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DINÂMICA CINEMATICA DE UMA ESTRUTURA 2R

DYNAMIC CINEMATIC TO A STRUCTURE 2R

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Resumo

Estruturas planas 2R podem resolver todos os problemas colocados por todas as estruturas antropomórficas robóticas. O estudo dos robôs antropomórficos pelo uso de uma estrutura plana 2R é um método muito mais fácil do que os métodos clássicos utilizados espaciais. O documento descreve um método para a determinação da dinâmica de uma estrutura robótica 2R equilibrado. Estruturas planas 2R são utilizadas na prática, apenas em forma equilibrada, para o qual no presente documento serão, inicialmente, o equilíbrio total e, em seguida, o estudo cinematico-dinâmico somente irá desenvolver-se no modelo já equilibrado. Relações dinâmicas apresentadas em seguida, brevemente, sem dedução será explicado e discutido com relação à sua aplicação. Com base no modelo apresentado e nos seguintes cálculos realizados, pode ser escolhido corretamente os dois motores eléctricos no actuador.

Palavras-chave: robôs antropomórficos, estrutura 2R, estrutura equilibrada, dinâmica.

Abstract

Flat structures 2R can solve all the problems posed by all the robotic anthropomorphic structures. The study of the anthropomorphic robots by the use of a flat structure 2R is a much easier method than classical used spatial methods. The paper outlines a method for the determination of dynamic to a robotic structure 2R balanced. 2R plane structures are used in practice only in the form balanced, for which in this paper will be made, initial, the total balance, and then the study cinematico-dynamic will only develop on the model already balanced. Dynamic relations presented then briefly without deduction will be explained and discussed with regard to their application. On the basis of the model presented and following calculations performed can be chosen correctly the two electric motors in the actuator.

Key-words: anthropomorphic robots, 2R structure, balanced structure, dynamic.

I. INTRODUCTION

Moving mechanical structures are used increasingly in almost all vital sectors of humanity (Tang, 2013; Tong, 2013). The robots are able to process integrated circuits sizes micro and nano, on which the man they can be seen even with electron microscopy (Lee, 2013; Lin, 2013). Dyeing parts in toxic environments, working in chemical and radioactive environments, or at depths and pressures at the bottom of huge oceans, or even cosmic space conquest and visiting exo-planets, are now possible, and were turned into from the dream in reality, because mechanical platforms sequential gearbox (Dong, 2013).

The man will be able to carry out its mission supreme, conqueror of new galaxies, because mechanical systems sequential gearbox (Perumaal, 2013).

Robots were developed and diversified, different aspects, but to-day, they start to be directed on two major categories: systems serial and parallel systems (Aldana, 2013; Padula, 2013; Tabaković, 2013).

Parallel systems are more solid, but more difficult to designed and handled, which serial systems were those which have developed the most (Cao, 2013).

Serial systems and they have different constructive diagrams, but over the last 30 years have been channelled on anthropomorphic structures (Reddy, 2012).

These structures are made up of simple components and couplers for rotation.

Their great advantage is fast movements, good dynamics, a high accuracy, a construction of simple modules STAS, economy of materials, low cost, and high reliability (Garcia E, 2007; Garcia-Murillo, 2013).

One disadvantage of less accurate has been removed because of stepper motors.

Compared with parallel systems (more solid but more cumbersome) serial systems may pose, and the disadvantage of stability something lower.

This disadvantage begins to be exceeded today in smart mode, through the construction of serial systems made up of elements doubled (in parallel).

This last invention, will lead to the strengthening of serial systems, and to their consolidation like the indisputable leader in diversity of mechatronics and robotic systems (He, 2013; Liu, 2013; Wang, 2013; Wen, 2012).

This work starts from a main idea, to study these systems on a single model, 3R, which has finally main movements lying on a single plane model, 2R.

II. METHODS

A. The Structure of Moving (Serial) Mechanical Systems

The most commonly used serial structures over the last 20 or 30 years are those of type 3R, 4R, 5R, 6R, having as constituents essential basic kinematic chain 3R, robot anthropomorphic (RRR), where main rotation around a vertical axis, causes the construction (Petrescu, 2012).

There are then a basic kinematic chain which has two revolutions 'bokeh' (two actuators, i.e. two motors) who work permanently in one plane, and immediately after main support which supports and rotates vertically complete assembly (Petrescu, 2011).

