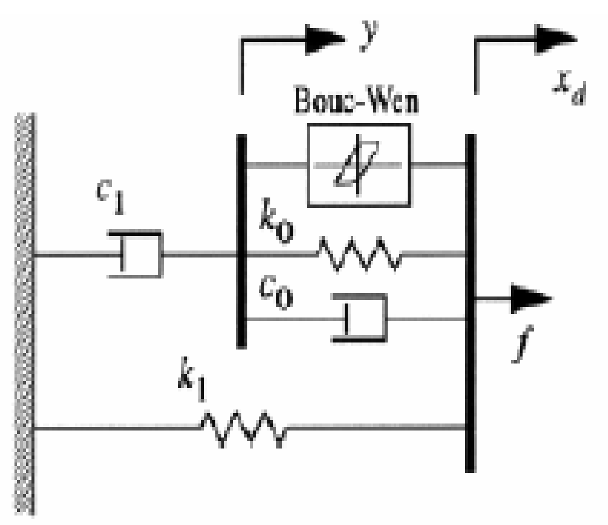
*** ROBO-PVAFM***

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

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

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

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



$$f = c_0(x' - y') + k_0(x - y) + k_1(x - x_0) + \alpha z$$

$$y' = \frac{1}{c_0 + c_1}[\alpha z + c_0 x' + k_0(x - y)]$$

$$z' = -\gamma |x' - y'| z |z|^{n-1} - \beta(x' - y')|z|^n + \delta(x' - y')$$

$$\alpha(i) = \alpha_3 i^3 + \alpha_2 i^2 + \alpha_1 i + \alpha_0$$

$$c_0(i) = c_{03} i^3 + c_{02} i^2 + c_{01} i + c_{00}$$

$$c_1(i) = c_{13} i^3 + c_{12} i^2 + c_{11} i + c_{10}$$

$$k_0(i) = k_{03} i^3 + k_{02} i^2 + k_{01} i + k_{00}$$

$$\delta = \sum \delta_{0i} \sin(2\pi \upsilon_i + \varphi_i)$$

$$\left(r_5^0\right) = \left(r_1^0\right) + \left[D_1^0\right]\left(r_2^1\right) + \left[D_2^0\right]\left(r_3^2\right) + \left[D_3^0\right]\left(r_4^3\right) + \left[D_4^0\right]\left(r_5^4\right)$$

$$D_4^0 = D_1^0 D_2^1 D_3^2 D_4^3$$

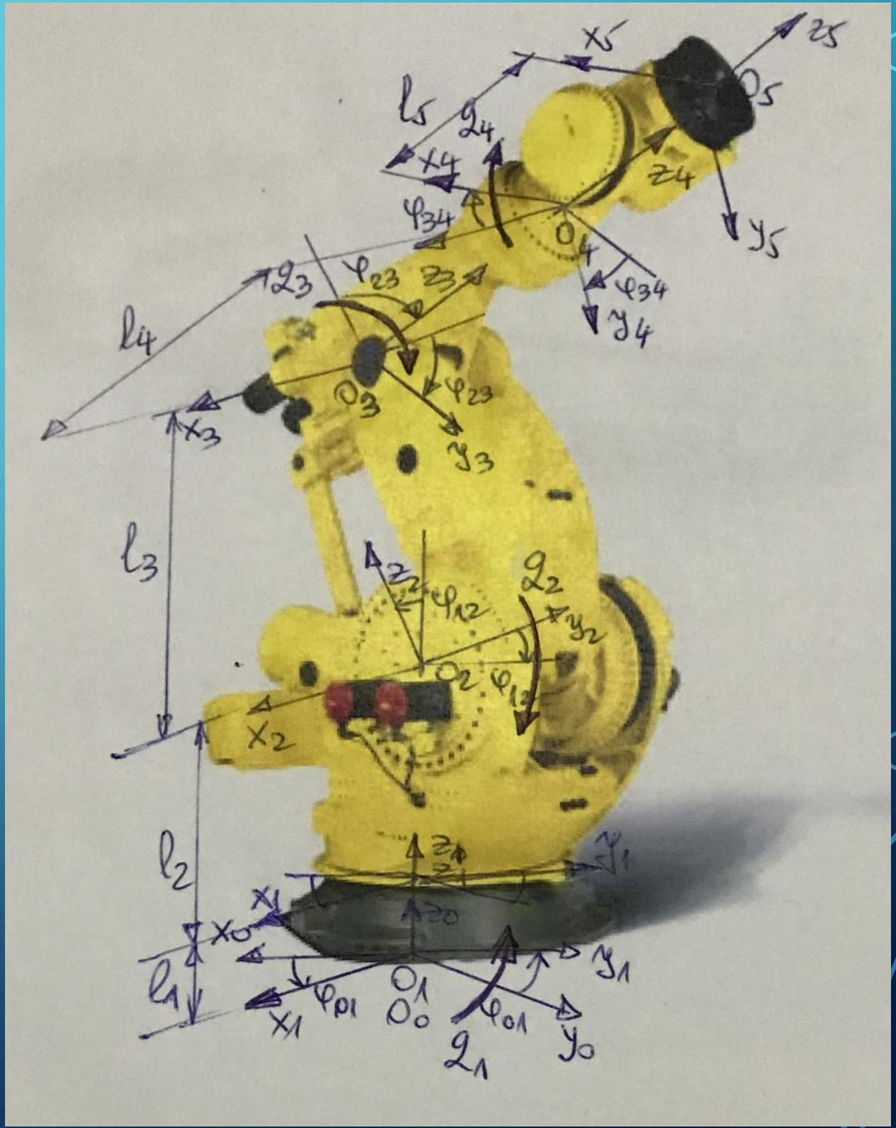
$$D_1^0 = \begin{bmatrix} c1 & -s1 & 0 \\ s1 & c1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, c1 = \cos(\varphi_{01} + \rho_1)$$

$$\begin{pmatrix} \omega_{5,0}^5 \\ v_{5,0}^5 \end{pmatrix} = T_4^5\left[T_3^4\left[T_2^3\left[T_1^2\begin{pmatrix} \omega_{1,0}^1 \\ v_{1,0}^1 \end{pmatrix} + \begin{pmatrix} \omega_{2,1}^2 \\ v_{2,1}^2 \end{pmatrix}\right]_1 + \begin{pmatrix} \omega_{3,2}^3 \\ v_{3,2}^3 \end{pmatrix}\right]_2 + \begin{pmatrix} \omega_{4,3}^4 \\ v_{4,3}^4 \end{pmatrix}\right]_3 + \begin{pmatrix} \omega_{5,4}^5 \\ v_{5,4}^5 \end{pmatrix}$$

$$\begin{pmatrix} \omega_{5,0}^0 \\ v_{5,0}^0 \end{pmatrix} = \begin{bmatrix} D_5^0 & 0 \\ 0 & D_5^0 \end{bmatrix}\begin{pmatrix} \omega_{5,0}^5 \\ v_{5,0}^5 \end{pmatrix}$$

$$D_5^0 = D_1^0 D_2^1 D_3^2 D_4^3 D_5^4$$

$$T_i^j = \begin{bmatrix} D_i^j & 0 \\ -D_i^j \hat{r}_j^i & D_i^j \end{bmatrix}$$

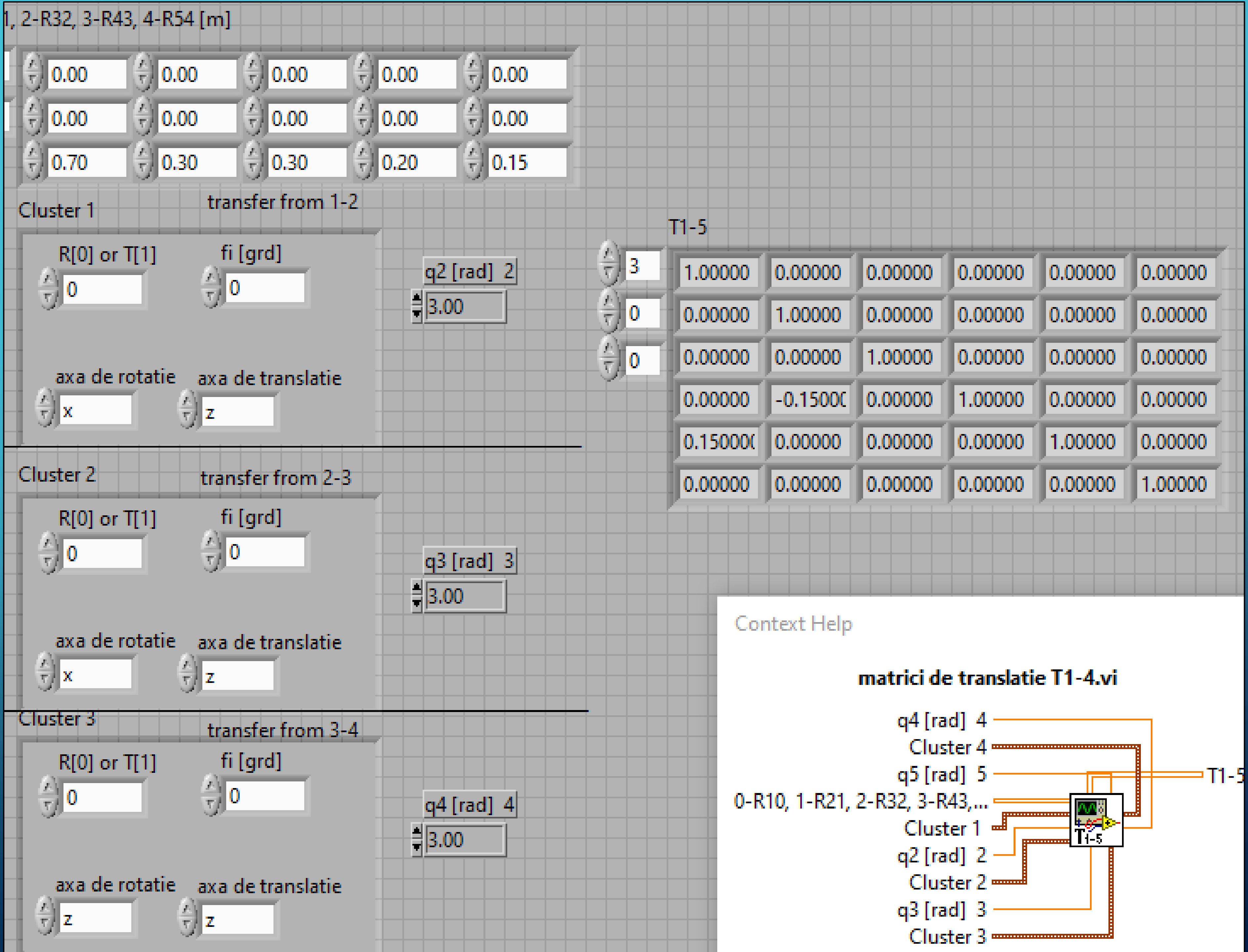


$$\begin{pmatrix} \varepsilon_{5,0}^{5} \\ a_{5,0}^{5} \end{pmatrix} = T_4^5 \left[T_3^4 \left[T_2^3 \left[T_1^2 \begin{pmatrix} \varepsilon_{1,0}^{1} \\ a_{1,0}^{1} \end{pmatrix} + S''(2) \right]_1 + S''(3) \right]_2 + S''(4) \right]_3 + S''(5)$$

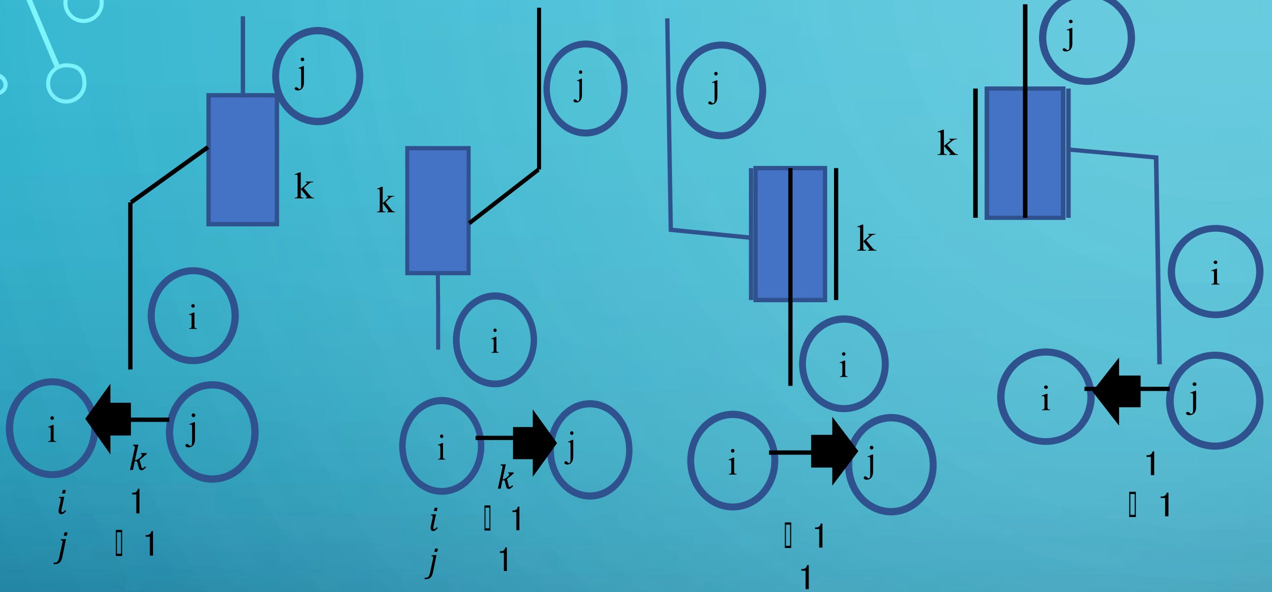
$$\begin{pmatrix} \varepsilon_{5,0}^{0} \\ a_{5,0}^{0} \end{pmatrix} = \begin{bmatrix} D_5^0 & 0 \\ 0 & D_5^0 \end{bmatrix} \begin{pmatrix} \varepsilon_{5,0}^{5} \\ a_{5,0}^{5} \end{pmatrix}$$

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

$$(a_{gi,0}^{0}) = \begin{pmatrix} \overline{D_1^0 a_{g1,0}^{1}} \\ \underline{D_2^0 a_{g2,0}^{2}} \\ D_3^0 a_{g3,0}^{3} \\ D_4^0 a_{g4,0}^{4} \end{pmatrix}, [z_u] = \begin{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot (1) & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot (-1) \end{bmatrix}$$

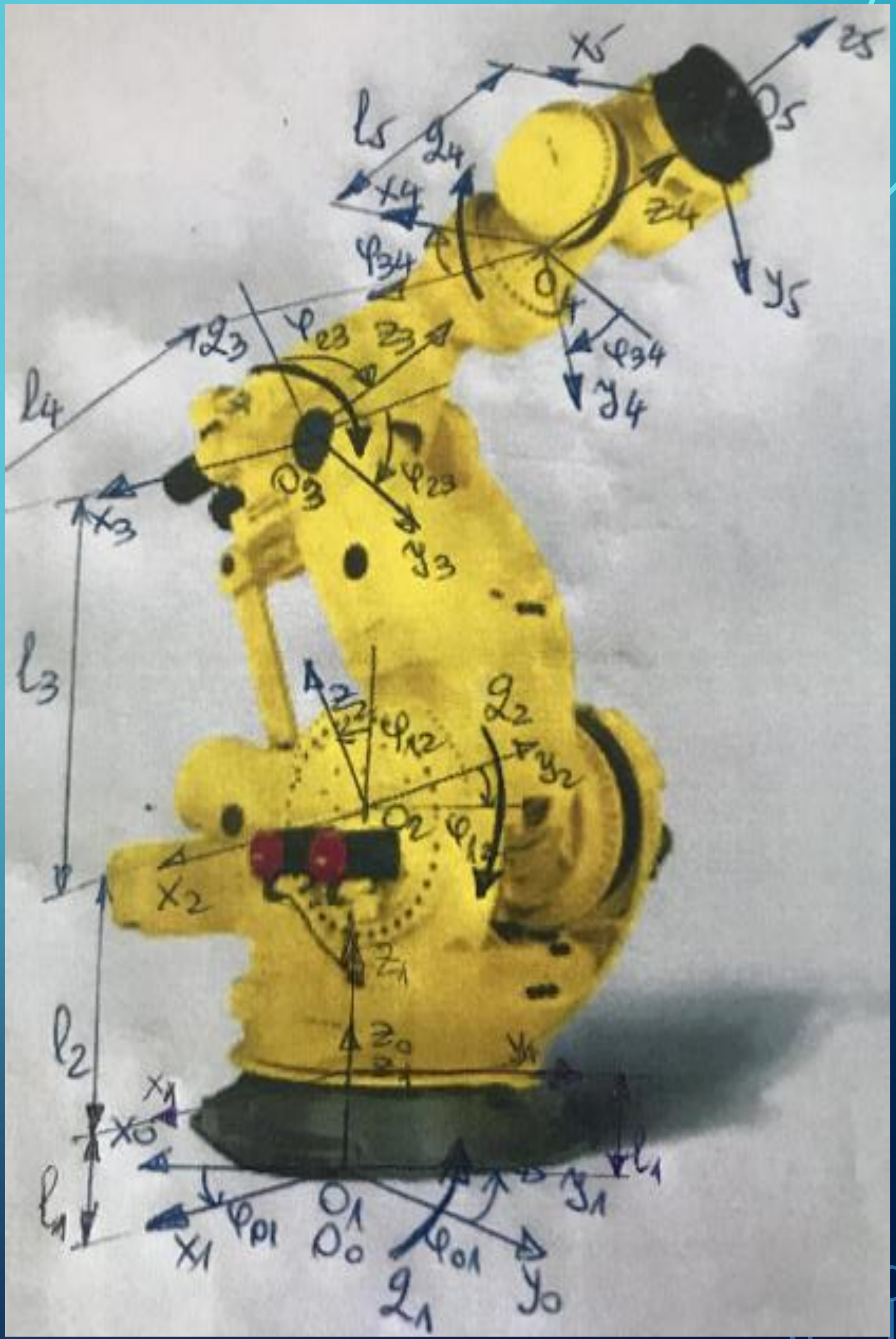


1, 2-R32, 3-R43, 4-R54 [m]
0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00
0.70 0.30 0.30 0.20 0.15
Cluster 1
transfer from 1-2
R[0] or T[1]
0
fi [grd]
0
axa de rotatie
x
axa de translatie
z
q2 [rad] 2
3.00
Cluster 2
transfer from 2-3
R[0] or T[1]
0
fi [grd]
0
axa de rotatie
x
axa de translatie
z
q3 [rad] 3
3.00
Cluster 3
transfer from 3-4
R[0] or T[1]
0
fi [grd]
0
axa de rotatie
z
axa de translatie
z
q4 [rad] 4
3.00
T1-5
3
0
0
1.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 1.00000 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 1.00000 0.00000 0.00000 0.00000
0.00000 -0.1500(0.00000 1.00000 0.00000 0.00000
0.15000(0.00000 0.00000 0.00000 1.00000 0.00000
0.00000 0.00000 0.00000 0.00000 0.00000 1.00000
Context Help
matrici de translatie T1-4.vi
q4 [rad] 4
Cluster 4
q5 [rad] 5
0-R10, 1-R21, 2-R32, 3-R43,...
Cluster 1
q2 [rad] 2
Cluster 2
q3 [rad] 3
Cluster 3
T1-5



$$[G] = \begin{bmatrix} -1 & +1 & 0 & 0 \\ 0 & -1 & +1 & 0 \\ 0 & 0 & -1 & -1 \\ 0 & 0 & 0 & +1 \end{bmatrix} \qquad [Z] = \begin{bmatrix} +1 & +1 & +1 & +1 \\ 0 & +1 & +1 & +1 \\ 0 & 0 & -1 & +1 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

Matrices of incidence bodies- joints [G] and joints- bodies [Z]



$$[Z_u] = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

Matrix [Zu]- incidence matrix Z joints-bodies for the space

Modified force- arm matrix [B^]

$$B = \begin{bmatrix} -b_{1,1} & b_{1,2} & 0 & 0 \\ 0 & -b_{2,2} & b_{2,3} & 0 \\ 0 & 0 & -b_{3,3} & -b_{3,4} \\ 0 & 0 & 0 & -b_{4,4} \end{bmatrix}$$

$$[B^{\wedge}] = \begin{bmatrix} 0 & b_{1,1z} & -b_{1,1y} & 0 & -b_{1,2z} & b_{1,2y} & \\ -b_{1,1z} & 0 & b_{1,1x} & b_{1,2z} & 0 & -b_{1,2x} & \cdots \\ b_{1,1y} & -b_{1,1x} & 0 & -b_{1,2y} & b_{1,2x} & 0 & \\ & \cdots & & \cdots & \cdots & & \cdots \end{bmatrix}$$

$$b_{i,k} = r_k - r_{gi}$$

$$\left(P^{0}\right)=[z_u]\left[(F^{0})\mp[m_u](a^{0}_{gi,0})\right]$$ - Active force matrix [P^0]

$$(F^{0})=\begin{pmatrix}\overline{D_1^{0}F_1^{1}}\\ D_2^{0}F_2^{2}\\ \hline D_3^{0}F_3^{3}\\ D_4^{0}F_4^{4}\end{pmatrix},[m_u]=\begin{bmatrix}\begin{bmatrix}1&0&0\\0&1&0\\0&0&1\end{bmatrix}[m_1] & 0 & 0\\ & \begin{bmatrix}1&0&0\\0&1&0\\0&0&1\end{bmatrix}[m_2] & \\ & 0 & [m_{4,5}]\end{bmatrix}$$

-Rezistive force [F^0]

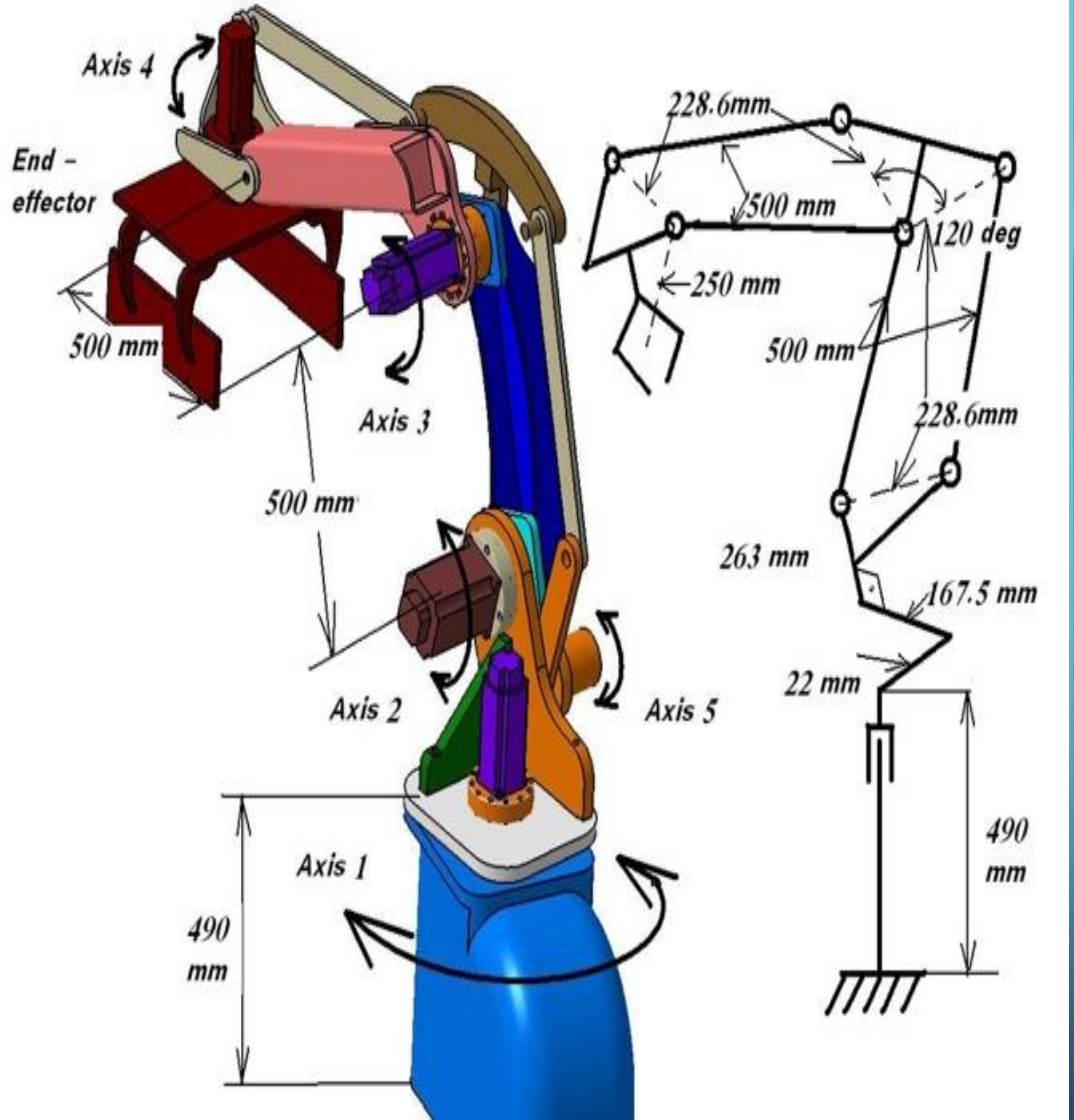
$$\left(M^{0}\right)=[z_u]\left[(M_R^0)+(K_{gi}'^{0})+[\hat{B}^0](P^0)\right]$$ - Active moment matrix [M^0]

$$(M_R^0)=\begin{pmatrix} \overline{D_1^0 M_1^1} \\ D_2^0 M_2^2 \\ \overline{D_3^0 M_3^3} \\ D_4^0 M_4^4 \end{pmatrix}, \left[\hat{B}^0\right]=\begin{bmatrix} [\hat{b}_{11}^0] & [\hat{b}_{12}^0] & [\hat{b}_{13}^0] & [\hat{b}_{14}^0] \\ [\hat{b}_{21}] & \begin{bmatrix} 0 & -b_{22z} & b_{22y} \\ b_{22z} & 0 & -b_{22x} \\ -b_{22y} & b_{22x} & 0 \end{bmatrix} & [\hat{b}_{23}^0] & [\hat{b}_{24}^0] \\ [\hat{b}_{31}^0] & [\hat{b}_{32}^0] & [\hat{b}_{33}^0] & [\hat{b}_{34}^0] \\ [\hat{b}_{41}^0] & [\hat{b}_{42}^0] & [\hat{b}_{43}^0] & [\hat{b}_{44}^0] \end{bmatrix}$$

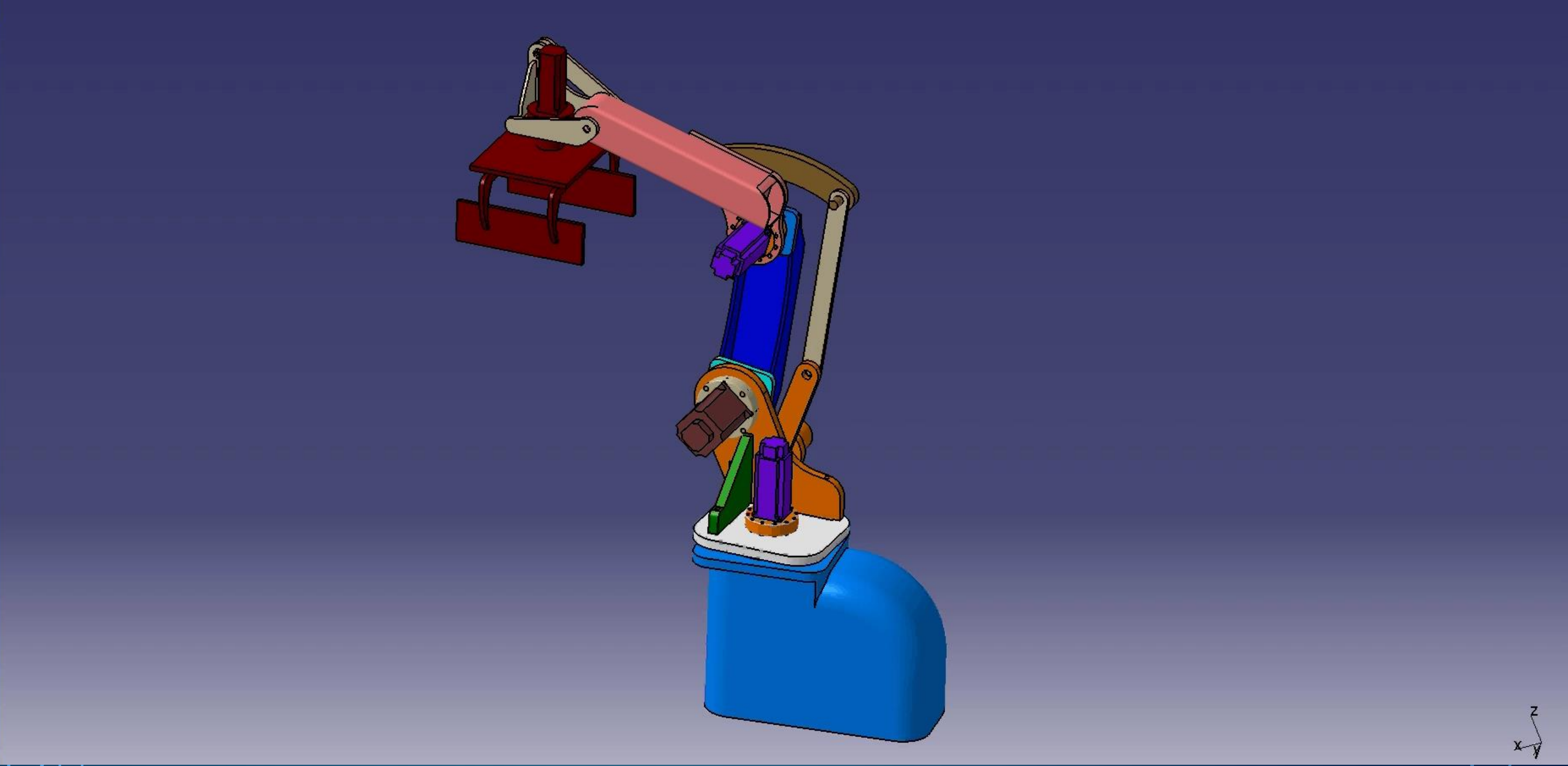
$$(b_{12}^0)=(r_2^0)-(r_{g1}^0)$$

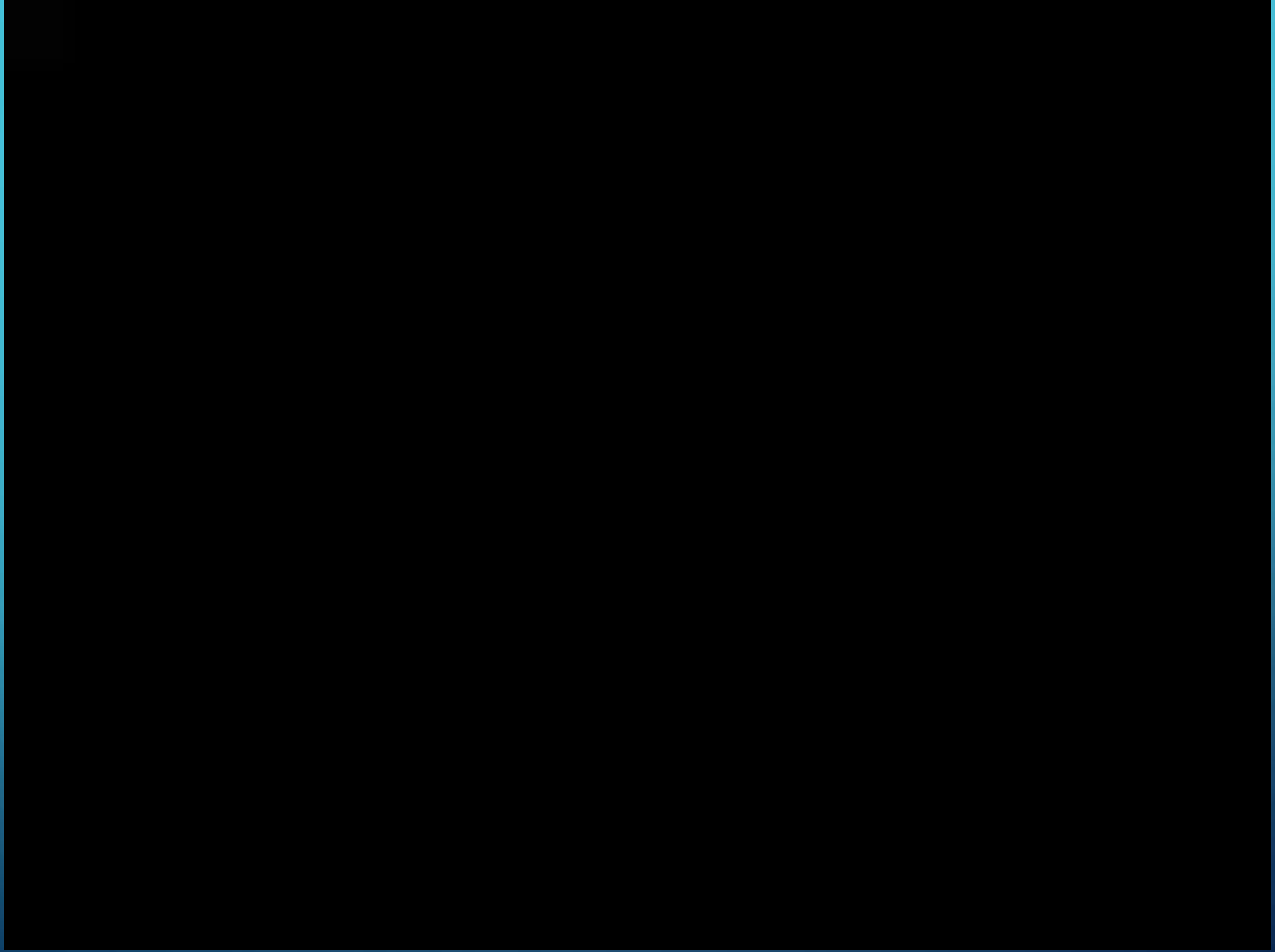
$$(K_{gi}'^{0})=\begin{pmatrix} \overline{D_1^0 K_{g1}'^{1}} \\ D_2^0 K_{g2}'^{2} \\ \overline{D_3^0 K_{g3}'^{3}} \\ D_4^0 K_{g4}'^{4} \end{pmatrix}, (K_{g2}'^{2})=[J_{g2}^2](\varepsilon_{2,1}^2)+[\hat{\omega}_{1,0}^2][J_{g2}^2](\omega_{2,1}^2)$$

- Variation of the cinetic moment (K'^0)


Axis 4
End - effector
500 mm
Axis 3
500 mm
Axis 2
Axis 5
Axis 1
490 mm
228.6mm
500 mm
120 deg
250 mm
500 mm
228.6mm
263 mm
167.5 mm
22 mm
490 mm


MIHAI





3. DESCRIPTION OF THE PROPER PLATFORM **ROBO-PVAFM**

The software platform contents the following components:

- the tab control of different type of robots that could be studied;
- the input data module for each type of robots;
- the module of the results that consist in the 2D and 3D characteristics for positions, velocities, accelerations, forces and moments including the space forces and moments position and angle with the base plan;

GUN type robot | ARM type robot | SCARA type robot | CARTESIAN type robot | DOUBLE PORTAL type robot

Cluster 1

R[0] or T[1]: 0 — fi [grd]: 0

axa de rotatie: z — axa de translatie: z

ROTATION OZ AXE

Cluster 2

R[0] or T[1]: 0 — fi [grd]: 0

axa de rotatie: x — axa de translatie: z

ROTATION OX AXE

Cluster 3

R[0] or T[1]: 0 — fi [grd]: 0

axa de rotatie: x — axa de translatie: z

ROTATION OX AXE

Cluster 4

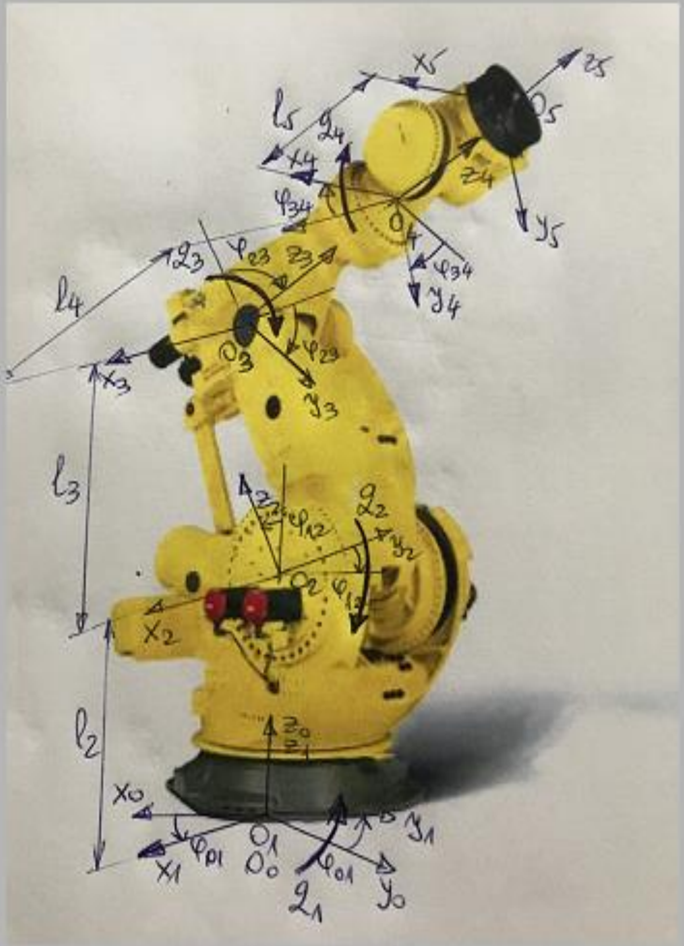
R[0] or T[1]: 0 — fi [grd]: 0

OREINTATION END-EFFECTER OZ AXE

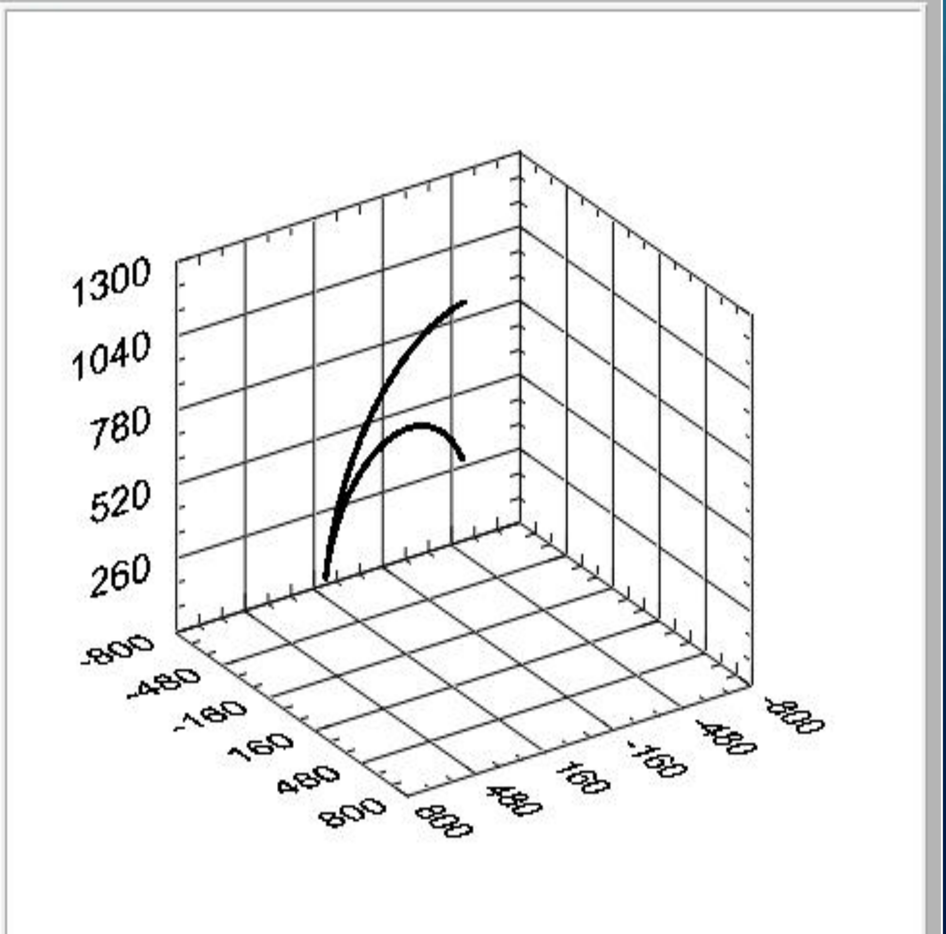
axa de rotatie: z — axa de translatie: z