This basic structure (Tang, 2013), 3R, a meet me at all robots serial manufactured on the principle of rotations. Vertical Bracket is was the same, but the drive train as follows, with the two turns situated in a plane can be positioned vertically (most often; the robots anthropomorphic, fig. 1b), or horizontally (case robots scale, fig. 1a).

It can thus passes from the study spatial movement, which is more difficult, to the study motion plane, basic movement, for all the robots and fillers serial movements of rotation.

Moving flat, horizontal or vertical, shall be undertaken far more easily than the spatial integration with the convenience simple in the space of which it is part (Garcia E., 2007).

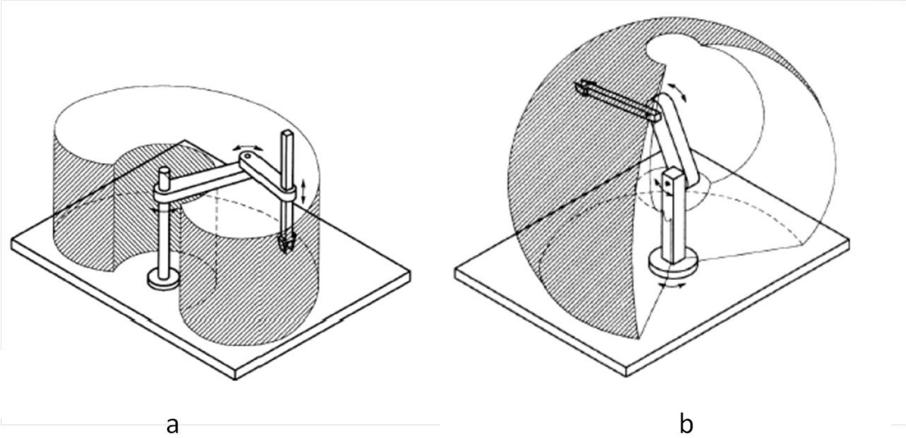

Figure 1. The basic structures 3R (a-scale structure ; b-anthropomorphic structure)

We will exemplify the basic structure existing in a few serial platforms of rotation, these being the most generalized (more widespread) at the present time. On this basic model (3R) have developed further robots 6R (He, 2013) today (fig. 2, rely only on revolutions using actuator that only electric motors, compact); they have a hardness greater penetration while maintaining the flexibility and models 3R, 4R and 5R.

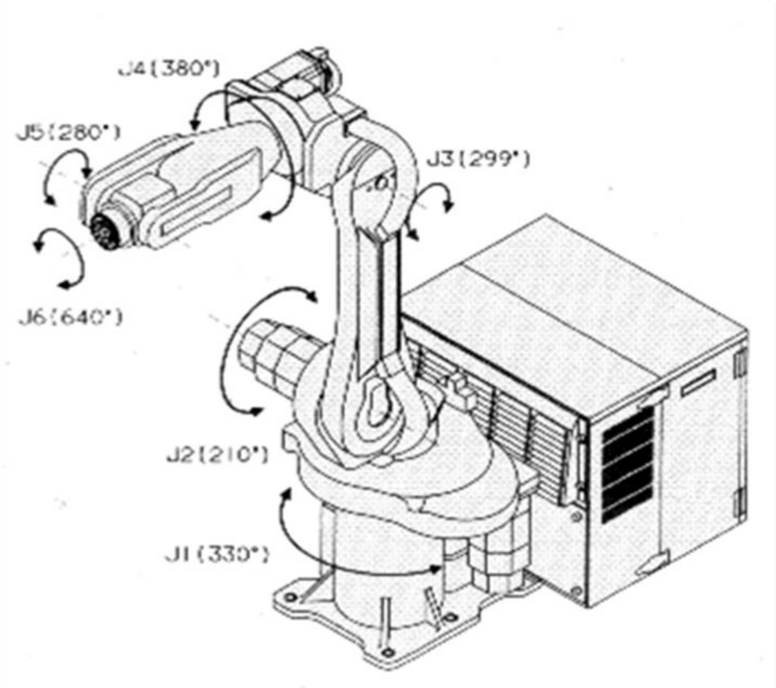

Figure 2. Structure 6R (anthropomorphic structure)

In figure 3 is illustrated geometro-cinematic a structure of basic 3R. Starting from this platform (Petrescu, 2009-2013) may be studied by addition any other scheme, n-R modern.

The platform (system) in figure 3, has three degree of mobility, which can be realized by three actuators (electric motors). First electric motor drives your whole system in a rotating around a vertical spindle O_0z_0. Engine (actuator) number 1, is mounted on the fixed (frame, 0) and causes mobile element 1 in a rotating around a vertical axis (The mobile element 1, then all the other elements (components) of the system).

Follows a kinematic chain plane (vertical), composed of two moving components and two couplers 'bokeh' engines. It's about the kinematic elements mobile 2 and 3, the assembly 2-3 being moved by the actuator of the second mounted to engage A (O_2), fixed on item 1. Therefore the second electric motor attached to the component 1 will result in the item 2 of rotating relative to the item 1, but he will move automatically entire drive train 2-3.

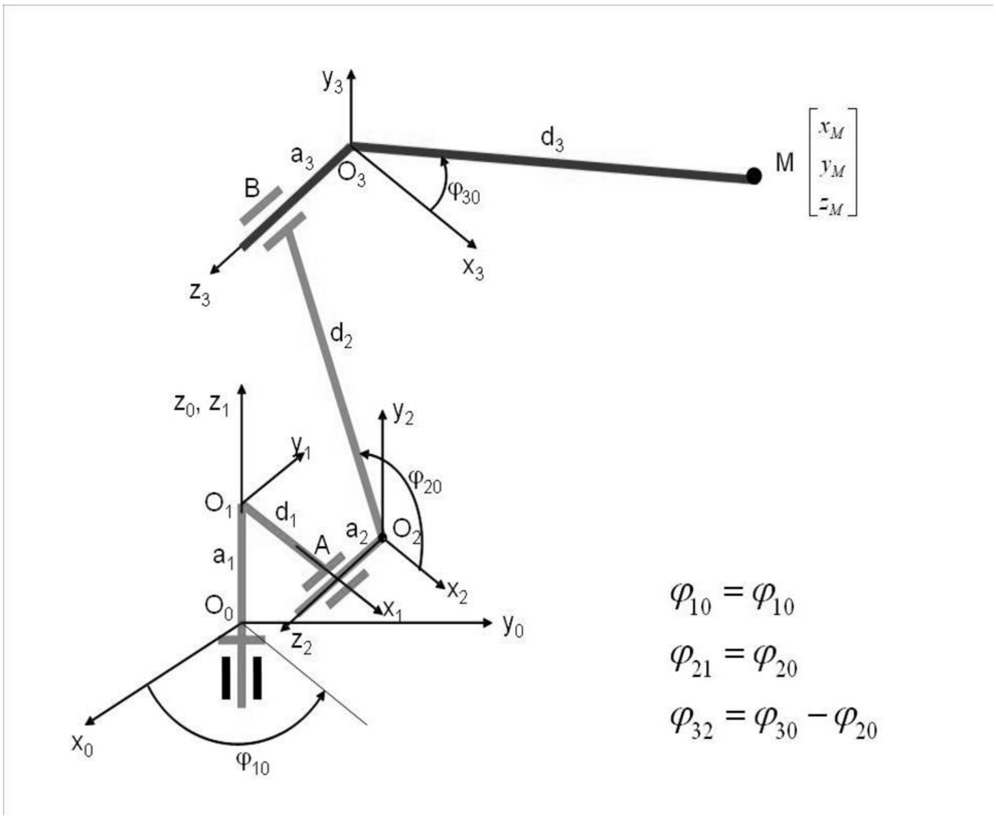

Figure 3. Layout geometro-cinematic a modern structures 3R (anthropomorphic)

Last actuator (electric motor) attached to the item (2), and in B (O_3), will rotate item 3 (relative in relation to 2).

Rotation φ_{10} carried out by the first actuator, is and relative (between items 1 and 0) and absolute (between elements 1 and 0).

Rotation φ_{20} carried out by the second actuator, is and relative (between items 2 and 1) and absolute (between items 2 and 0), due to the arrangement.

Rotation $\theta=\varphi_{32}$ carried out by the third actuator, is only relative (between items 3 and 2); the corresponding absolute (between items 3 and 0) as a function of $\theta=\varphi_{32}$ and φ_{20}.

The drive train 2-3 (consisting of kinematic elements 2 and 3) is a kinematic chain plan, which fall within a single plane or in one or more of the other plane parallel to each other. It is a special kinematic system, which will be examined separately. It shall be considered as item 1 of which is caught the drive train 2-3 as being fixed, couplers kinematic engines A(O_2) and B(O_3) becoming first fixed coupler, and the coupler to make two mobile, which are both couplers kinematic C5, of rotation.