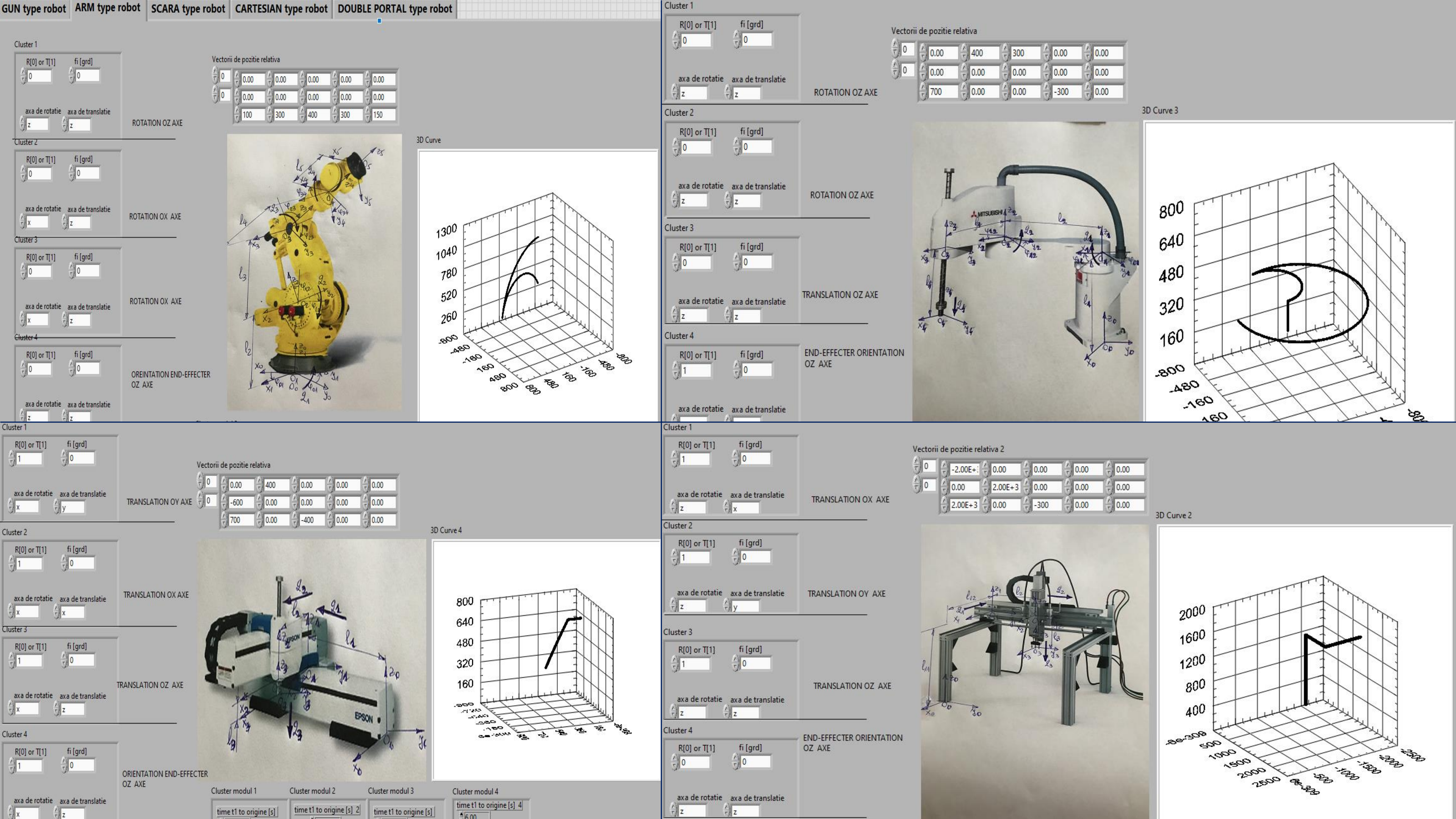
Vectorii de pozitie relativa

0	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00
	100	300	400	300	150

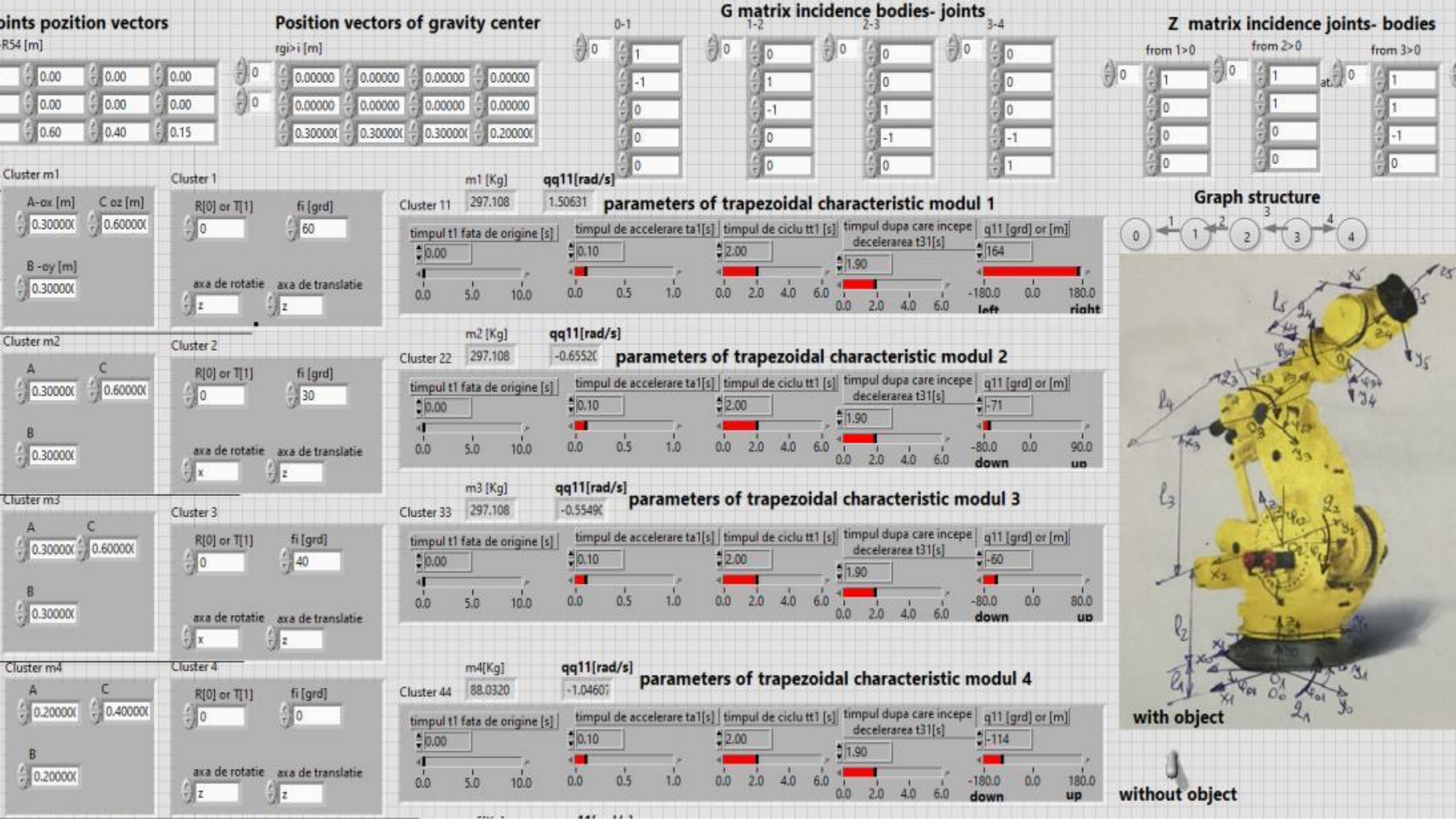


3D Curve





GUN type robot
ARM type robot
SCARA type robot
CARTESIAN type robot
DOUBLE PORTAL type robot
Cluster 1
R[0] or T[1]
fi [grd]
axa de rotatie
axa de translatie
ROTATION OZ AXE
Cluster 2
ROTATION OX AXE
Cluster 3
ROTATION OX AXE
Cluster 4
OREINTATION END-EFFECTER OZ AXE
Vectorii de pozitie relativa
3D Curve
Cluster 1
ROTATION OZ AXE
Cluster 2
ROTATION OZ AXE
Cluster 3
TRANSLATION OZ AXE
Cluster 4
END-EFFECTER ORIENTATION OZ AXE
Vectorii de pozitie relativa
3D Curve 3
MITSUBISHI
Cluster 1
TRANSLATION OY AXE
Cluster 2
TRANSLATION OX AXE
Cluster 3
TRANSLATION OZ AXE
Cluster 4
ORIENTATION END-EFFECTER OZ AXE
Vectorii de pozitie relativa
3D Curve 4
EPSON
Cluster modul 1
Cluster modul 2
Cluster modul 3
Cluster modul 4
time t1 to origine [s]
Cluster 1
TRANSLATION OX AXE
Cluster 2
TRANSLATION OY AXE
Cluster 3
TRANSLATION OZ AXE
Cluster 4
END-EFFECTER ORIENTATION OZ AXE
Vectorii de pozitie relativa 2
3D Curve 2



oints pozition vectors
R54 [m]
Position vectors of gravity center
rgi>i [m]
G matrix incidence bodies- joints
0-1
1-2
2-3
3-4
Z matrix incidence joints- bodies
from 1>0
from 2>0
from 3>0
Cluster m1
A-ox [m]
C oz [m]
B -oy [m]
Cluster 1
R[0] or T[1]
fi [grd]
axa de rotatie
axa de translatie
m1 [Kg]
qq11[rad/s]
Cluster 11
parameters of trapezoidal characteristic modul 1
timpul t1 fata de origine [s]
timpul de accelerare ta1[s]
timpul de ciclu tt1 [s]
timpul dupa care incepe decelerarea t31[s]
q11 [grd] or [m]
left
right
Graph structure
Cluster m2
Cluster 2
m2 [Kg]
Cluster 22
parameters of trapezoidal characteristic modul 2
down
up
Cluster m3
Cluster 3
m3 [Kg]
Cluster 33
parameters of trapezoidal characteristic modul 3
Cluster m4
Cluster 4
m4[Kg]
Cluster 44
parameters of trapezoidal characteristic modul 4
with object
without object

- The input data module, for each type of robot, contents the following:
  - a cluster with data on the parallelepiped dimensions of each robot body, a filling coefficient and the respective body material, for the most accurate determination of the mass and the calculation of the inertia tensors and the variation of the kinetic moments;
  - a cluster with data on the axes of motion, the direction of motion and the angle of the home position of each body, data necessary for the generation of dual linear and angular velocity vectors, the generation of transfer matrices, 3x3 type, from one Cartesian system to another, necessary for position analysis and 6x6 type matrices required for velocity and acceleration analysis;
  - cluster with trapezoidal characteristics data for each robot module comprising the time from the origin, the acceleration time with respect to the maximum value of the Jerk, the cycle time, the time after which the deceleration of the movement starts as well as the linear or angular value of the movement, parameters necessary for the calculation and observance of the maximum allowed velocity for each module and of the calculations all other parameters in the kinematic and dynamic analysis;

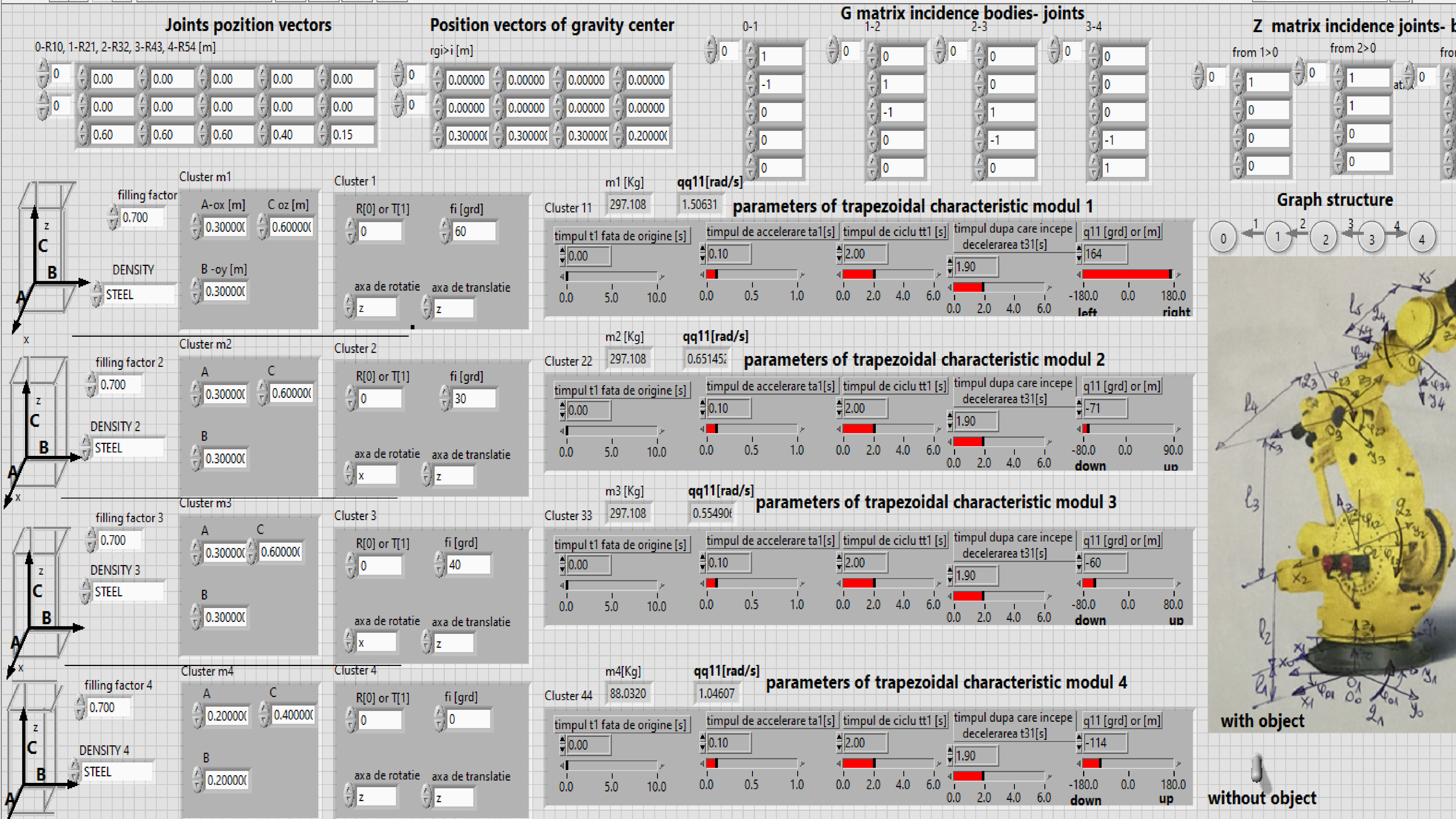
- data regarding the column matrices for the generation of incidence matrix bodies-joints **G** and joints-bodies **Z**, matrices necessary for determining the forces in the joints;
- the graph associated with each structure, necessary to define the previous column matrices;
- the scheme of the robot with the coordinate axis systems for each joint, with the representation of the movement of the current Cartesian system compared to the previous one (5th class mechanisms, ensuring a single degree of mobility);
- button for selecting the existence of the object to be handled.

Advantages to use this platform

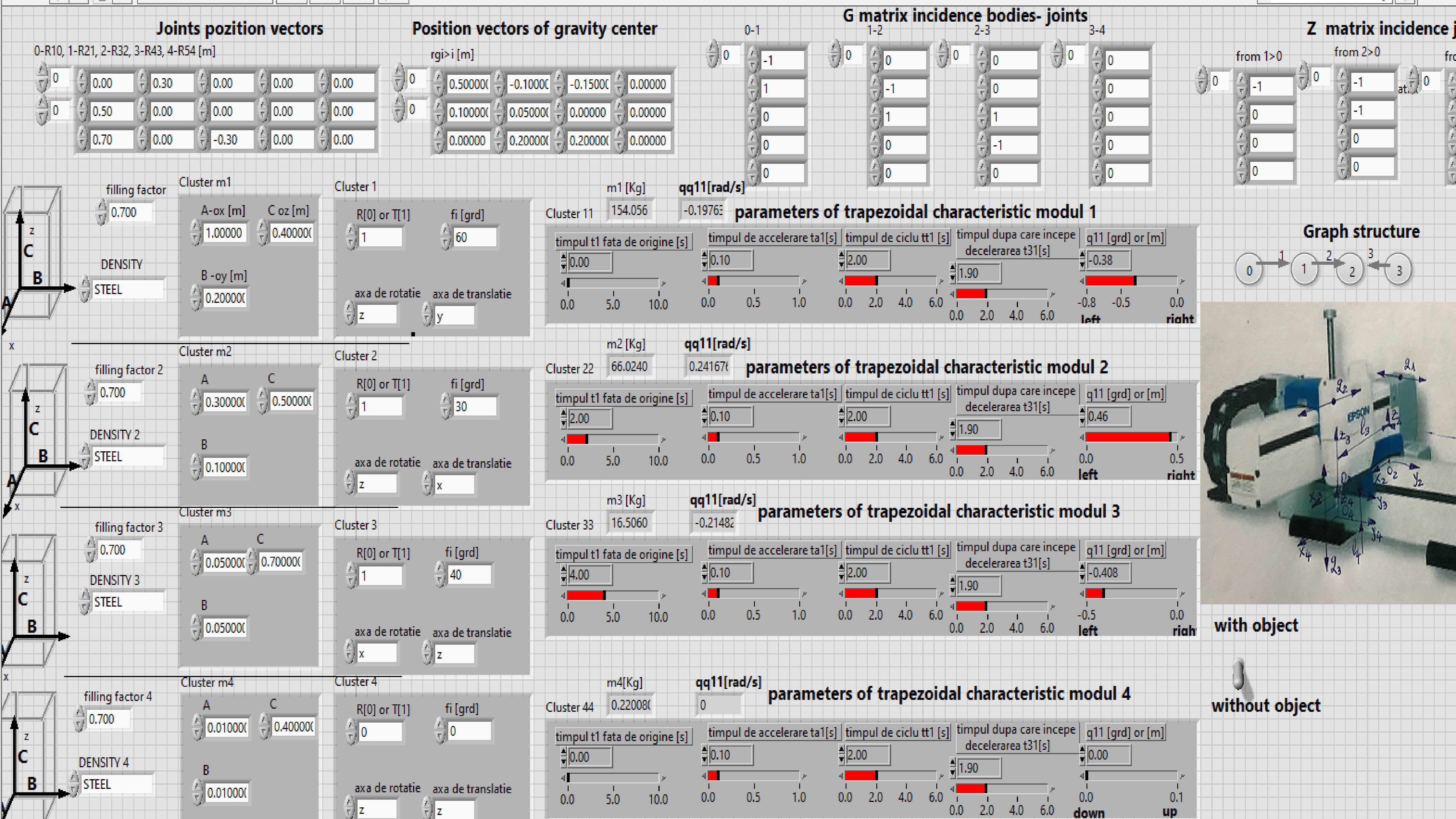
- (i) this platform cover the possibility to analyse the variation of positions (P), velocities (V), accelerations (A), forces (F) and moments (M) in different conditions movements: successive, simultaneously or combination of them;
- (ii) the platform, by using the matrices of the incidence body-joints ***G*** and matrix of the incidence joints- bodies ***Z***, cover the analyse of the joints position to the dynamic behaviour;
- (iii) influence of presence or absence of the manipulated object in end- effecter;
- (iv) the influence of the change of the body's material and dimensions to the dynamic behaviour was analysed;
- (v) by using the cluster for each trapezoidal characteristics with the velocities parameters is possible to analysis haw influence each of them the dynamic behaviour;

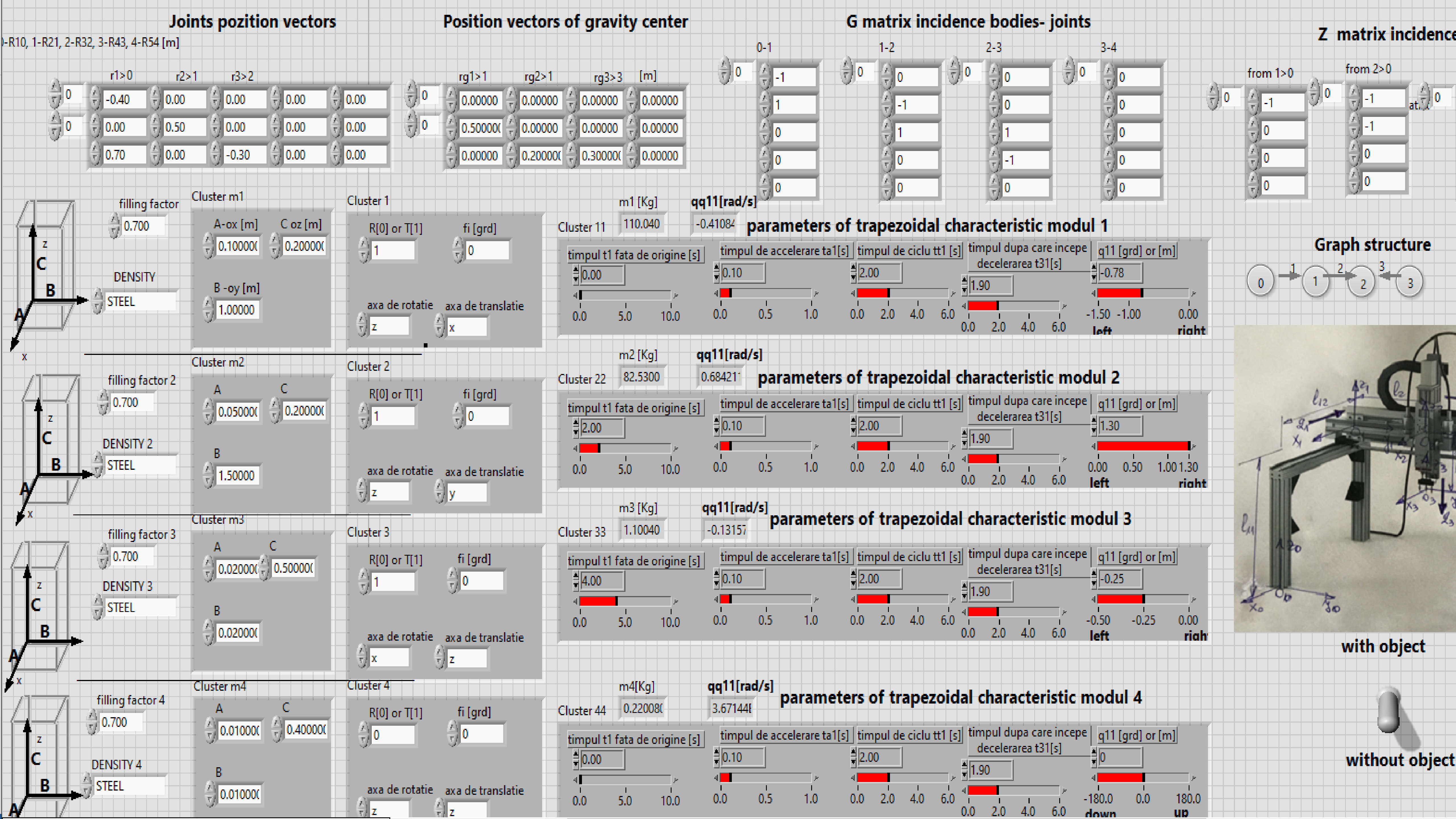
- (vi) the platform offers the possibility to see haw will be influenced each dynamic parameters by the constructive and functional parameters;
- (vii) the platform could be used to perform the inertia tensor of each robot's module;
- (viii) the platform cover the assisted analyse of the following robots types: Arm, Scale, Cartesian, Portal and Gun.

In the future, this platform will be designed for the analyse of inverse kinematics (IK), direct dynamics (DD), multi robots application and for the animation of them.

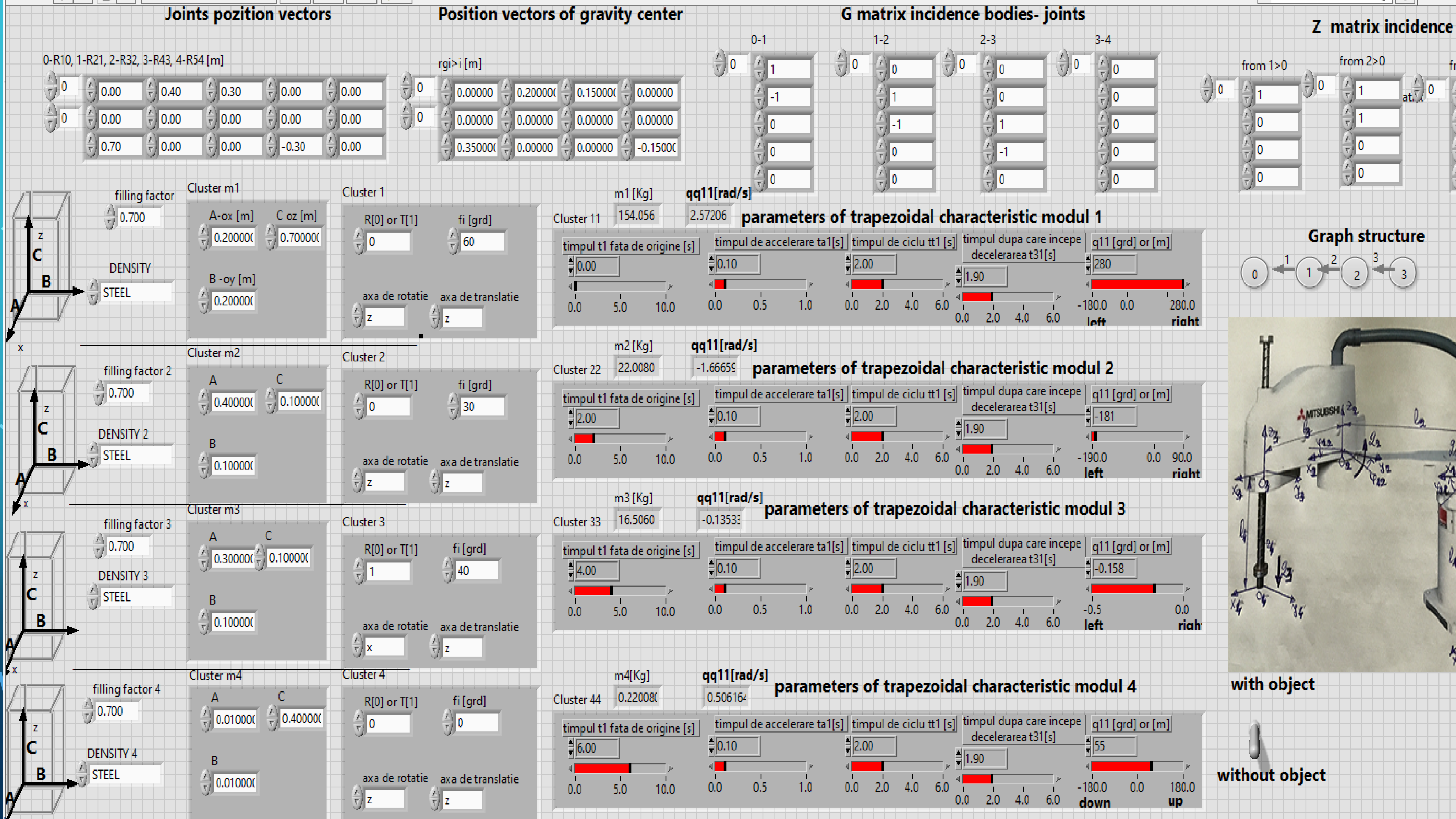


Joints pozition vectors
0-R10, 1-R21, 2-R32, 3-R43, 4-R54 [m]
0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00
0.60 0.60 0.60 0.40 0.15
Position vectors of gravity center
rgi>i [m]
0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000
G matrix incidence bodies- joints
0-1
1-2
2-3
3-4
Z matrix incidence joints-
from 1>0
from 2>0
Cluster m1
filling factor
0.700
DENSITY
STEEL
A-ox [m]
C oz [m]
B -oy [m]
Cluster 1
R[0] or T[1]
fi [grd]
60
axa de rotatie
axa de translatie
Cluster 11
m1 [Kg]
297.108
qq11[rad/s]
1.50631
parameters of trapezoidal characteristic modul 1
timpul t1 fata de origine [s]
timpul de accelerare ta1[s]
timpul de ciclu tt1 [s]
timpul dupa care incepe decelerarea t31[s]
q11 [grd] or [m]
0.00
0.10
2.00
1.90
164
left
right
Cluster m2
filling factor 2
0.700
DENSITY 2
STEEL
Cluster 2
30
Cluster 22
m2 [Kg]
297.108
qq11[rad/s]
parameters of trapezoidal characteristic modul 2
-71
down
up
Cluster m3
filling factor 3
0.700
DENSITY 3
STEEL
Cluster 3
40
Cluster 33
m3 [Kg]
297.108
qq11[rad/s]
parameters of trapezoidal characteristic modul 3
-60
down
up
Cluster m4
filling factor 4
0.700
DENSITY 4
STEEL
Cluster 4
0
Cluster 44
m4[Kg]
88.0320
qq11[rad/s]
1.04607
parameters of trapezoidal characteristic modul 4
-114
down
up
Graph structure
with object
without object


Joints pozition vectors
0-R10, 1-R21, 2-R32, 3-R43, 4-R54 [m]
0.00 0.30 0.00 0.00 0.00
0.50 0.00 0.00 0.00 0.00
0.70 0.00 -0.30 0.00 0.00
Position vectors of gravity center
rgi>i [m]
0.50000(-0.1000(-0.1500(0.00000
0.10000(0.05000(0.00000 0.00000
0.00000 0.20000(0.20000(0.00000
G matrix incidence bodies- joints
0-1 1-2 2-3 3-4
-1 0 0 0
1 -1 0 0
0 1 1 0
0 0 -1 0
0 0 0 0
Z matrix incidence j
from 1>0 from 2>0
-1 -1
0 -1
0 0
0 0
filling factor
0.700
DENSITY
STEEL
Cluster m1
A-ox [m] C oz [m]
1.00000 0.40000(
B -oy [m]
0.20000(
Cluster 1
R[0] or T[1] fi [grd]
1 60
axa de rotatie axa de translatie
z y
m1 [Kg] qq11[rad/s]
Cluster 11 154.056 -0.19763
parameters of trapezoidal characteristic modul 1
timpul t1 fata de origine [s] 0.00
timpul de accelerare ta1[s] 0.10
timpul de ciclu tt1 [s] 2.00
timpul dupa care incepe decelerarea t31[s] 1.90
q11 [grd] or [m] -0.38
left right
Graph structure
0 1 2 3
filling factor 2
0.700
DENSITY 2
STEEL
Cluster m2
A C
0.30000(0.50000(
B
0.10000(
Cluster 2
R[0] or T[1] fi [grd]
1 30
axa de rotatie axa de translatie
z x
m2 [Kg] qq11[rad/s]
Cluster 22 66.0240 0.24167(
parameters of trapezoidal characteristic modul 2
timpul t1 fata de origine [s] 2.00
timpul de accelerare ta1[s] 0.10
timpul de ciclu tt1 [s] 2.00
timpul dupa care incepe decelerarea t31[s] 1.90
q11 [grd] or [m] 0.46
left right
EPSON
filling factor 3
0.700
DENSITY 3
STEEL
Cluster m3
A C
0.05000(0.70000(
B
0.05000(
Cluster 3
R[0] or T[1] fi [grd]
1 40
axa de rotatie axa de translatie
x z
m3 [Kg] qq11[rad/s]
Cluster 33 16.5060 -0.21482
parameters of trapezoidal characteristic modul 3
timpul t1 fata de origine [s] 4.00
timpul de accelerare ta1[s] 0.10
timpul de ciclu tt1 [s] 2.00
timpul dupa care incepe decelerarea t31[s] 1.90
q11 [grd] or [m] -0.408
left righ
with object
without object
filling factor 4
0.700
DENSITY 4
STEEL
Cluster m4
A C
0.01000(0.40000(
B
0.01000(
Cluster 4
R[0] or T[1] fi [grd]
0 0
axa de rotatie axa de translatie
z z
m4[Kg] qq11[rad/s]
Cluster 44 0.22008(0
parameters of trapezoidal characteristic modul 4
timpul t1 fata de origine [s] 0.00
timpul de accelerare ta1[s] 0.10
timpul de ciclu tt1 [s] 2.00
timpul dupa care incepe decelerarea t31[s] 1.90
q11 [grd] or [m] 0.00
down up

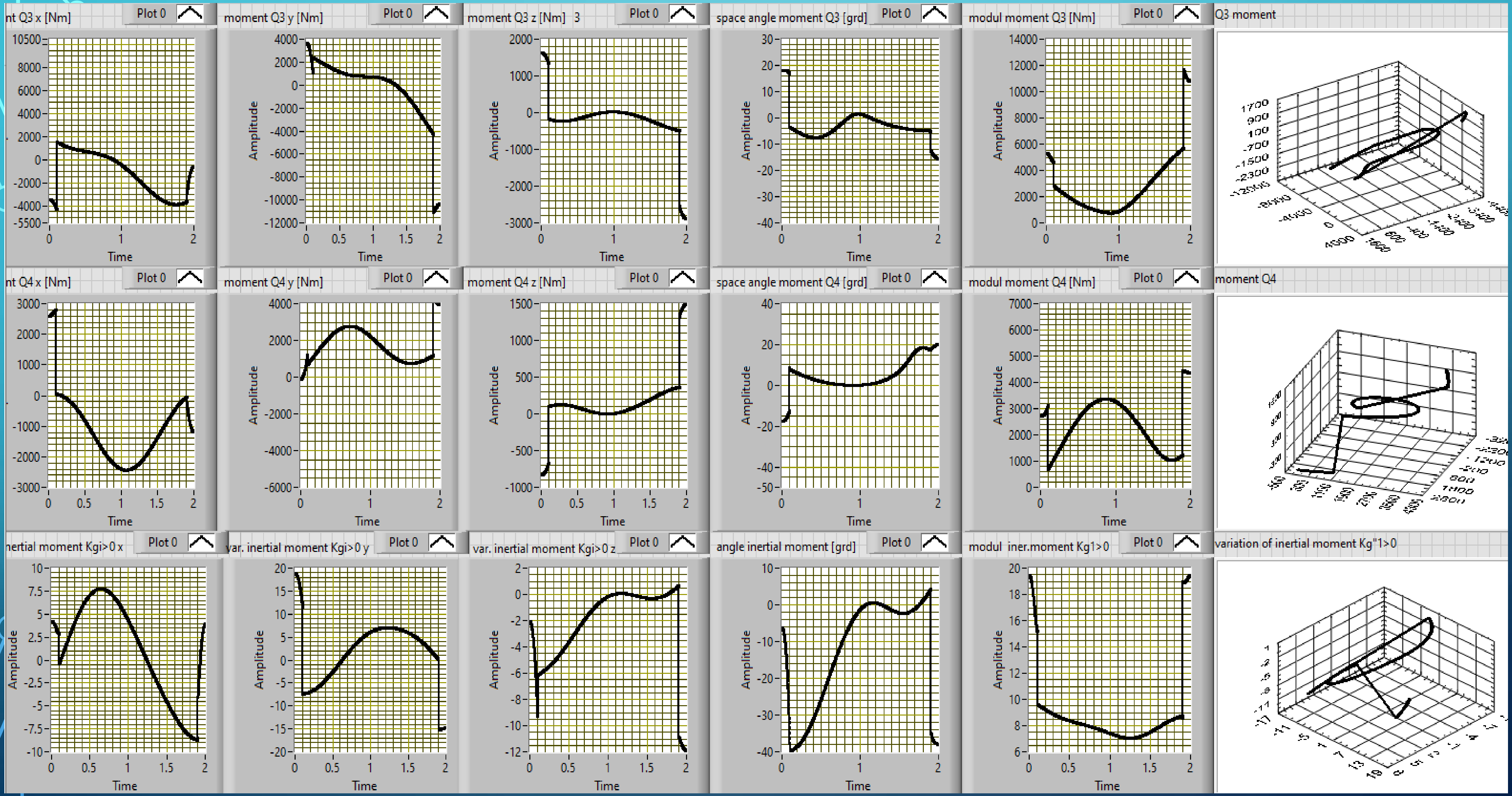


Joints pozition vectors
)-R10, 1-R21, 2-R32, 3-R43, 4-R54 [m]
r1>0
r2>1
r3>2
-0.40
0.00
0.70
0.50
-0.30
Position vectors of gravity center
rg1>1
rg2>1
rg3>3
[m]
0.00000
0.50000(
0.20000(
0.30000(
G matrix incidence bodies- joints
0-1
1-2
2-3
3-4
Z matrix incidence
from 1>0
from 2>0
filling factor
0.700
DENSITY
STEEL
Cluster m1
A-ox [m]
C oz [m]
0.10000(
0.20000(
B -oy [m]
1.00000
Cluster 1
R[0] or T[1]
fi [grd]
axa de rotatie
axa de translatie
m1 [Kg]
110.040
qq11[rad/s]
-0.41084
Cluster 11
parameters of trapezoidal characteristic modul 1
timpul t1 fata de origine [s]
timpul de accelerare ta1[s]
timpul de ciclu tt1 [s]
timpul dupa care incepe decelerarea t31[s]
q11 [grd] or [m]
0.00
0.10
2.00
1.90
-0.78
left
right
Graph structure
filling factor 2
DENSITY 2
Cluster m2
0.05000(
1.50000
Cluster 2
m2 [Kg]
82.5300
0.68421
Cluster 22
parameters of trapezoidal characteristic modul 2
1.30
filling factor 3
DENSITY 3
Cluster m3
0.02000(
0.50000(
Cluster 3
m3 [Kg]
1.10040
-0.13157
Cluster 33
parameters of trapezoidal characteristic modul 3
4.00
-0.25
with object
filling factor 4
DENSITY 4
Cluster m4
0.01000(
0.40000(
Cluster 4
m4[Kg]
0.22008(
3.67144
Cluster 44
parameters of trapezoidal characteristic modul 4
down
up
without object

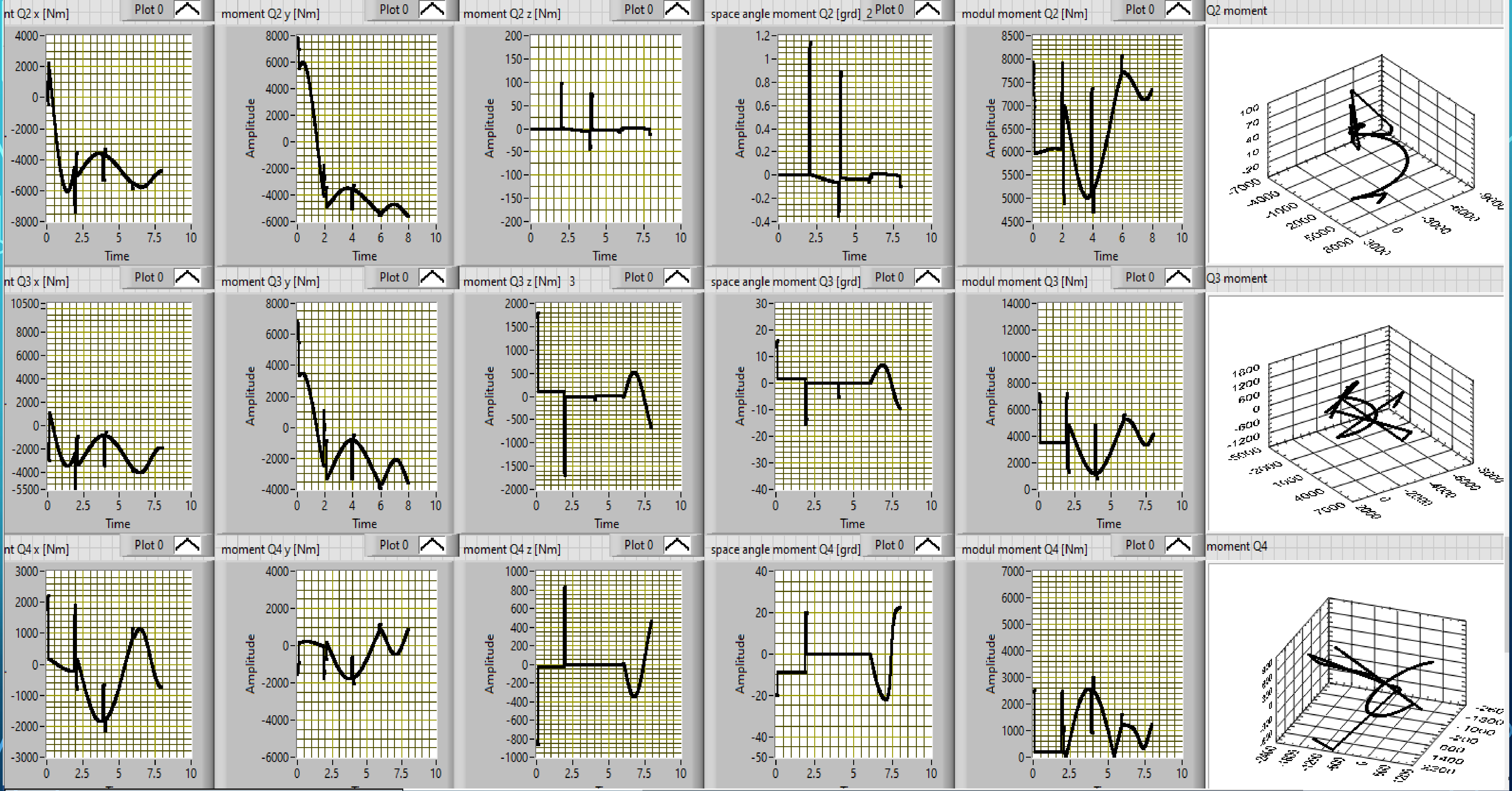


Joints pozition vectors
0-R10, 1-R21, 2-R32, 3-R43, 4-R54 [m]
0.00 0.40 0.30 0.00 0.00
0.00 0.00 0.00 0.00 0.00
0.70 0.00 0.00 -0.30 0.00
Position vectors of gravity center
rgi>i [m]
0.00000 0.20000 0.15000 0.00000
0.00000 0.00000 0.00000 0.00000
0.35000 0.00000 0.00000 -0.15000
G matrix incidence bodies- joints
0-1
1-2
2-3
3-4
Z matrix incidence
from 1>0
from 2>0
Graph structure
with object
without object
filling factor
DENSITY
STEEL
Cluster m1
A-ox [m]
C oz [m]
B -oy [m]
Cluster 1
R[0] or T[1]
fi [grd]
axa de rotatie
axa de translatie
m1 [Kg]
154.056
qq11[rad/s]
2.57206
Cluster 11
parameters of trapezoidal characteristic modul 1
timpul t1 fata de origine [s]
timpul de accelerare ta1[s]
timpul de ciclu tt1 [s]
timpul dupa care incepe decelerarea t31[s]
q11 [grd] or [m]
filling factor 2
DENSITY 2
Cluster m2
Cluster 2
m2 [Kg]
22.0080
-1.66659
Cluster 22
parameters of trapezoidal characteristic modul 2
filling factor 3
DENSITY 3
Cluster m3
Cluster 3
m3 [Kg]
16.5060
-0.13533
Cluster 33
parameters of trapezoidal characteristic modul 3
filling factor 4
DENSITY 4
Cluster m4
Cluster 4
m4[Kg]
0.22008
0.50616
Cluster 44
parameters of trapezoidal characteristic modul 4
left
right
down
up
MITSUBISHI

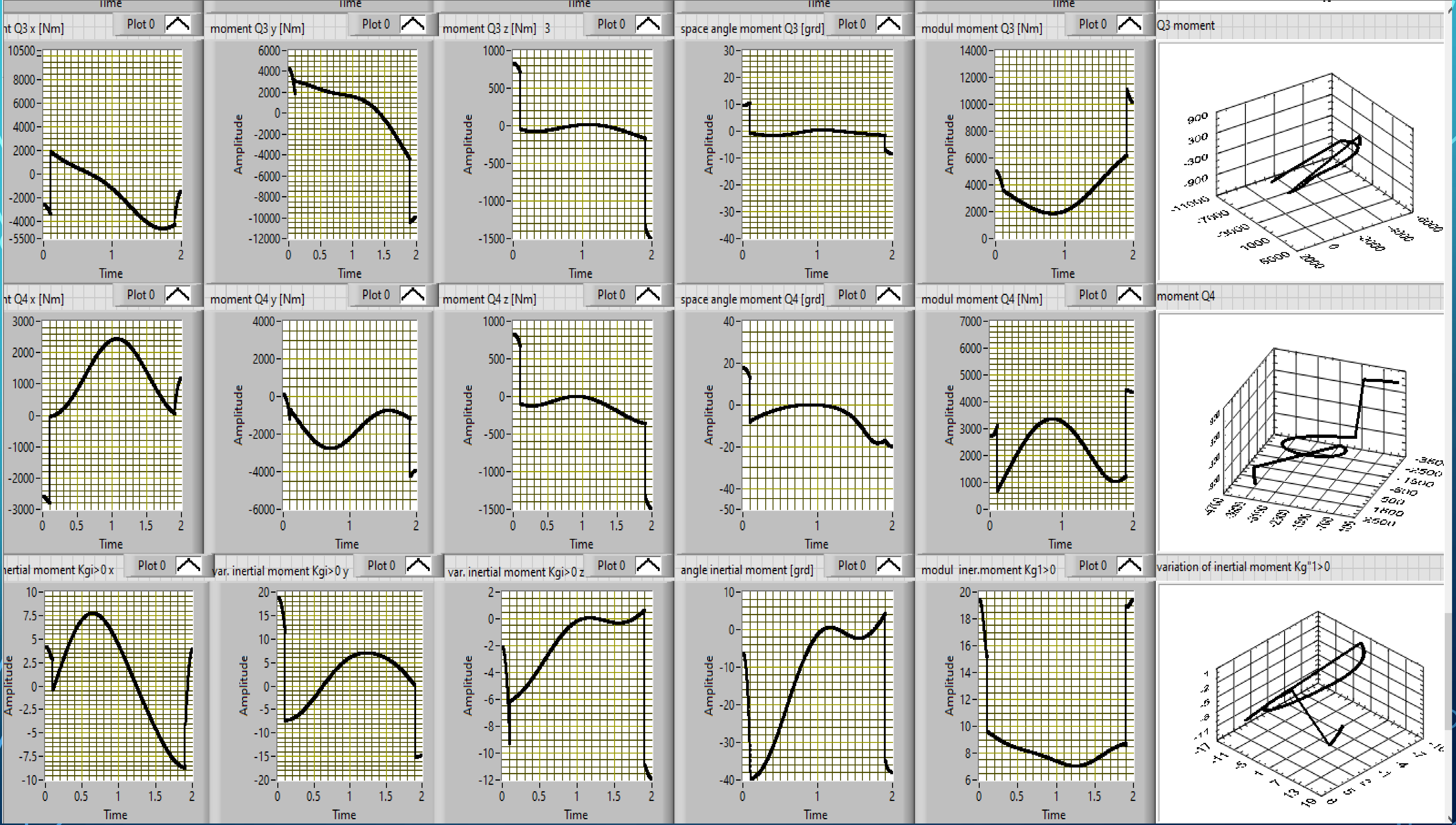
SOME OF THE RESULTS OF THE ASSISTED ANALYSE



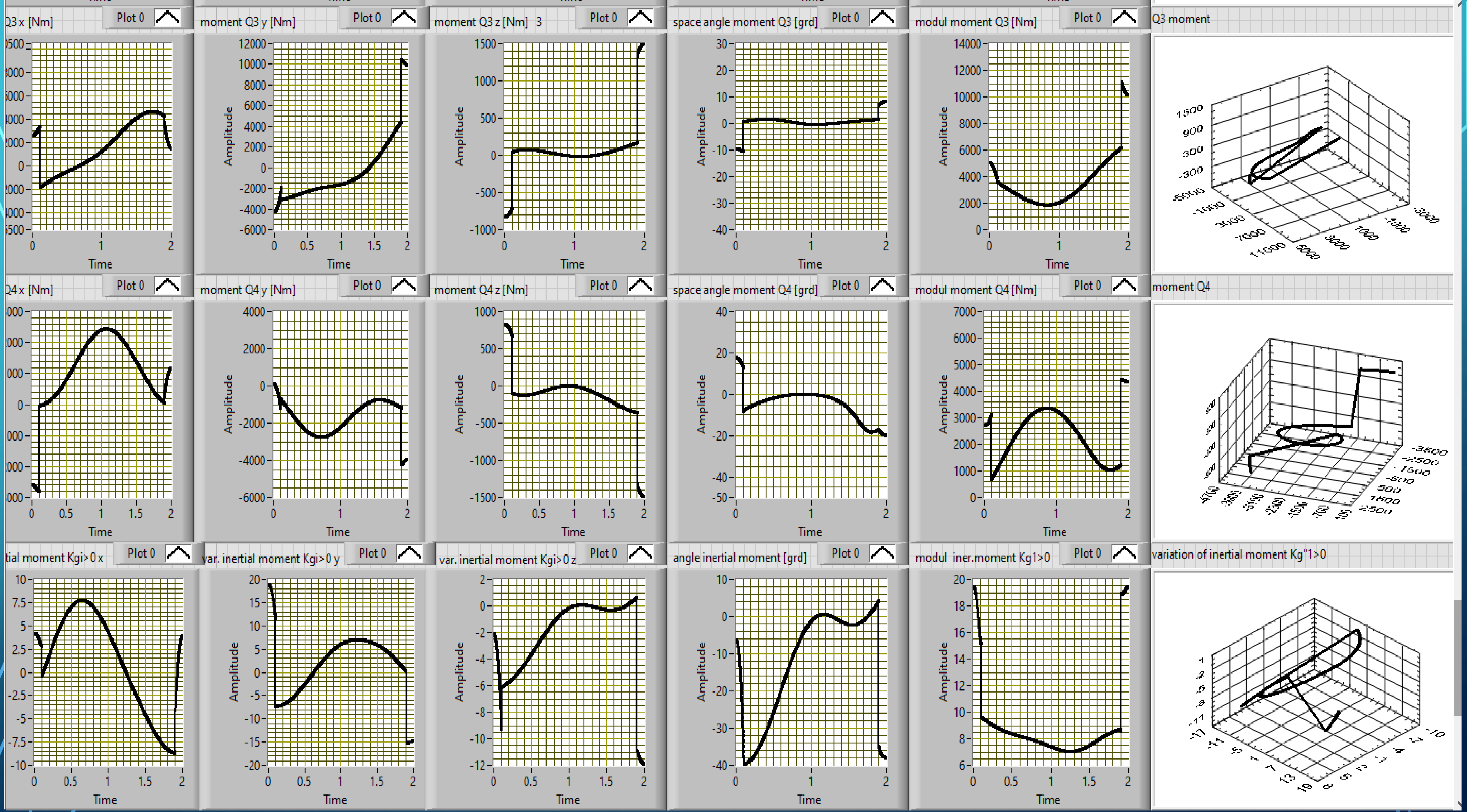
characteristics of the moments in joint 3 and 4, and variation of the kinetic moment in the simultaneously movements