The drive train 2-3 having degree of mobility 2, must be actuated by two motors (Liu, 2013).

It is preferred that the two actuators to be two electric motors, a direct current, or alternately. Action can be done but with different engines. Hydraulic motors, pneumatic, sonic, etc.

Structural schematic kinematic chain plan 2-3 (fig. 4) resembles with cinematic scheme.

The conductor 2 is linked to the element considered fixed coupler 1 by the term O_2 engines, and drive element 3 is connected to the element mobile 2 by engage engines O_3.

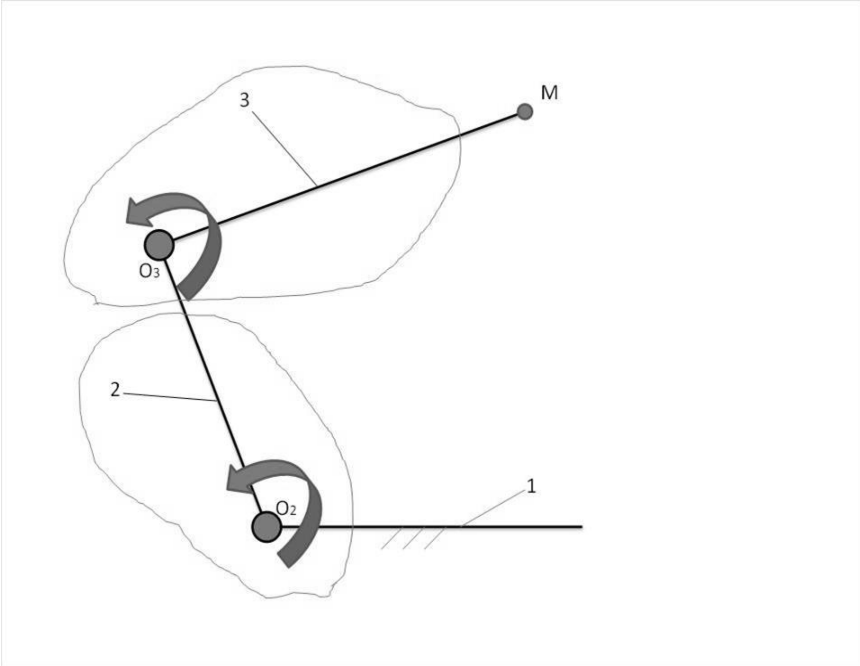

Figure 4. Structural schematic kinematic chain plan 2-3 linked to item 1 considered fixed

This results in a kinematic chain open with two degree of mobility, which can be realized by the two actuators, i.e. the two electric motors, mounted on 'bokeh' couplers engines A and B or O_2 or O_3 (Garcia-Murillo, 2013; Flavio de Melo, 2012).

B. Static and Total Balance of Kinematic Chain Plan, by the Conventional Method (with Counterweights)

The mechanism in Fig. 4 (the cinematic chain plan), must be balanced to have a normal operation (Petrescu, 2011-2012). Obtain open kinematic chain as shown in Fig. 5.