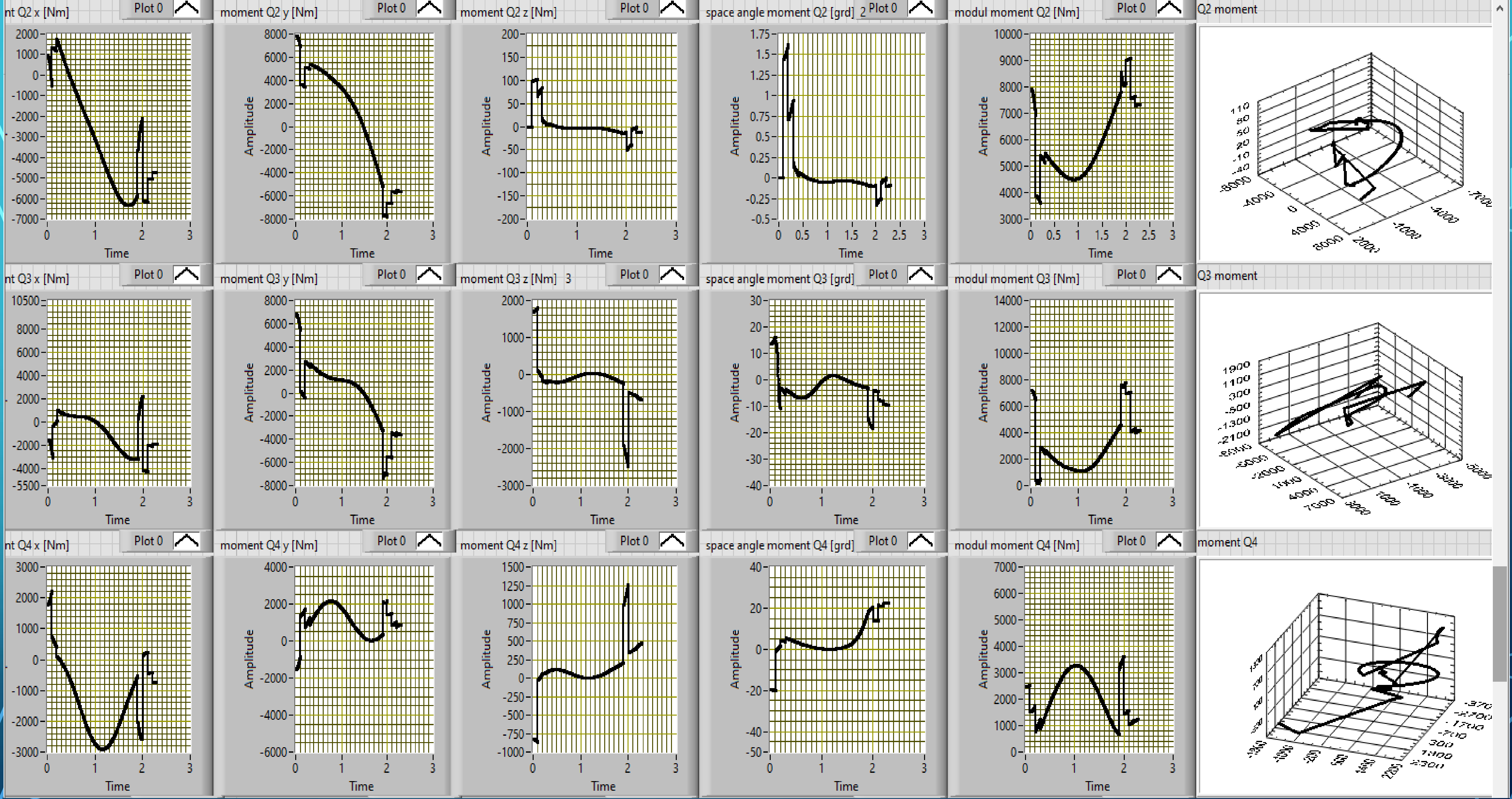
characteristics of the moments in joint 3 and 4, and variation of the kinetic moment in the successive movements.



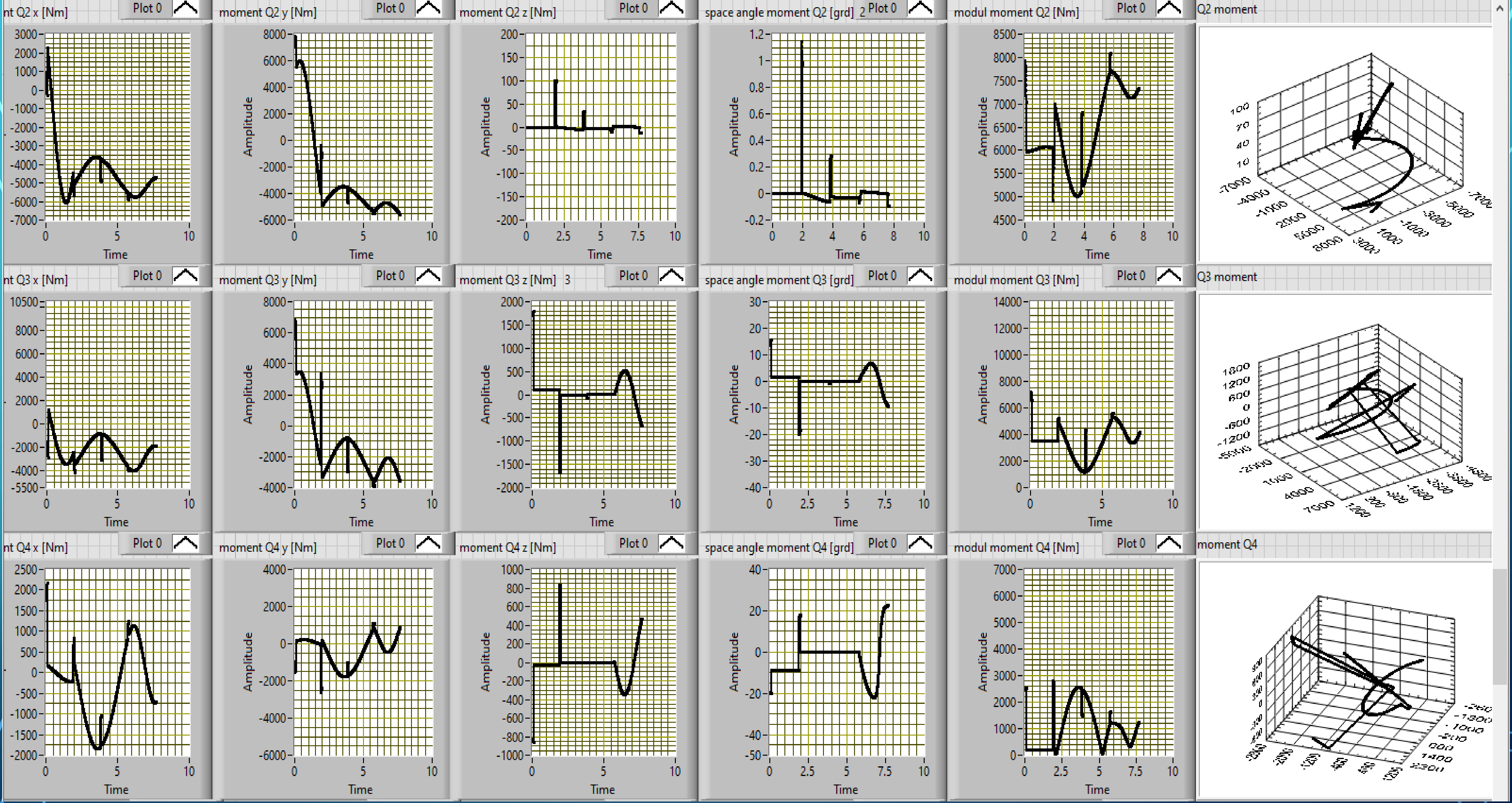
Was changed the pozition of the joints 2,3,and4 in the matrices G and Z



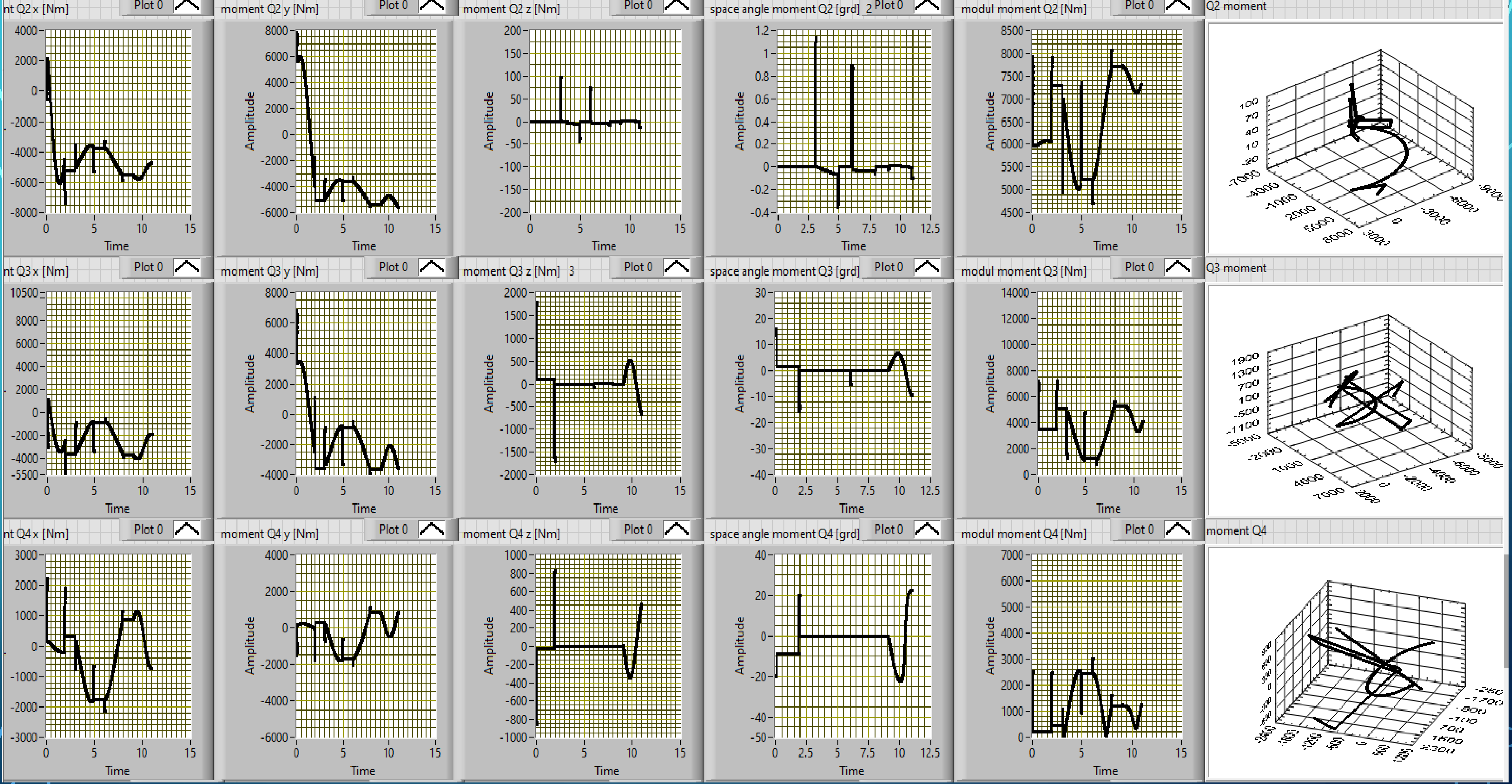
Was changed in initial pozition of the joints 2,3,and4



characteristics of the moments in joint 3 and 4, and variation of the kinetic moment in the successive after acceleration time 0.1s and simultaneously movements.



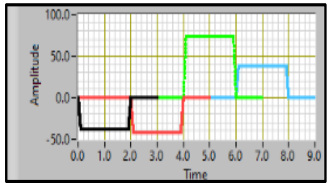
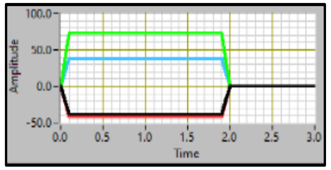
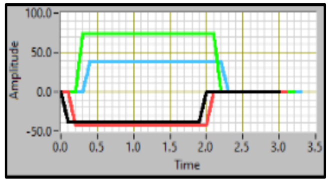
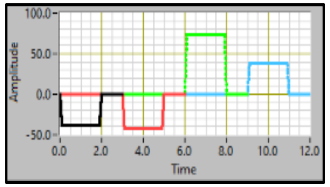
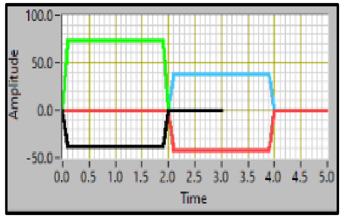
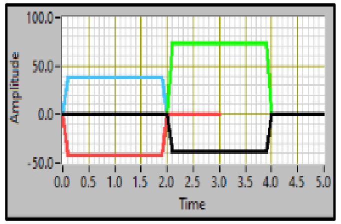
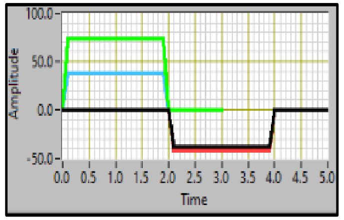
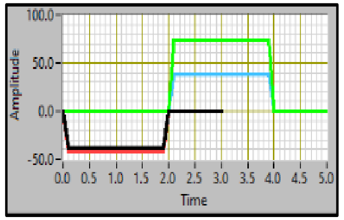
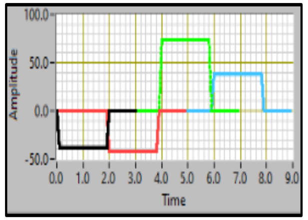
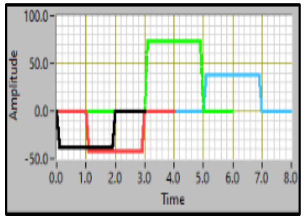
characteristics of the moments in joint 3 and 4, and variation of the kinetic moment in the successive and simultaneously movements in the deceleration time 1.9-2s.



characteristics of the moments in joint 3 and 4, and variation of the kinetic moment in the successive movements and time delay of 1s.

4. APPLY PLATFORM TO PERFORM THE DYNAMIC BEHAVIOR IN ROBOTICS

Optimisation algorithm with weight theory

Nr. of studied case	Type of movement	Trapezoidal characteristics of relative velocities in all four robot's joints
1	0-2-4-6	
2	0-0-0-0	
3	0-0.1-0.2-0.3	
4	0-3-6-9	
5	0-2-0-2	
6	2-0-2-0	
7	2-2-0-0	
8	0-0-2-2	
9	0-1.9-3.9-5.9	
10	0-1-3-5	

The **used algorithm for optimization**, contents the following steps:

(i)establish the constructive and functional parameters of the robot that needded to be studied;

(ii)determine some forces and moments characteristics by changed some of the constructive or functional parameters, or type of movements;

(iii)construct the table with the maximal variation of all these forces and moments;

(iv)impose for each type of forces or moments one maximal **pounder** (if all forces and moments are the same impact to the global dynamic behavior of the robot- the values of all pounders will be the same);

(v)calculate for each force and moments and cases, **the pounder values** by using the proportion between the minimum value of each force variation and the current variation from minimum to maximum forces and moments and multiply with the maximum pounder values (using also the **Neutrosophic** and **Extenics** theory)[16,17];

(vi)calculate separately for up and down movements of the robot's arm and **determine the case what the sum** of these total pounders have **maximal value.**

$$MOF(t_i, tt_i, t_{ai}, t_{di}, l_i, \varphi_i) = \tag{23}$$

$$\min(\text{range}M_{1x,y,z}) \cap \min(\text{range}|M|_1 \cap \min(\text{range} < M_1) \cap \min(\text{range}M_{2x,y,z} \cap \min(\text{range}|M|_2) \cap \min(\text{range} < M_2) \cap \min(\text{range}M_{3x,y,z} \cap \min(\text{range}|M|_3) \cap \min(\text{range} < M_3) \cap \min(\text{range}M_{4x,y,z}) \cap \min(\text{range}|M|_4) \cap \min(\text{range} < M_4)$$

where: *t*i is the time to origin of time [s]; *tt*i- the cycle time [s]; *t*ai- the acceleration time [s]; *t*di- the time when begin the deceleration [s]; *l*i- the length of each body [m]; *φ*i- angle position of each body [rad]; *M*i,x,y,z- active moment in each joints [Nm]; |***Mi***|- module of the active moment in each joints, [Nm]; < ***Mi*** - angle in a space of each active moment vector, [rad].

This ***MOF* function have 20 conditions** to be simultaneously touch, but that will be possible by using Neutrosophic theory [16,17], that mince all these conditions will be touch between T (true) and F (false)= *p*i(T)∪*p*j(F) where *p*i,j are the weights for each criteria and for each cases, otherwise the *MOF* result will be null, because it is impossible that all 20 moments components for each of studied cases to be minimum in the same time.

$$MOF = \max\left(\sum_1^{20} p_i \frac{M_{i,x,y,z,<,min}}{M_{i,x,y,z,<,crt}}\right)_{\text{cases}} \tag{24}$$

where: ***pi* is the maximal pounder** for each; ***Mi*,*x*,*y*,*z*, „*min*- the minimum value of each** of these moments and angle's moments; ***Mi*,*x*,*y*,*z*, „*crt*- the current value** of the moments for each of the studied cases.

Table 4. The maximal range of the angular and linear accelerations and of the angle in the space

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_i=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

Table 5. The results after applied the algorithm of the multi objective function (*mof*)

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

Table 1 The maximal range of the moments variation in all robot’s joints

case	M1x	M1y	M1z	M1	<M1	M2x	M2y	M2z	M2	<M2
0-3-6-9	5,00	4,50	1,80	4,00	0,06	4,50	2,20	1,80	0,80	0,47
0-0-0-0	4,00	4,00	1,50	0,90	0,06	5,00	1,50	1,50	0,80	0,20
0-0.1-0.2-0.3	3,80	3,50	1,40	3,00	0,05	5,00	1,50	1,50	0,60	0,20
0-2.9-5.8-8.7	2,50	3,50	1,80	3,50	0,07	5,00	1,30	1,70	0,80	0,28
0-3-3-0	3,50	4,00	2,00	3,30	0,07	5,00	1,50	2,00	0,80	0,28
0-0-3-3	4,00	4,20	1,25	3,00	0,05	5,00	1,80	1,30	0,70	0,20
3-3-0-0	2,50	4,50	1,80	3,00	0,06	5,00	1,50	1,60	1,25	0,25
0-3-0-3	3,50	3,80	1,40	2,80	0,04	5,00	1,50	1,20	1,25	0,16
0-2.9-2.9-0	4,00	4,00	2,00	3,40	0,05	4,50	1,40	2,00	0,70	0,25
2.9-0-0-2.9	3,80	3,80	1,80	3,50	0,06	5,00	1,60	1,70	0,80	0,23
2.9-0-2.9-0	4,00	3,80	1,50	4,50	0,06	5,00	1,90	1,60	1,20	0,23
0-2.9-0-2.9	2,50	3,80	1,25	2,00	0,05	5,00	1,20	1,25	1,25	0,20
0-2.9-0-2.9 q'=1-2-3-3	4,00	7,00	1,25	2,30	0,04	5,70	0,45	1,25	1,50	0,15
0-0-0-0 q'=1-2-3-3	4,00	6,80	1,25	2,30	0,04	5,50	0,50	1,20	1,30	0,14
minimum range	2,50	3,50	1,25	0.9	0.04	4,50	0,45	1,20	0,60	0,14

M3x	M3y	M3z	M3	<M3	M4x	M4y	M4z	M4	<M4
6,00	3,00	7,00	10,00	0,09	1,30	4,00	8,00	7,00	0,23
6,00	3,80	8,00	10,00	0,09	1,30	1,70	8,00	6,00	0,25
5,60	3,90	7,50	9,00	0,08	1,40	1,90	8,00	7,00	0,25
6,00	3,00	7,80	9,50	0,13	0,50	3,50	7,80	6,00	0,25
6,00	3,00	8,00	9,80	0,10	1,70	2,80	9,00	6,00	0,25
6,00	3,30	7,80	9,60	0,08	1,30	3,00	8,30	4,00	0,26
5,00	3,00	8,00	9,80	0,08	2,00	2,00	8,00	6,00	0,25
6,00	3,80	7,80	9,00	0,12	2,30	2,80	8,00	6,00	0,30
5,80	3,80	8,00	9,80	0,08	1,80	2,80	8,50	6,00	0,25
5,00	3,00	7,80	9,00	0,08	1,10	1,70	8,00	7,00	0,24
5,50	3,40	8,00	9,60	0,08	1,20	1,60	8,00	6,00	0,20
5,00	3,50	7,50	9,00	0,12	2,40	2,50	8,00	7,00	0,20
7,00	2,40	10,00	10,50	0,18	2,50	4,50	10,00	7,00	0,25
6,80	2,50	7,80	11,50	0,17	2,50	4,30	10,00	7,00	0,35
5,00	2,40	7,00	9,00	0,08	0,50	1,60	7,80	4,00	0,20