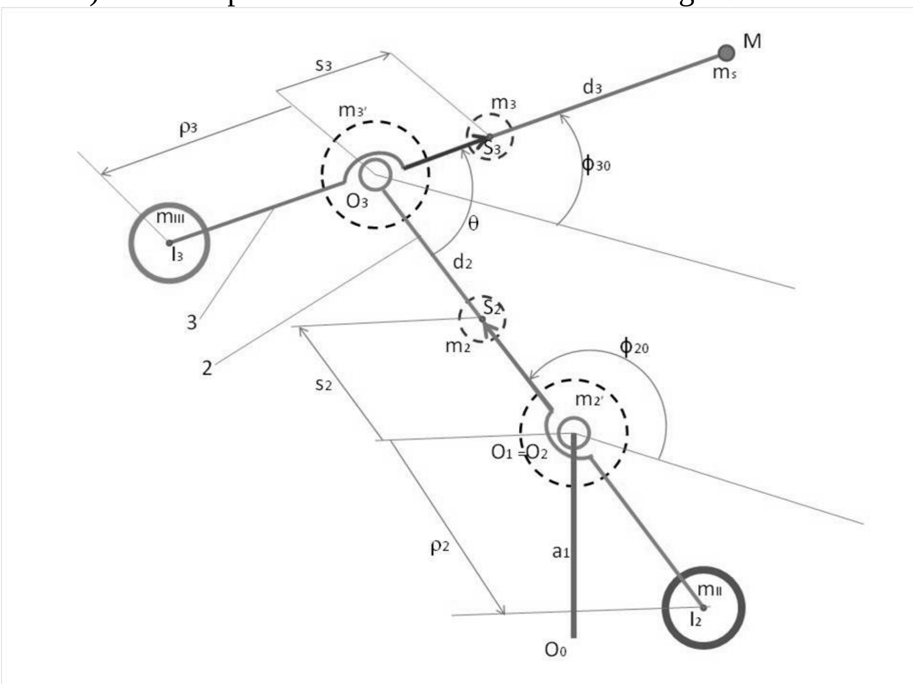

Figure 5. Static total balance of kinematic chain plan

Write moments amount of weight forces on item 3 in relation to the point O_3 (the relationship 1).

$$\sum M_{O_3}^{(3)} = 0 \quad \Rightarrow m_s \cdot d_3 + m_3 \cdot s_3 = m_{III} \cdot \rho_3 \tag{1}$$

As a general rule to choose the balance weight m_{III} and results by calculation distance of assembly, ρ_3 (the relationship 2).

$$\rho_3 = \frac{m_s \cdot d_3 + m_3 \cdot s_3}{m_{III}} \tag{2}$$

After balancing, weight of element 3 concentrated in swing O_3 takes the value $m_{3'}$ given of relationship (3).

$$m_{3'} = m_3 + m_s + m_{III} \tag{3}$$

It is written in the amount forces moments of the weight on the items 2 and 3 (considered as a common platform) in relation to the point O_2 (relationship 4).

$$\sum M_{O_2}^{(2+3)} = 0 \Rightarrow m_{3'} \cdot d_2 + m_2 \cdot s_2 = m_{II} \cdot \rho_2 \tag{4}$$

To choose the balance weight m_{II} and results by calculation distance of assembly, ρ_2 (the relationship 5).

$$\rho_2 = \frac{m_{3'} \cdot d_2 + m_2 \cdot s_2}{m_{II}} \tag{5}$$

After equilibration, the mass entire cinematic chain plan (consisting of a number of elements 2 and 3) is concentrated in joint between O_2 and takes the value $m_{2'}$ given of relationship (6).

$$m_{2'} = m_{3'} + m_2 + m_{II} \tag{6}$$

The forces of the Kinematic chain plan balanced can be seen in Figure 6.