Table 2 The assisted results after was applied the *MOF* (the relations 23 and 24)

case	M1x	M1y	M1z	M1	<M1	M2x	M2y	M2z	M2	<M2
0-3-6-9	50,0000	77,77778	69,44444	22,5	66,66667	100	20,45455	66,66667	75	29,78723
0-0-0-0	62,5000	87,5	83,33333	100	72,72727	90	30	80	75	70
0-0.1-0.2-0.3	65,7895	100	89,28571	30	80	90	30	80	100	70
0-2.9-5.8-8.7	100,0000	100	69,44444	25,71429	57,14286	90	34,61538	70,58824	75	50
0-3-3-0	71,4286	87,5	62,5	27,27273	57,14286	90	30	60	75	50
0-0-3-3	62,5000	83,33333	100	30	80	90	25	92,30769	85,71429	70
3-3-0-0	100,0000	77,77778	69,44444	30	66,66667	90	30	75	48	56
0-3-0-3	71,4286	92,10526	89,28571	32,14286	100	90	30	100	48	87,5
0-2.9-2.9-0	62,5000	87,5	62,5	26,47059	80	100	32,14286	60	85,71429	56
2.9-0-0-2.9	65,7895	92,10526	69,44444	25,71429	66,66667	90	28,125	70,58824	75	60,86957
2.9-0-2.9-0	62,5000	92,10526	83,33333	20	66,66667	90	23,68421	75	50	60,86957
0-2.9-0-2.9	100,0000	92,10526	100	45	80	90	37,5	96	48	70
0-2.9-0-2.9 q'=1-2-3-3	62,5000	50	100	39,13043	100	78,94737	100	96	40	93,33333
0-0-0-0 q'=1-2-3-3	62,5000	51,47059	100	39,13043	100	81,81818	90	100	46,15385	100

M3x	M3y	M3z	M3	<M3	M4x	M4y	M4z	M4	<M4	
83,33333	80	100	90	88,88889	38,46154	40	97,5	57,14286	86,95652	1340,5805
83,33333	63,15789	87,5	90	88,88889	38,46154	94,11765	97,5	66,66667	80	1540,6866
89,28571	61,53846	93,333333	100	100	35,71429	84,21053	97,5	57,14286	80	1533,8004
83,33333	80	89,74359	94,736842	61,53846	100	45,71429	100	66,66667	80	1474,2384
83,33333	80	87,5	91,836735	80	29,41176	57,14286	86,666667	66,66667	80	1353,4022
83,33333	72,72727	89,74359	93,75	100	38,46154	53,33333	93,975904	100	76,92308	1521,1034
100	80	87,5	91,836735	100	25	80	97,5	66,66667	80	1451,3923
83,33333	63,15789	89,74359	100	66,66667	21,73913	57,14286	97,5	66,66667	66,66667	1453,0792
86,2069	63,15789	87,5	91,836735	100	27,77778	57,14286	91,764706	66,66667	80	1404,8813
100	80	89,74359	100	100	45,45455	94,11765	97,5	57,14286	83,33333	1491,5949
90,90909	70,58824	87,5	93,75	100	41,66667	100	97,5	66,66667	100	1472,7397
100	68,57143	93,333333	100	66,66667	20,83333	64	97,5	57,14286	100	1526,6529
71,42857	100	70	85,714286	44,44444	20	35,55556	78	57,14286	80	1402,1969
73,52941	96	89,74359	78,26087	47,05882	20	37,2093	78	57,14286	57,14286	1405,1608

$$\{F\} \bigcap \{M\} = \{Best\ Solution\ Dynamic\ Behavior\}$$

Studied case	Max {Ponder F}= {Best sol.}	Max {Ponder M}= {Best sol.}	Max {Ponder F} & Max {Ponder M}
0-0-0-0	**1592,75**	**1540,68**	**3133,43**
0-4-4-0	1563,58	1353,40	2916,98
0-4-0-4	1417,91	1453,07	2870,98
4-0-4-0	1648,34	1472,73	3121,07
0-4-8-12	1390,65	1340,58	2731,23
0-4-8-12/l1/0.8	1417,52	1474,23	2891,75
0-4-8-12/l1/0.8/l2/0.8	1455,38	1402,19	2957,57
0-0.1-0.2-0.3	**1596,99**	**1533,80**	**3130,79**
0-0-0-0/l1,l2,qq	910,93	1402,19	2313,12

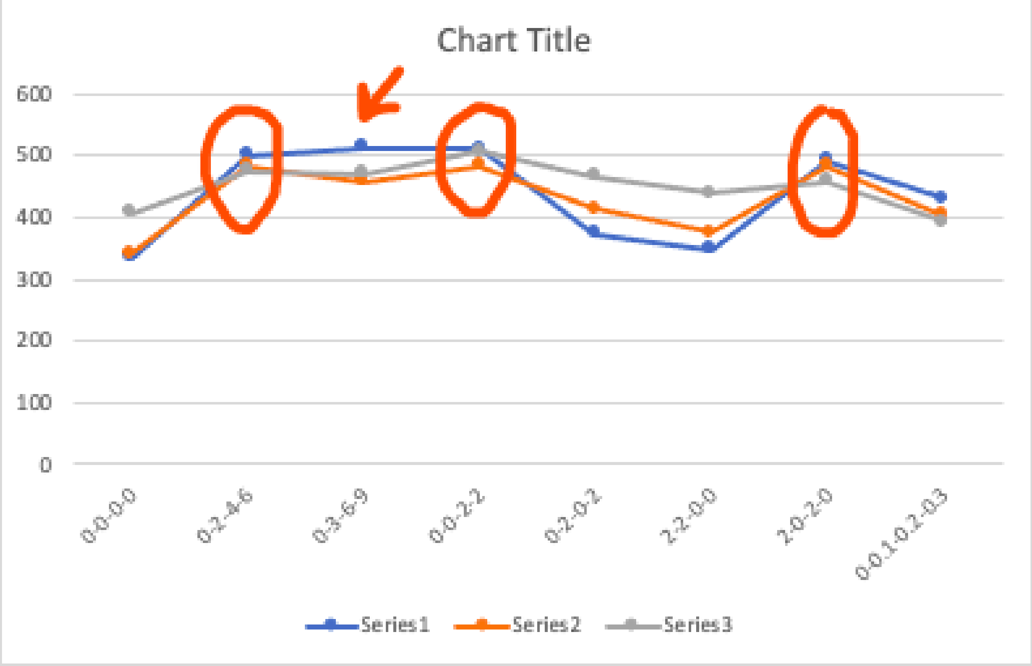
Movement	100	100	100	100	100	100
0-0-0-0	38,8235294	46,6666667	51,5789474	80	65,7894737	52,6315789
0-2-4-6	100	93,3333333	84,4827586	88,8888889	86,2068966	47,6190476
0-3-6-9	94,2857143	100	89,0909091	100	83,3333333	46,5116279
0-0-2-2	82,5	87,5	100	88,8888889	100	52,6315789
0-2-0-2	50,7692308	48,2758621	65,3333333	94,1176471	65,7894737	48,7804878
2-2-0-0	41,25	70	61,25	88,8888889	45,4545455	41,6666667
2-0-2-0	67,3469388	100	81,6666667	80	62,5	100
0-0.1-0.2-0.3	63,4615385	73,6842105	75,3846154	88,8888889	83,3333333	44,4444444

		l2=1.0m	l2, l3=1.0m
0-0-0-0	335,490196	341,547831	405,845865
0-2-4-6	500,530925	482,297832	474,68254
0-3-6-9	513,221585	456,629318	470,43956
0-0-2-2	511,520468	483,240793	507,019445
0-2-0-2	373,066035	412,49269	465,480582
2-2-0-0	348,510101	374,77393	439,267399
2-0-2-0	491,513605	482,72449	458,237179
0-0.1-0.2-0.3	429,197031	402,432377	392,218323

Dimension of the second body was changed

Movement	/Q2/	<Q2	/Q3/	<Q3	/Q4/	<Q4
0-0-0-0	12750,00	3,40	11800,00	30,00	4400,00	36,00
0-2-4-6	5000,00	2,30	6800,00	30,00	3500,00	40,00
0-3-6-9	5000,00	3,40	6800,00	30,00	3500,00	36,00
0-0-2-2	7700,00	2,80	5900,00	23,00	3000,00	36,00
0-2-0-2	9500,00	3,30	8000,00	20,00	4500,00	36,00
2-2-0-0	12000,00	2,70	11000,00	25,00	6300,00	27,00
2-0-2-0	8000,00	2,20	10000,00	20,00	4900,00	19,00
0-0.1-0.2-0.3	9800,00	3,10	9900,00	27,00	3100,00	38,00

When was changed the lengh of the bodies 2 and 3



Dimension of the second body was changed l2=1.0m

Movement	100	100	100	100	100	100
0-0-0-0	39,2156863	64,7058824	50	66,6666667	68,1818182	52,7777778
0-2-4-6	100	95,6521739	86,7647059	66,6666667	85,7142857	47,5
0-3-6-9	100	64,7058824	86,7647059	66,6666667	85,7142857	52,7777778
0-0-2-2	64,9350649	78,5714286	100	86,9565217	100	52,7777778
0-2-0-2	52,6315789	66,6666667	73,75	100	66,6666667	52,7777778
2-2-0-0	41,6666667	81,4814815	53,6363636	80	47,6190476	70,3703704
2-0-2-0	62,5	100	59	100	61,2244898	100
0-0.1-0.2-0.3	51,0204082	70,9677419	59,5959596	74,0740741	96,7741935	50

TABLE I- THE WEIGHT THEORY APPLIED TO THE MOMENTS

Movement	100	100	100	100	100	100	
0-0-0-0	38,8235294	46,6666667	51,5789474	80	65,7894737	52,6315789	335,490196
0-2-4-6	100	93,3333333	84,4827586	88,8888889	86,2068966	47,6190476	500,530925
0-3-6-9	94,2857143	100	89,0909091	100	83,3333333	46,5116279	513,221585
0-0-2-2	82,5	87,5	100	88,8888889	100	52,6315789	511,520468
0-2-0-2	50,7692308	48,2758621	65,3333333	94,1176471	65,7894737	48,7804878	373,066035
2-2-0-0	41,25	70	61,25	88,8888889	45,4545455	41,6666667	348,510101
2-0-2-0	67,3469388	100	81,6666667	80	62,5	100	491,513605
0-0.1-0.2-0.3	63,4615385	73,6842105	75,3846154	88,8888889	83,3333333	44,4444444	429,197031

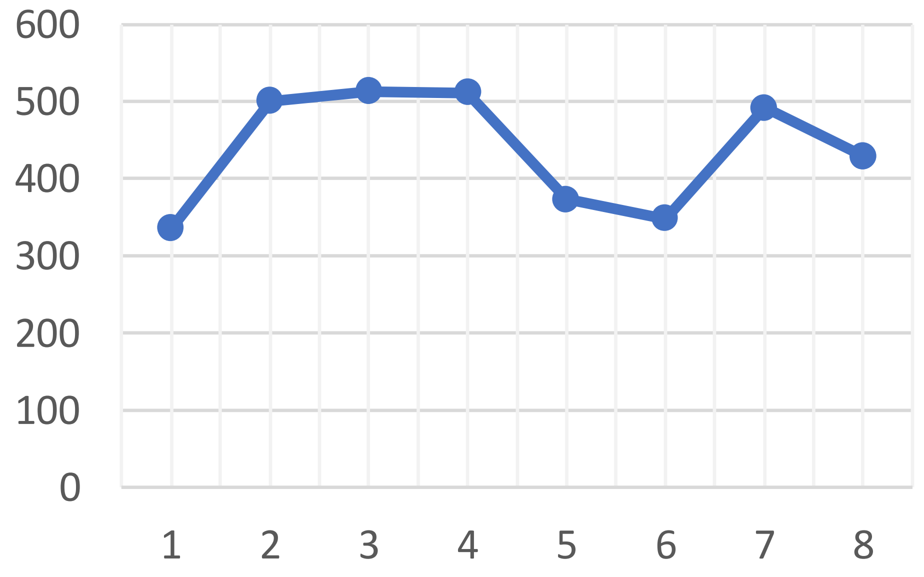


Fig.6. The moments variation vs. type of movements

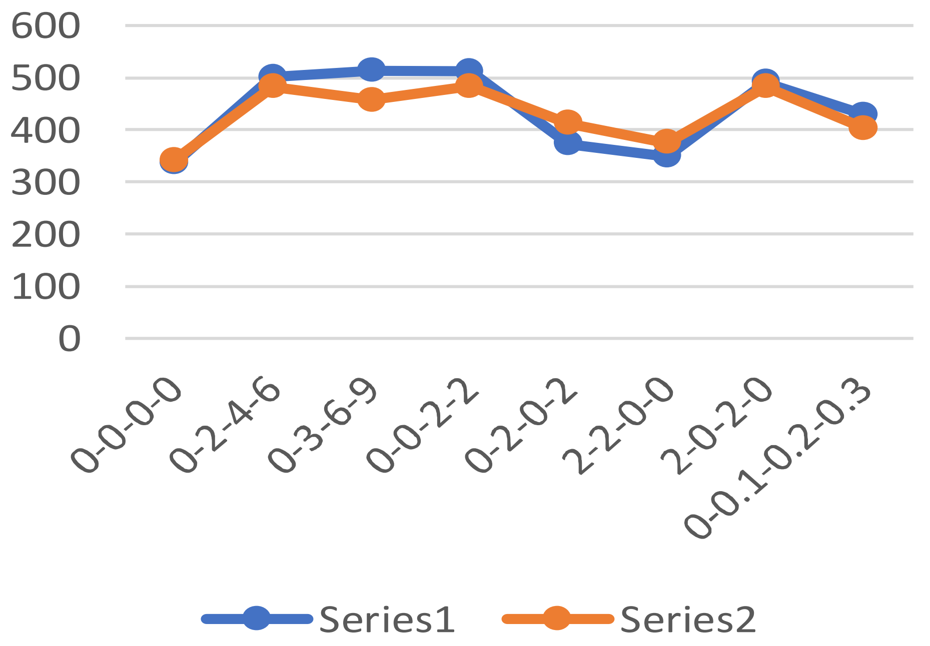
The best solution from the moment variation is the case 3, the succesive movements with 1s pause, 0-3-6-9.

A. Influences of the robot’s length to the dynamic behavior

After were comparative analyzed the figs.6-9 we can do the following remarks:

(i) the movement 0-0-2-2 is more efficiently from dynamic behavior point of view, when were changed the lengths of bodies or without these changes;

		l2=1.0m
0-0-0-0	335,490196	341,547831
0-2-4-6	500,530925	482,297832
0-3-6-9	**513,221585**	456,629318
0-0-2-2	511,520468	**483,240793**
0-2-0-2	373,066035	412,49269
2-2-0-0	348,510101	374,77393
2-0-2-0	491,513605	482,72449
0-0.1-0.2-0.3	429,197031	402,432377



without change the lengths; series 2- where was c
The moments variation when was changed the l_2

B. Influences of the robot's velocities, accelerations, forces and moments to the dynamic behavior

(ii) the sum of all influences variation of velocities, accelerations, forces and moments determine the best solution of movement to be 2-0-2-0;

(iii) variation of the velocities determine the best solution of the movement to be 2-0-2-0;

(iv) variation of the accelerations determine the best solution of movement to be 0-2-0-2;

(v) variation of the forces determine the best solution of movement to be 2-2-0-0;

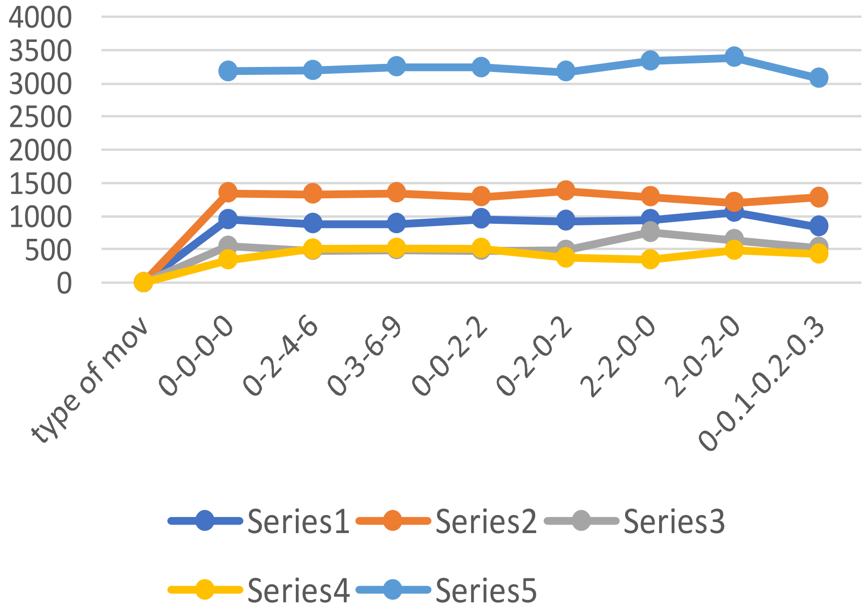
(vi) variation of the moments determine the best solution of the movement to be 2-0-2-0;

(vii) in the sum of influences the more important is the variation of velocities and moments, have the same influence to choose the best solution of the movement 2-0-2-0, that mince the first and thread movement of joints is both successive after the second and four joints;

(viii) the variation of the moments determine the best solution of movement to be 0-3-6-9, the successive movements in all joints with one second of break, but the increasing the length l_2 of the second robot body and also l_2 and l_3 , determine the best movement to be 0-0-2-2.

TABLE II- THE WEIGHT THEORY APPLIED TO THE VELOCITIES, ACCELERATIONS, FORCES AND MOMENTS VARIATION VS. THE TYPE OF MOVEMENTS

type of mov	velocities	acceleration	forces	moments	
0-0-0-0	951,878	1347,87	543,74	335,490196	3.178,978
0-2-4-6	884,200	1.328	480,78	500,530925	3.193,361
0-3-6-9	886,285	1344,83	498,12	513,221585	3.242,457
0-0-2-2	954,656	1288	480,65	511,520468	3.234,826
0-2-0-2	931,021	1376,56	491,57	373,066035	3.172,217
2-2-0-0	938,436	1288,16	757,57	348,510101	3.332,676
2-0-2-0	1.055,057	1201,55	637,73	491,513605	3.385,851
0-0.1-0.2-0.3	843,805	1279,16	524,25	429,197031	3.076,412



series1- velocities; series 2- accelerations; series 3- forces; series 4- moments; series 5- sum of them

Fig.9. The variation of velocities, accelerations, forces, moments and sum of them versus the type of movements

C. *Influences of the materials and other dimensions to the dynamic behavior*

After was analyzed the simulation results obtained by using the proper platform ROBO-PVAFM we can do the following remarks:

(i)The best solution of the movements when were changed the base dimensions of all robot's bodies is the successive movements 2-0-2-0 two by two joints;

(ii) for the steel material of all bodies the best solution is the successive movements with 1 second break between them, 0-3-6-9;

(iii) for the aluminum materials of all bodies the best solution is successive and simultaneously movements two by two 2-0-2-0;

	alumin.A,B>0.4	cast iron A,B>0.4	Sum
0-0-0-0	336,7521368	265,0877193	601,83986
0-2-4-6	247,6960784	277,421638	525,11772
0-3-6-9	247,6960784	275,410628	523,10671
0-0-2-2	265,3735632	311,6666667	577,04023
0-2-0-2	287,178105	309,2577031	596,43581
2-2-0-0	259,8978495	241,4957983	501,39365
2-0-2-0	338,7055567	333,3333333	672,03889
0-0.1-0.2-0.3	268,4461153	320,3508772	588,79699

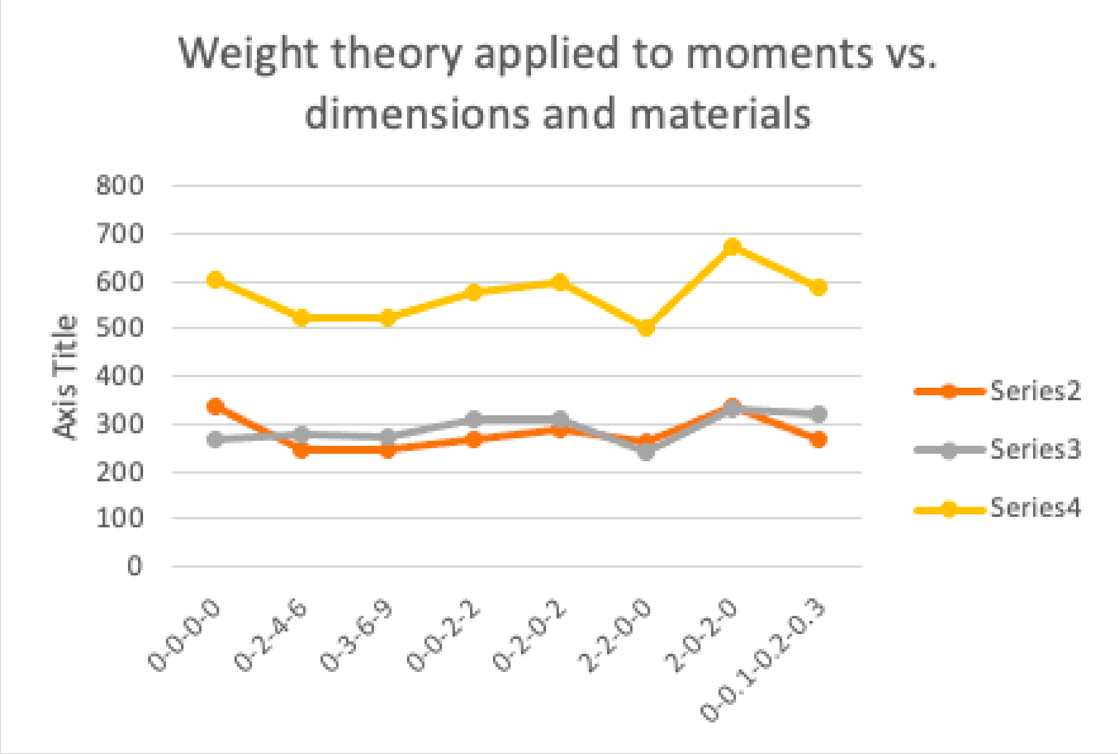


Fig.10.The results after was applied the weight theory to the moments variations vs. all base dimensions of the robot's bodies.

C'. Influences of the materials to the dynamic behaviour

(iv) for the cast iron the best solution is the simultaneously movement 0-0-0-0;

(v) the optimal solution from the point of view of dynamic behavior and which does not depend on the material of the structure is
0-0-2-2.

	steel	alumin.	cast iron	sum
0-0-0-0	220,15233	225,72537	354,16667	1020,1967
0-2-4-6	275,95238	290,12987	234,8062	1076,8408
0-3-6-9	314,28571	300,5848	224,90385	1154,0601
0-0-2-2	293,12997	333,33333	255,80294	1175,3962
0-2-0-2	270,26132	295,12987	232,98327	1068,6358
2-2-0-0	283,09091	226,34921	283,21429	1075,7453
2-0-2-0	296,91769	298,91534	244,26332	1137,014
0-0.1-0.2-0.3	272,39737	300,89717	209,73758	1055,4295

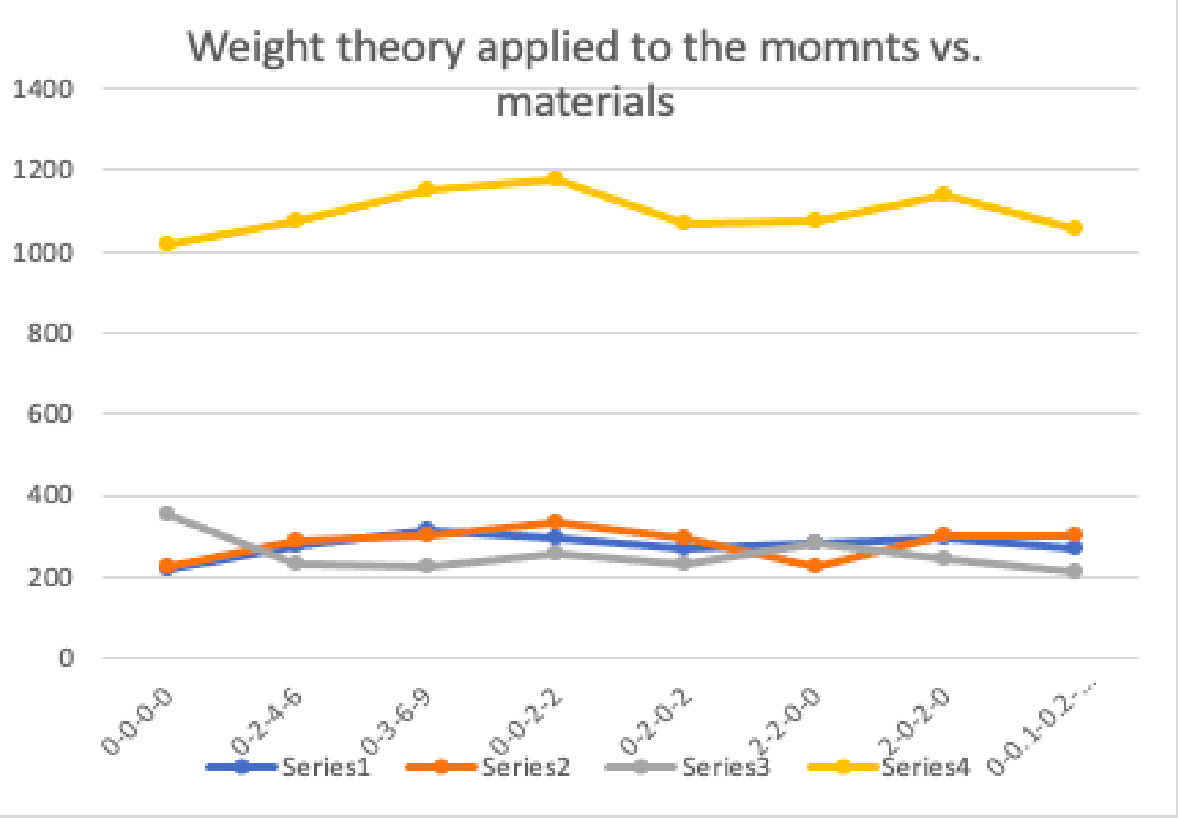


Fig.11. The results after was applied the weight theory to the moments variation vs. all materials of the robot's bodies.

*D. Influences of the position bodies-joints and joints-bodies, **G** and **Z** matrices of the joints to the dynamic behavior*

Moment	x	y	z	<	modul
Simultaneously movement, joint position 2 and 3 were changed					
Q3	6000	14000	2250	20	8000
Q4	6000	8000	3000	40	3000
Simultaneously movement, joints in initial condition					
Q3	6000	15000	4500	35	4000
Q4	5500	4000	2250	40	3000
Successive movement, joints in initial condition					
Q3	5000	10000	3200	30	6900
Q4	4000	3000	1600	40	2500
Successive movement after 0.1s, joints in initial conditions					
Q3	4000	15000	4500	35	7000
Q4	5000	4000	2050	40	2500
Successive movement and simultaneously movement after 1.9s, joints in initial conditions					
Q3	5000	11000	3300	35	6000
Q4	4000	3000	1600	40	2500
Successive movement with 1s break, joints in initial conditions					
Q3	6500	10500	3300	30	6000
Q4	4000	3000	1600	40	2500

After were analysed all simulation results, the synthetic table II, we can do the following remarks:

(i) the best solution with the minimum variation of the moment in the end-effector joint, Q4 will be the successive movement with one second break between them;

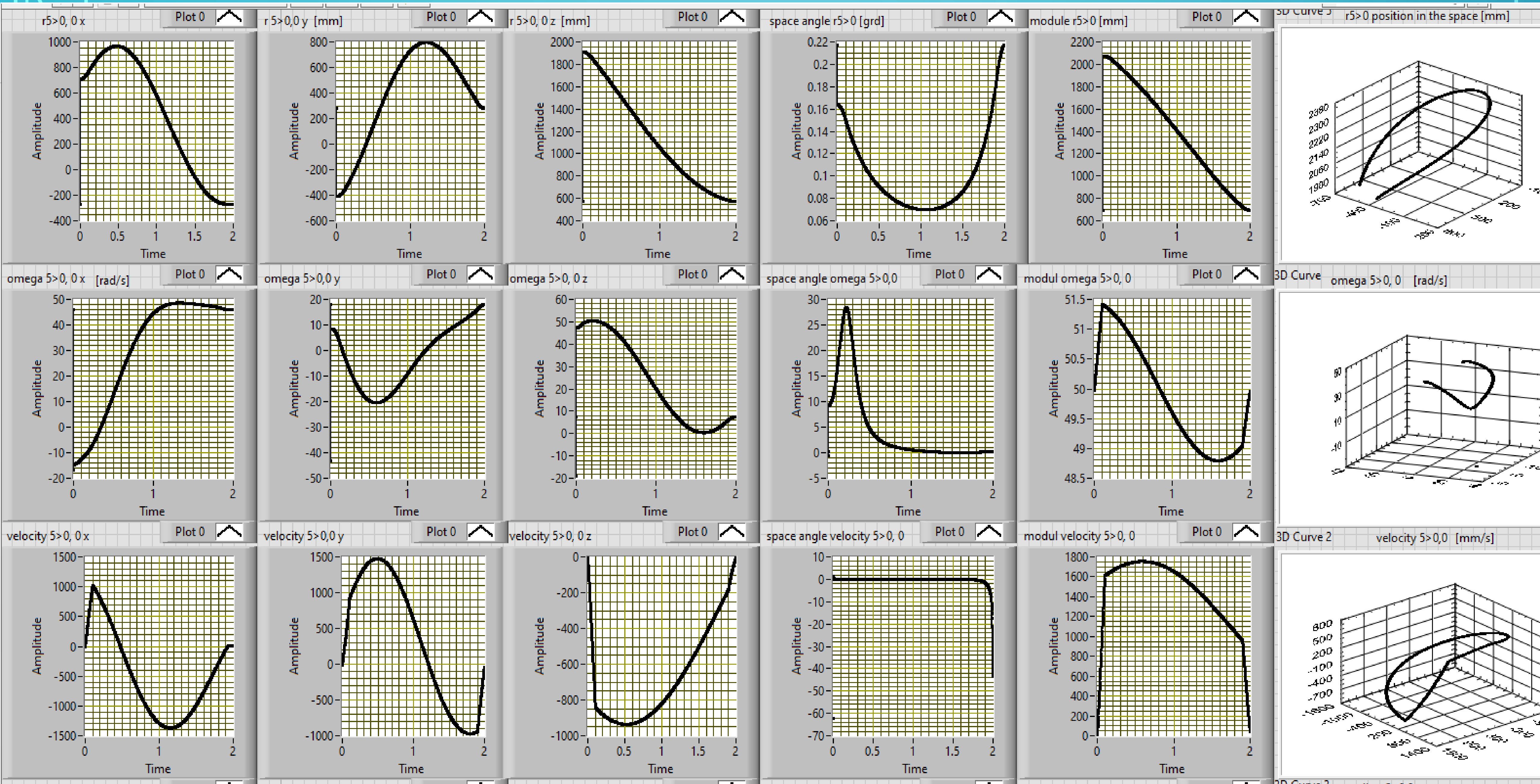
(ii) the best solution for the minimum variation of the moment in the three joint, Q3 will be the case of the simultaneously movement with changed position of joints 2 and 3;

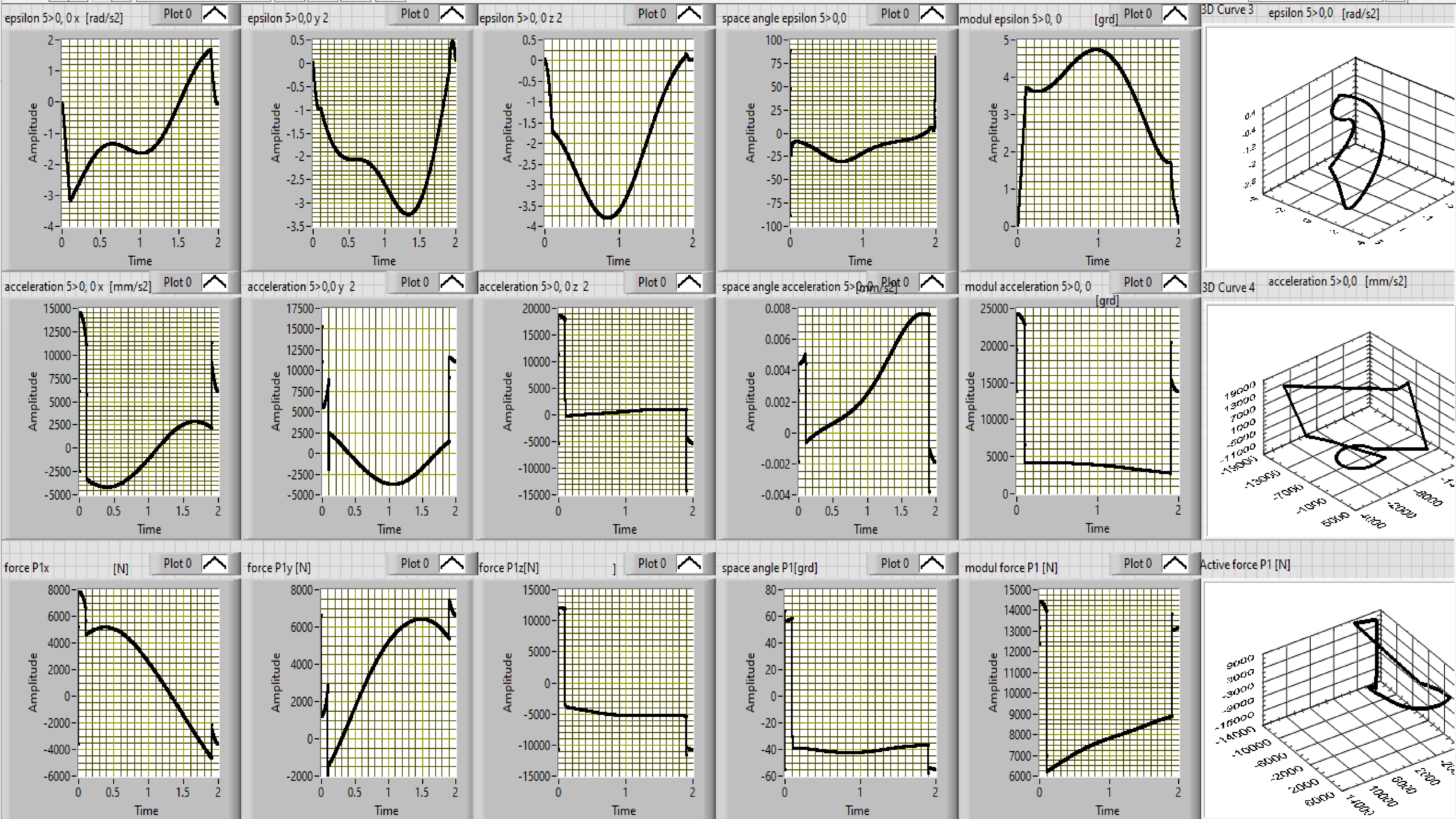
(iii) by point of view of the minimum variation of the module of moments vectors in joint 2, Q3 the best solutions are simultaneously movement with initial positions of all joints, and successive movements for end effecter joint moment, Q4;

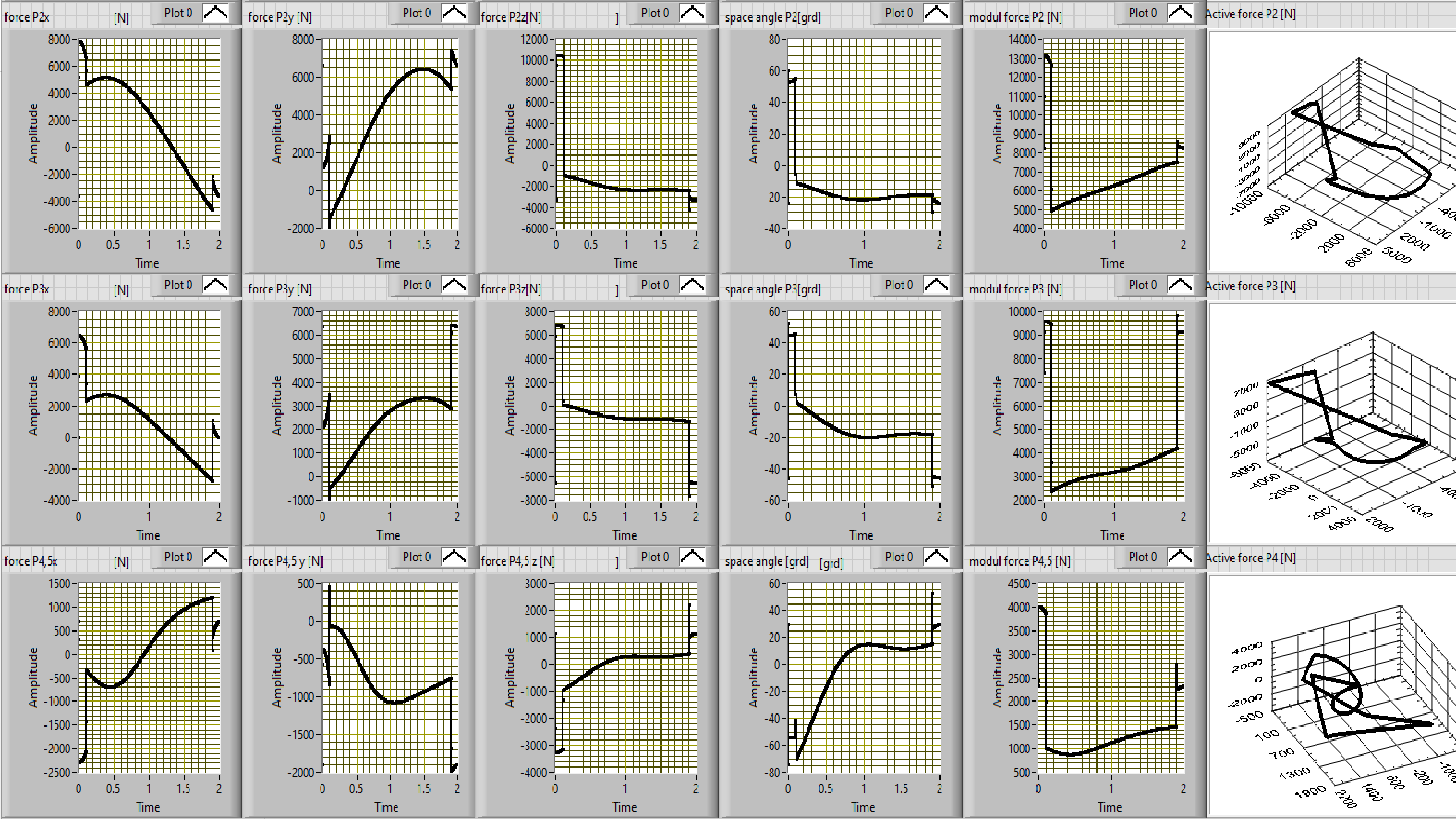
(iv) the all successive movement determine increasing the proper frequency of the end-effecter because the induced oscillation by variation of acceleration;

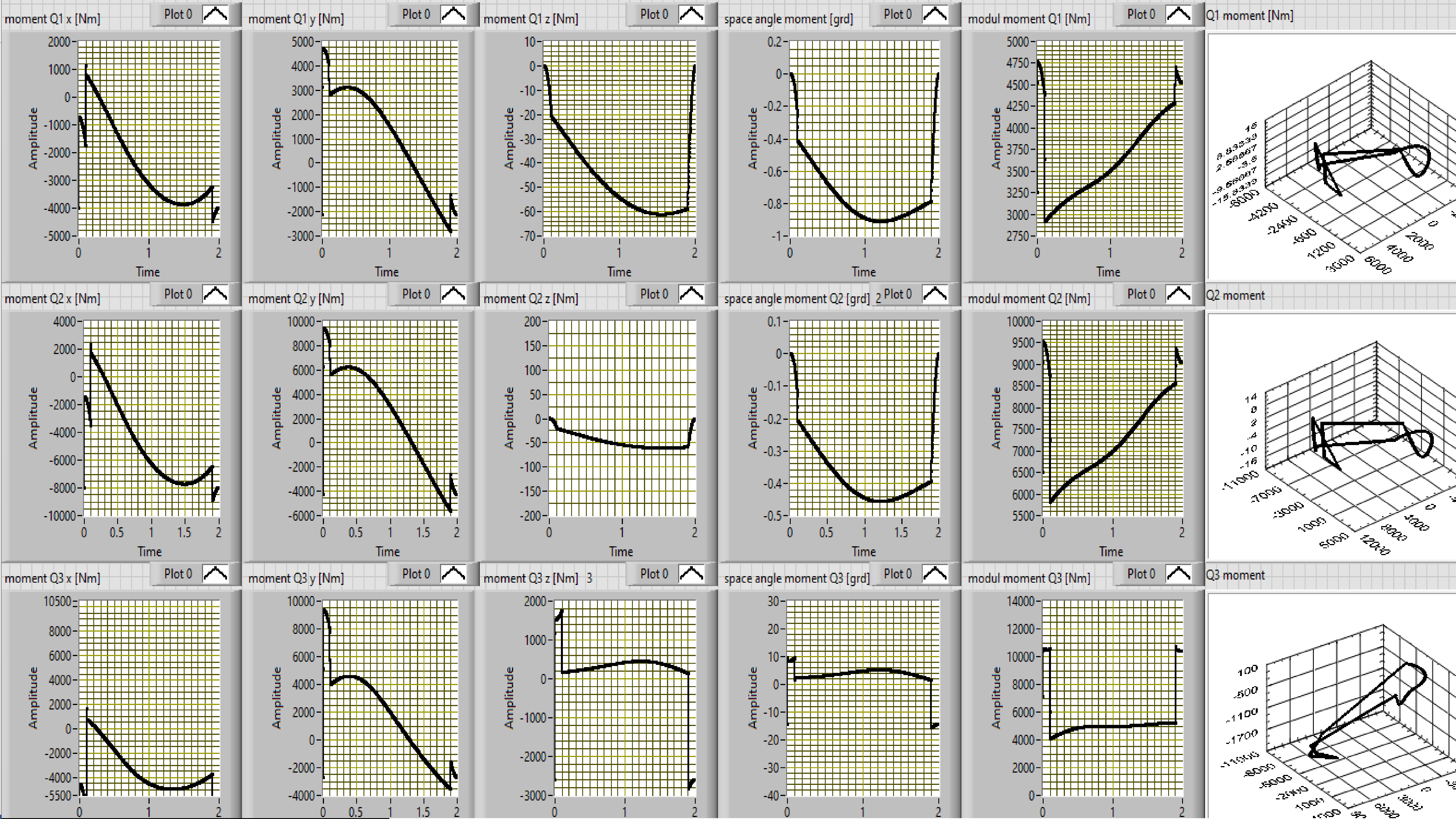
(v) between the analysed cases of simultaneously movement with joint 2 and 3 position were changed and the simultaneously movement in initial positions of the joints 2 and 3, the best one by point of view of Q3, is the case with joint 2 and 3 in new position, and by point of view of Q4 is the case without any changes of joints 2 and 3.