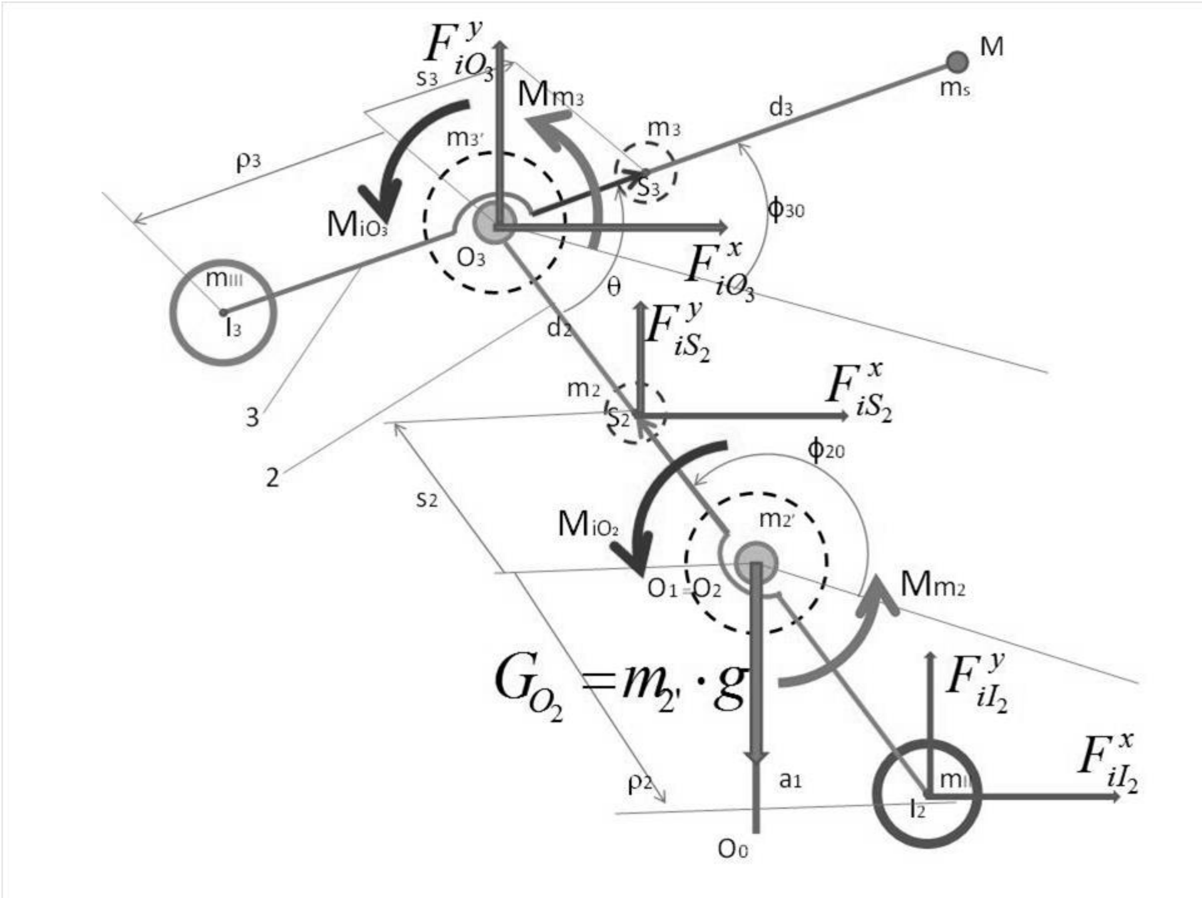

Figure 6. Forces of the kinematic chain plan balanced

Dynamics of the kinematic chain plan balanced can be monitored in figure 7 (relationship 7).

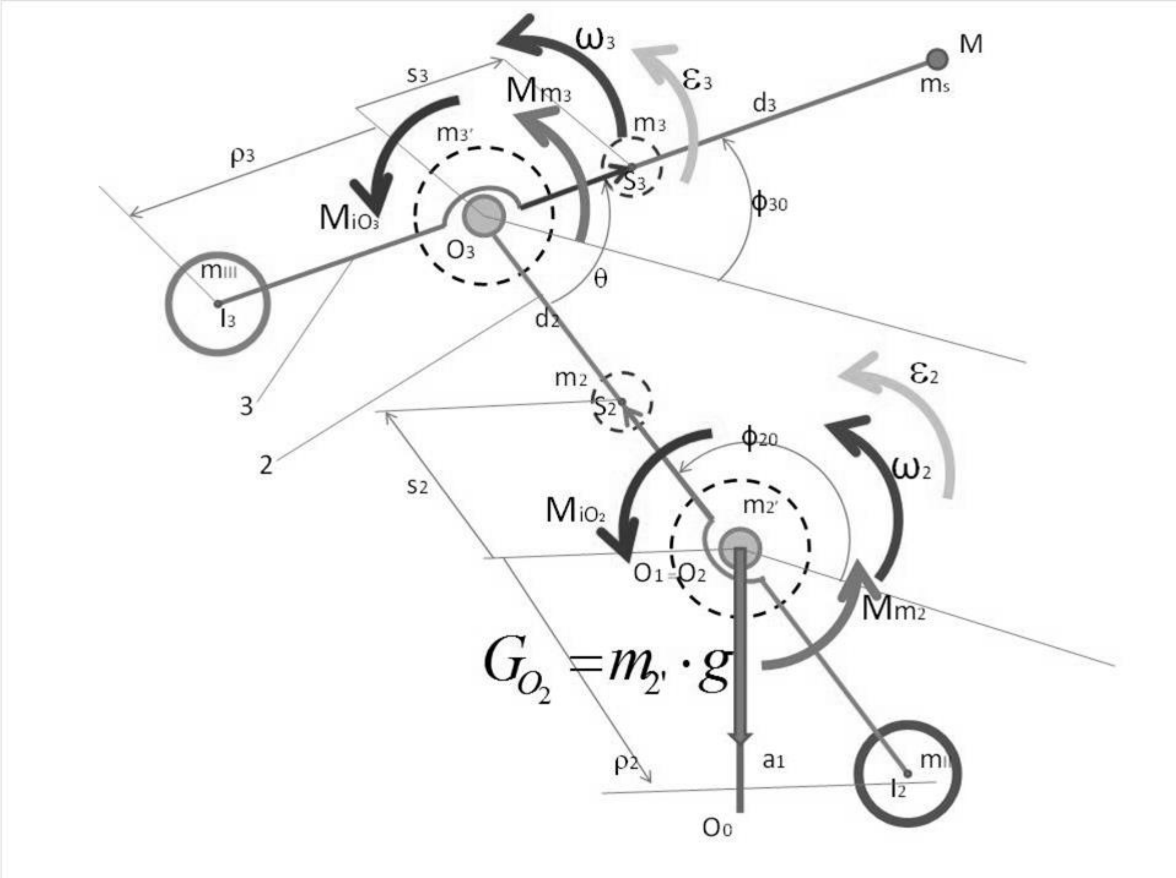

Figure 7. Dynamics of the kinematic chain plan balanced

C. Dynamic Cinematic

Are known following parameters:

$x_M, y_M, m_2, m_3, d_2, d_3, s_2, s_3, \rho_2, \rho_3, \omega_2, \dot{\theta}, M_{m_2}, M_{m_3}$.

Shall initially be calculated ω_3, ε_2, ε_3 and positions (relations 7 and 8), (Petrescu, 2011-2012).

$$\begin{cases} \omega_3 = \dot{\theta} + \omega_2 \\ \varepsilon_2 = \dfrac{M_{m_2}}{m_{3'} \cdot d_2^2 + m_2 \cdot s_2^2 + m_{II} \cdot \rho_2^2} = \dfrac{M_{m_2}}{J_{O_2}^*} \\ \varepsilon_3 = \dfrac{M_{m_3}}{m_s \cdot d_3^2 + m_3 \cdot s_3^2 + m_{III} \cdot \rho_3^2} = \dfrac{M_{m_3}}{J_{O_3}} \end{cases} \tag{7}$$

$$
\begin{cases}
d = \sqrt{x_M^2 + y_M^2} \\
d^2 = x_M^2 + y_M^2 \\
\cos\varphi = \dfrac{x_M}{d} \\
\sin\varphi = \dfrac{y_M}{d} \\
\cos O_2 = \dfrac{d_2^2 + d^2 - d_3^2}{2 \cdot d_2 \cdot d} \\
\sin O_2 = \dfrac{\sqrt{4 \cdot d_2^2 \cdot d^2 - \left(d_2^2 + d^2 - d_3^2\right)^2}}{2 \cdot d_2 \cdot d} \\
\cos\varphi_2 = \cos\varphi \cdot \cos O_2 \mp \sin\varphi \cdot \sin O_2 \\
\sin\varphi_2 = \sin\varphi \cdot \cos O_2 \pm \sin O_2 \cdot \cos\varphi \\
x = d_2 \cdot \cos\varphi_2 \\
y = d_2 \cdot \sin\varphi_2 \\
\varphi_2 = semn(\sin\varphi_2) \cdot \arccos(\cos\varphi_2) \\
\cos M = \dfrac{d_3^2 + d^2 - d_2^2}{2 \cdot d_3 \cdot d} \\
\sin M = \dfrac{\sqrt{4 \cdot d_3^2 \cdot d^2 - \left(d_3^2 + d^2 - d_2^2\right)^2}}{2 \cdot d_3 \cdot d} \\
\cos\varphi_3 = \cos\varphi \cdot \cos M \pm \sin\varphi \cdot \sin M \\
\sin\varphi_3 = \sin\varphi \cdot \cos M \mp \sin M \cdot \cos\varphi \\
\varphi_3 = semn(\sin\varphi_3) \cdot \arccos(\cos\varphi_3)
\end{cases}
\tag{8}
$$

Then can be determined by calculating linear speeds and linear accelerations (system 9).

$$
\begin{cases}
\dot{x} = -y \cdot \omega_2 \\
\dot{y} = x \cdot \omega_2 \\
\ddot{x} = -x \cdot \omega_2^2 - y \cdot \varepsilon_2 \\
\ddot{y} = -y \cdot \omega_2^2 + x \cdot \varepsilon_2 \\
\dot{x}_M = \dot{x} - (y_M - y) \cdot \omega_3 \\
\dot{y}_M = \dot{y} + (x_M - x) \cdot \omega_3 \\
\ddot{x}_M = \ddot{x} - (\dot{y}_M - \dot{y}) \cdot \omega_3 - (y_M - y) \cdot \varepsilon_3 \\
\ddot{y}_M = \ddot{y} + (\dot{x}_M - \dot{x}) \cdot \omega_3 + (x_M - x) \cdot \varepsilon_3
\end{cases}
\tag{9}
$$