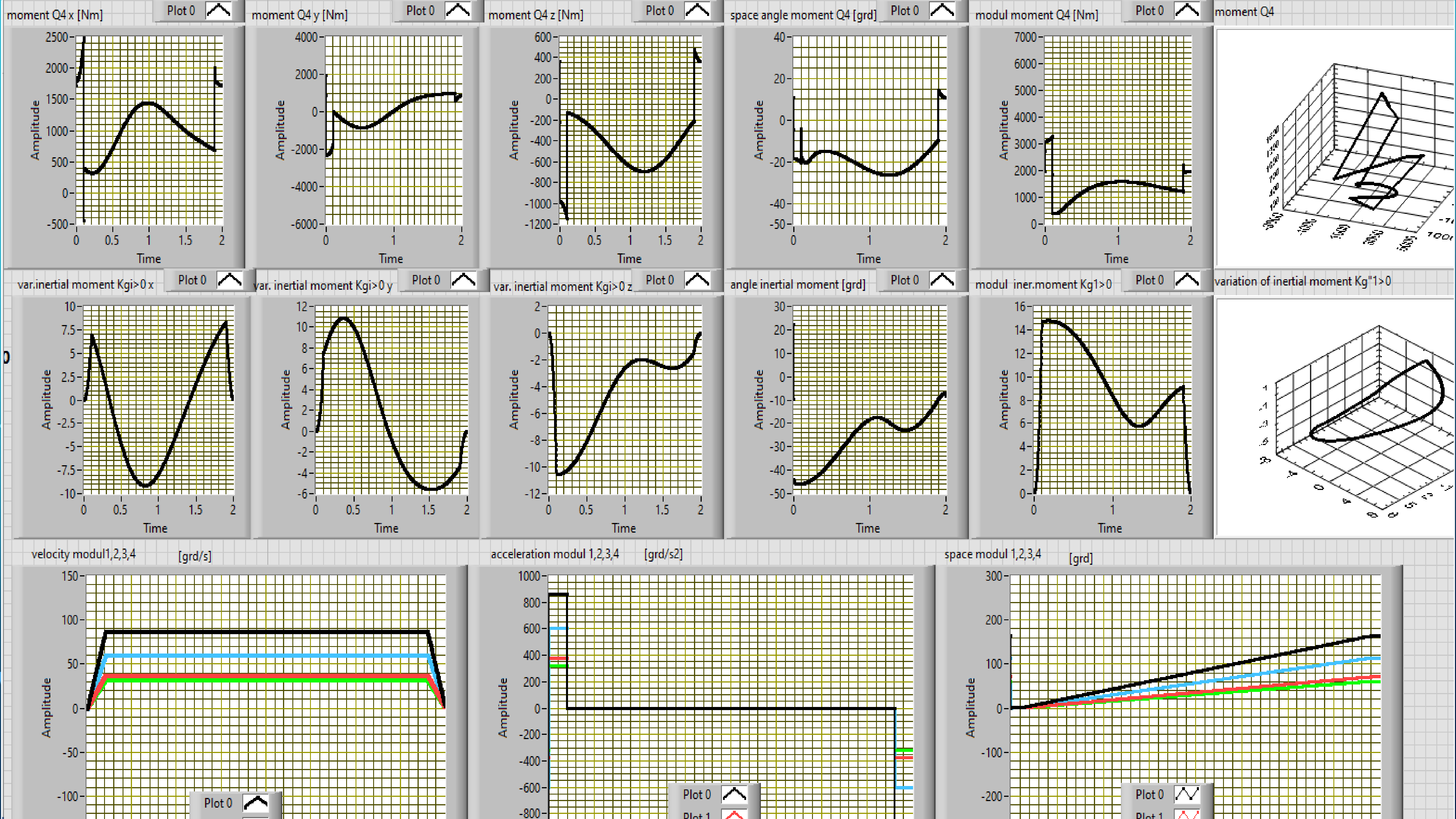
POZITIONS, VELOCITIES, ACCELERATIONS, FORCES AND MOMENTS RESULTS WITH ROBO- PVAFM PLATFORM




epsilon 5>0, 0 x [rad/s2]
epsilon 5>0,0 y 2
epsilon 5>0, 0 z 2
space angle epsilon 5>0,0
modul epsilon 5>0, 0 [grd]
3D Curve 3
epsilon 5>0,0 [rad/s2]
acceleration 5>0, 0 x [mm/s2]
acceleration 5>0,0 y 2
acceleration 5>0, 0 z 2
space angle acceleration 5>0, 0 [mm/s2]
modul acceleration 5>0, 0 [grd]
3D Curve 4
acceleration 5>0,0 [mm/s2]
force P1x [N]
force P1y [N]
force P1z[N]
space angle P1[grd]
modul force P1 [N]
Active force P1 [N]
Plot 0
Amplitude
Time


force P2x [N]
Plot 0
force P2y [N]
force P2z[N]
space angle P2[grd]
modul force P2 [N]
Active force P2 [N]
force P3x [N]
force P3y [N]
force P3z[N]
space angle P3[grd]
modul force P3 [N]
Active force P3 [N]
force P4,5x [N]
force P4,5 y [N]
force P4,5 z [N]
space angle [grd] [grd]
modul force P4,5 [N]
Active force P4 [N]
Amplitude
Time


moment Q1 x [Nm]
moment Q1 y [Nm]
moment Q1 z [Nm]
space angle moment [grd]
modul moment Q1 [Nm]
Q1 moment [Nm]
moment Q2 x [Nm]
moment Q2 y [Nm]
moment Q2 z [Nm]
space angle moment Q2 [grd]
modul moment Q2 [Nm]
Q2 moment
moment Q3 x [Nm]
moment Q3 y [Nm]
moment Q3 z [Nm]
space angle moment Q3 [grd]
modul moment Q3 [Nm]
Q3 moment
Plot 0
Amplitude
Time


moment Q4 x [Nm]
moment Q4 y [Nm]
moment Q4 z [Nm]
space angle moment Q4 [grd]
modul moment Q4 [Nm]
moment Q4
var.inertial moment Kgi>0 x
var. inertial moment Kgi>0 y
var. inertial moment Kgi>0 z
angle inertial moment [grd]
modul iner.moment Kg1>0
variation of inertial moment Kg"1>0
velocity modul1,2,3,4
[grd/s]
acceleration modul 1,2,3,4
[grd/s2]
space modul 1,2,3,4
[grd]
Plot 0
Plot 1
Amplitude
Time

5.CONCLUSIONS

The proposed ROBO-PVAFM software platform provides, compared to other similar platforms, the following research possibilities:

- analysis of the variation of positions (P), linear and angular velocities (V), linear and angular accelerations (A) as well as of forces (F) and moments (M) in the conditions of simultaneous or successive movements;
- PVAFM analysis in the conditions of changing the direction of the various joint- body element, or body- joint element;
- PVAFM analysis in the conditions of movement with or without the object to be manipulated;
- complete analysis by modifying the various dimensions of the bodies or their materials;
- analysis by partial or total modification of the parameters of the velocity characteristics, parameters such as acceleration time, cycle time, time from the common origin of time, or the time after which the deceleration starts, or linear or angular displacement values for various joints;

- the platform offers a broad framework for analysis by highlighting both 2D and 3D features, as well as the variation on each axis of various kinematic and dynamic parameters;
- the possibility to interactively calculate the inertia tensors for each body and to ensure the visualization of the way in which the dimensions of the bodies influence the dynamics of the movement is important for the constructive optimization taking into account the optimization of the overall dynamic behavior of the robotic structure;
- the proposed software platform ROBO-PVAFM is general and can be applied to any robotic structure or to any complex multirobot structure with up to 5 DOF;
- the maximum values of these vectors can be used in the dimensioning of the various mechanical parts of the robots;
- solving with this platform the problem of forward kinematics (*FK*) and inverse dynamics (*ID*) ensures an important support in the development and future solution of inverse kinematics (*IK*) by iterative numerical methods, as well as direct dynamics (*DD*) with the establishment of quasi-real variation of velocities and accelerations, respectively of the quasi-real variation of the moments by using these new results.

6. FUTURE WORK AND AI APPLIED IN IK

applications;

- will be included in the platform the ***IK*** and ***DD*** of robots.

THE PROPOSAL OF THE NEW DYNAMIC NEURAL NETWORK

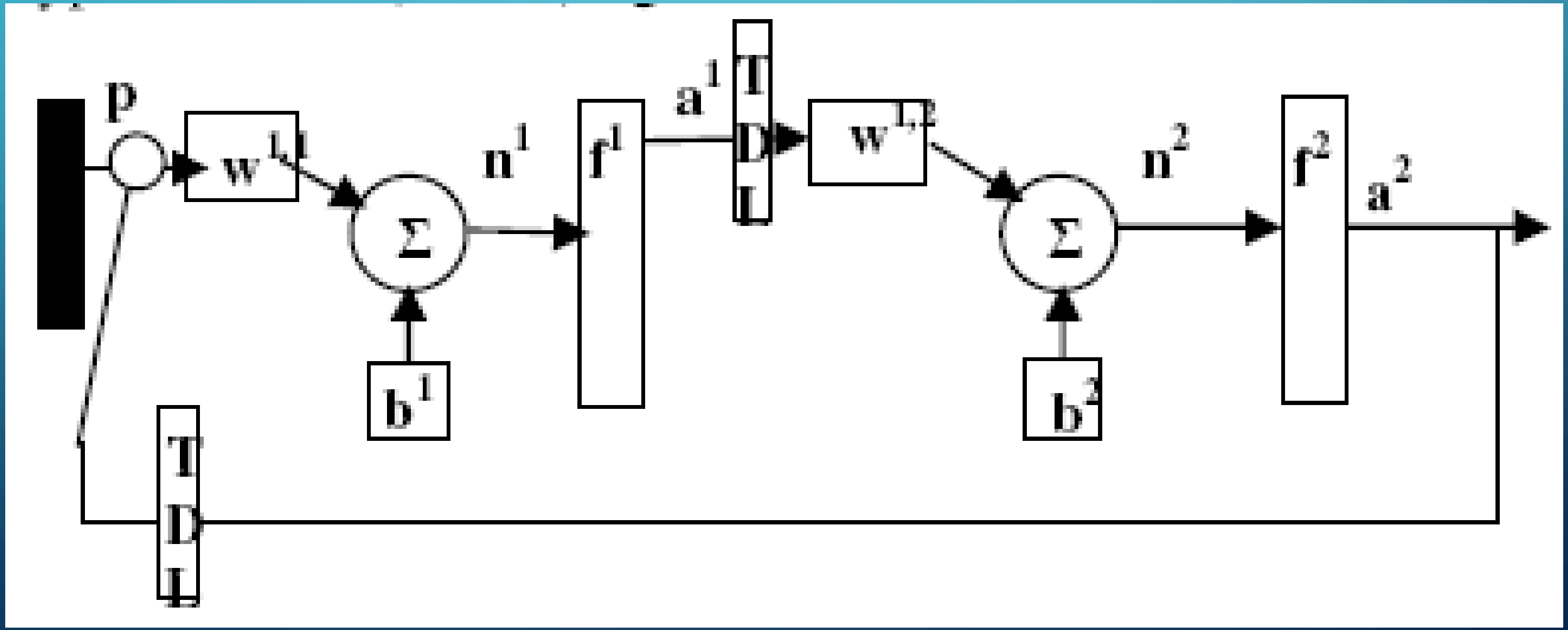
$$n^1(t) = w^{1,1}p^1 + w^{1,2}a^2(t-1) + b^1$$

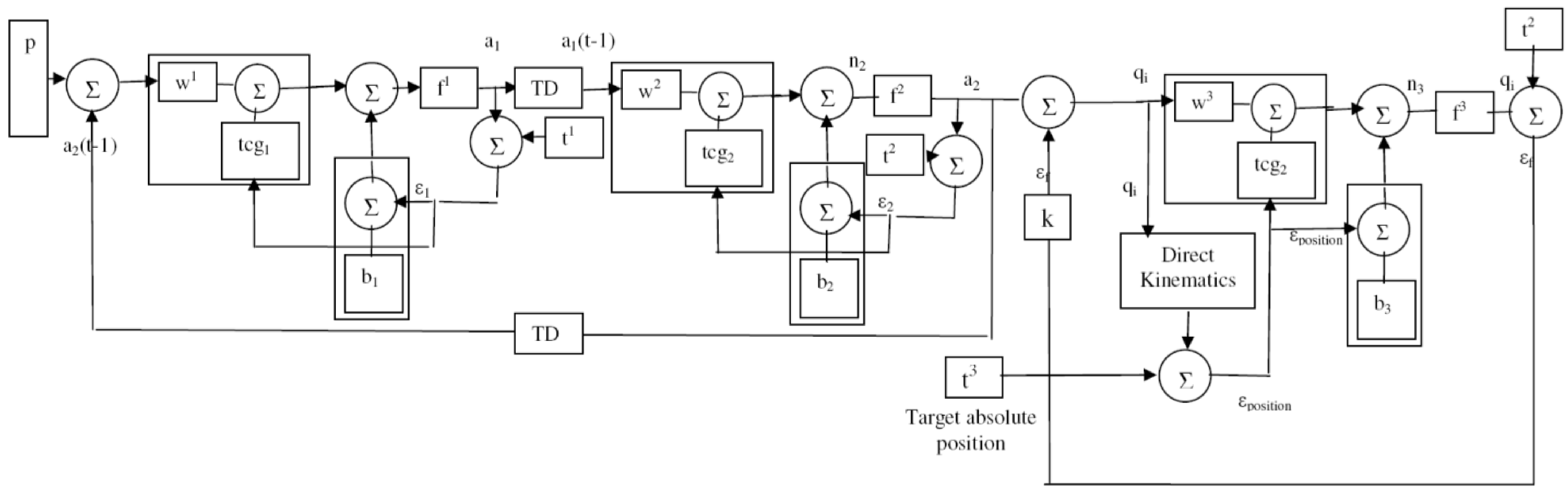
$$a^1(t) = \frac{a(1-e^{-n^1})}{1+e^{-n^1}}$$

$$n^2(t) = w^{2,1}a^1(t-1) + b^2$$

$$a^2(t) = \frac{a(1-e^{-n^2})}{1+e^{-n^2}}$$

f^1 and f^2 are the sigmoid activation functions, and a is the gain of these functions





p
Σ
a2(t-1)
w1
Σ
tcg1
Σ
Σ
b1
f1
a1
a1(t-1)
TD
Σ
t1
ε1
w2
Σ
tcg2
Σ
n2
f2
a2
t2
Σ
Σ
ε2
b2
TD
Σ
εf
k
qi
qi
w3
Σ
tcg2
Direct Kinematics
Σ
n3
f3
qi
t2
Σ
εf
Σ
εposition
b3
t3
Target absolute position
Σ
εposition

The parameters what were researched are:

p_1- the number of neurons;

p_2 – the first teaching gain;

p_3- step of the first time delay;

p_4- the first sensitive function gain;

p_5- the second teaching gain;

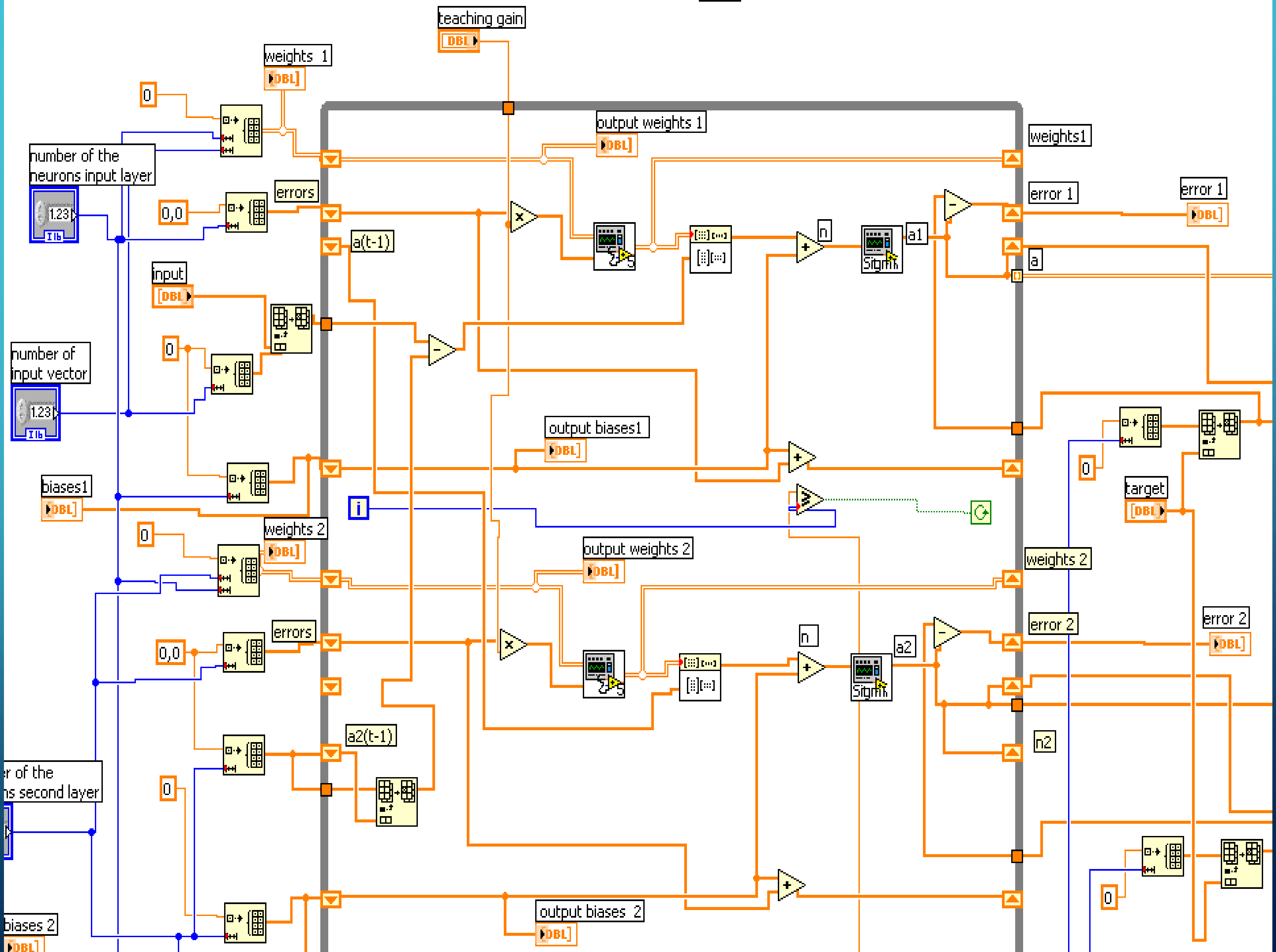
p_6- the step of the second time delay;

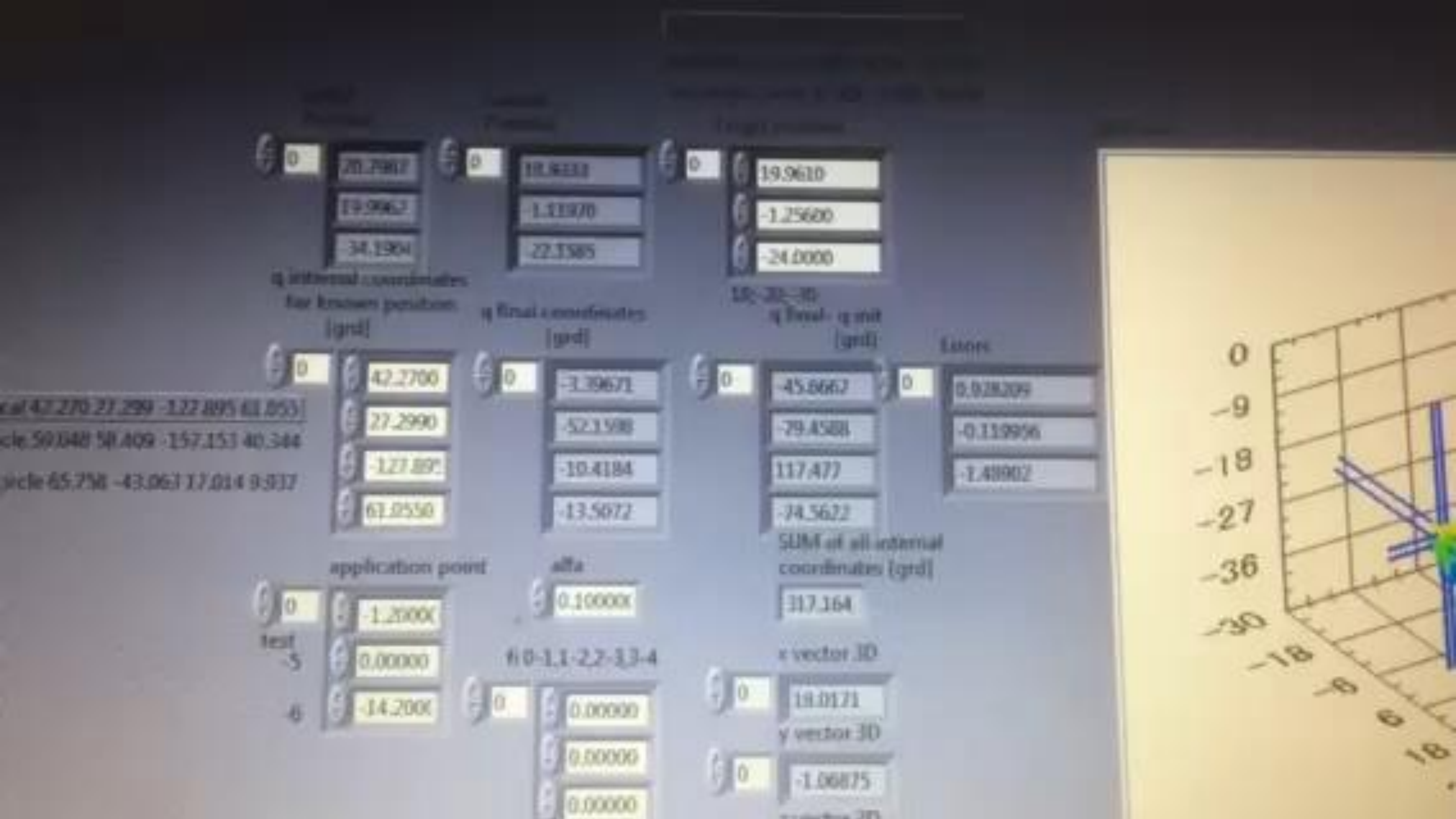
p_7- the second sensitive function gain;

p_8- the magnitude gain of the proportional error control;

p_9- the third sensitive function gain and some more recurrent links.

$$
\begin{aligned}
n_1 &= [\underbrace{w^1}_{p_1} + \underbrace{tcg_1}_{p_2} \cdot \varepsilon_1](p - a_2(t - p_3 + 1)) + (b_1 + \varepsilon_1) \\
a_1 &= \frac{p_4(1 - e^{-n_1})}{1 + e^{-n_1}} \\
\varepsilon_1 &= t_1 - a_1 \\
n_2 &= [w^2 + \underbrace{tcg_2}_{p5} \cdot \varepsilon_2](a_1(t - p_6 + 1)) + (b_2 + \varepsilon_2) \\
a_2 &= \frac{p_7(1 - e^{-n_2})}{1 + e^{-n_2}} \\
\varepsilon_2 &= t_2 - a_2 \\
q_i &= p_8(a_2 - \varepsilon_f) \\
r_i &= \begin{pmatrix} c_1 s_2 l_3 + (c_1 c_2 s_3 + c_1 s_2 c_3) l_4 \\ s_1 s_2 l_3 + (s_1 c_2 s_3 + s_1 s_2 c_3) l_4 \\ l_1 + l_2 + c_2 l_3 + (-s_2 s_3 + c_2 c_3) l_4 \end{pmatrix} \\
\varepsilon_{pos} &= t_3 - r_i \\
n_3 &= [w^3 + \underbrace{tcg_2}_{p_5} \cdot \varepsilon_{pos}](q_i) + (b_3 + \varepsilon_{pos}) \\
a_3 &= \frac{p_9(1 - e^{-n_3})}{1 + e^{-n_3}} \\
\varepsilon_f &= t_2 - a_3
\end{aligned} \quad (9)
$$


teaching gain
weights 1
number of the
neurons input layer
errors
0,0
a(t-1)
input
number of
input vector
biases1
weights 2
errors
0,0
a2(t-1)
r of the
ns second layer
biases 2
output weights 1
output biases1
output weights 2
output biases 2
n
a1
a2
n2
weights1
error 1
a
target
weights 2
error 2
error 1
error 2


19.9610
-1.25600
-24.0000
1.8;-20;-30
q internal coordinates
for known position
[grd]
q final coordinates
[grd]
q final - q init
[grd]
Errors
42.2700
27.2990
-127.89
61.0550
cal 42.270 27.299 -127.895 61.055
cle 59.048 58.409 -157.153 40.344
ycle 65.758 -43.063 17.014 9.937
-3.39671
-52.1598
-10.4184
-13.5072
-45.6662
-79.4588
117.477
-74.5622
0.928209
-0.119956
-1.48902
SUM of all internal
coordinates [grd]
317.164
application point
-1.2000
0.00000
-14.2000
test
-5
-6
alfa
0.10000
fi 0-1,1-2,2-3,3-4
0.00000
0.00000
0.00000
x vector 3D
18.0121
y vector 3D
-1.06875
0
-9
-18
-27
-36

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THANK YOU FOR YOUR ATTENTION!

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