The following shall be recalculated rotation speeds and angular accelerations (see the system 10).

$$
\begin{cases}
\omega_2 = \dfrac{\dot{y}\cdot\cos\varphi_2 - \dot{x}\cdot\sin\varphi_2}{d_2} \\
\omega_3 = \dfrac{(\dot{y}_M - \dot{y})\cdot\cos\varphi_3 - (\dot{x}_M - \dot{x})\cdot\sin\varphi_3}{d_3} \\
\varepsilon_2 = \dfrac{\ddot{y}\cdot\cos\varphi_2 - \ddot{x}\cdot\sin\varphi_2}{d_2} \\
\varepsilon_3 = \dfrac{(\ddot{y}_M - \ddot{y})\cdot\cos\varphi_3 - (\ddot{x}_M - \ddot{x})\cdot\sin\varphi_3}{d_3}
\end{cases}
\tag{10}
$$

Compare rotation speeds obtained with those of entry. If there are any differences, are obtained corresponding engine moments new rotational speeds from diagrams characteristic of electric motors. With the new moments obtained shall be redo calculations (using relationships 7-10).

For O_3 were used notations without a letter that indicate, and for the point M have been made notations with the index M.

III. DISCUSSION

Moments electric motors (actuators) have values that varies in the range restricted, once with angular speed value of the engine in question, as shown in the characteristic diagram presented by the producer concerned (see the Fig. 8).

As shown in Fig. 8, the variation in torque with angular speed is small, so that the engine torque can be considered constant throughout the portion of operation.

An important remark which should not be overlooked is that both electric motors, a direct current and alternating current asynchronous, have a feature of stable operation.

If the load increases the engine angular speed and hence that of the mechanism (open kinematic chain) is reduced by adapting to increased load, and when the load is reduced and it is possible to operate at a higher speed naturally actuator angular speed increases, in accordance with its functional feature internal.

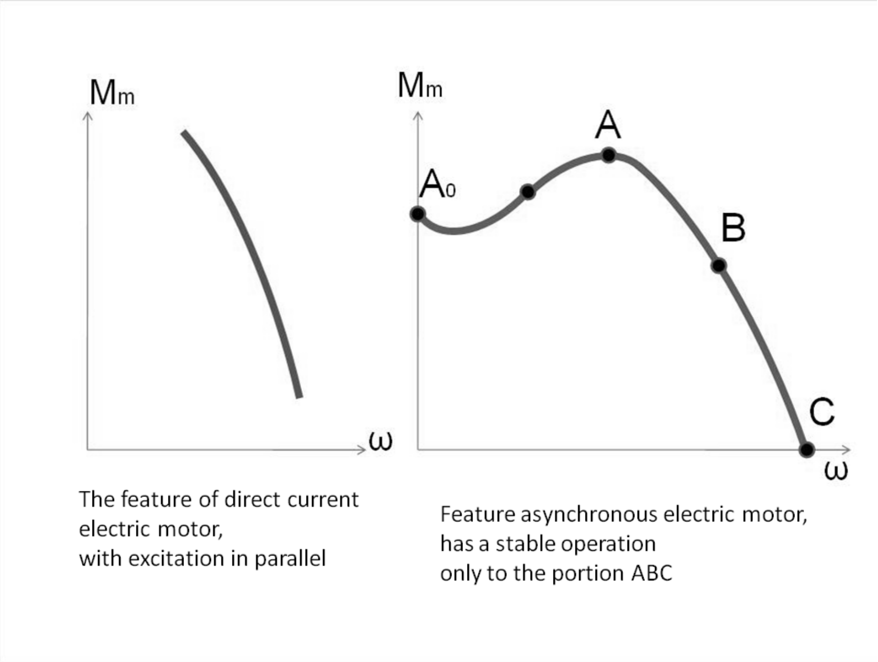

Figure 8. Electric motors feature

IV. CONCLUSIONS

Flat structures 2R can solve all the problems posed by all the robotic anthropomorphic structures. The study of the anthropomorphic robots by the use of a flat structure 2R is a much easier method than classical used spatial methods.

The method proposed in this work has the advantage of greatly simplify day-to-systems design calculations to mechatronics and robotic. Win time, saves work, it's possible to work out a direct dynamic synthesis easier serial systems, without it being necessary experimental testing. For teaching method is a total simplification of the dynamic design, and thus increasing the understanding of this phenomenon.

Dynamic shown in work has a special character because we are an open kinematic chain which has two degree of mobility.

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