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Switching from Flat to Spatial Motion to 3R Mechatronic Systems

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Abstract: The anthropomorphic robots are part of the classical series of mechatronic systems, being in the form of arms and having at least three space rotation, to which other components may eventually be added, thus lengthening the entire kinematic chain. You can also add all the planetary or spatial rotating arms or others that are translating. At the end we always have the end effector element that can be a manipulator, that is, a hand to grasp the objects, in which case one can speak of a prehensive device, that is a gripping device that today imitates very well a human hand even if it is one mechanical, may also be a painting, cutting or welding device, or one for machining. The base support and schematics of all anthropomorphic robots remain the 3R space system. It has been presented in other works and studied matrix spatially, or more simply in a plan, but in this case, it is necessary to move from the working plane to the real space, or vice versa, passage that we will present in this study. Projections of point *M* on planar axes will be marked with the higher *P* (Plan) index to distinguish them from the corresponding space axes. Due to the fact that the vertical projection plane is removed from the $O\rho$ axis with a constant distance $a_2 + a_3$, (the vertical working plane does not project directly on the $O\rho$ axis, but on an axis parallel to it distal to the length $a_2 + a_3$) the projection of the *M* point on the horizontal plane of the space will not fall in *M* 'but at the point *M*''. Therefore, the projections of *M* on the axes *Ox* and *Oy* will not be those of point *M*' but those of point *M*'', according to the relations given by the system (2). We want to remove the angle of 90°C from the relations (2), which had an important explanatory role in the understanding of the phenomenon, to see how the equation of transition from plane to spatial axes is written, here (in the horizontal plane of space) about a rotation, whose relations should not be automatically detained, but deduced logically, which is why we will immediately move from the logically determined system (2) to the convenient system (3), which will now be obtained from (2) the angle of 90°C from the trigonometric relations. Perhaps the method used may seem rather difficult, but compared to spatial matrix methods, it is extremely straightforward and direct, contributing to transforming the space movement into a flat, much easier to understand and studied movement. In the system (4) we centralize all the transition relations from the plane to the spatial movement.

Keywords: Anthropomorphic Mechatronic Systems, Robots, Geometry, Kinematics, Switching from Flat to Spatial Motion

Introduction

Anthropomorphic mechatronic systems are the most widely used robotics systems worldwide today in industry and in all automated environments. These systems are best suited to the modern automation and mechatronisation needs of the modern world, being mobile, dynamic, light, robust, complex, technologically simple, easy to design and manufactured, implemented, maintained and used in almost any industrial site, both in machine building and in special environments, such as chemical, toxic, dyeing, underwater, nuclear, in space.... Anthropomorphic robots are flexible, dynamic, stable, lightweight, fast, fast, inexpensive, easy-to-install, mechanical, mechanical, mechanical and mechanical systems with a pleasant appearance, modern industrial design and easy to design and implement in any workplace, imposed. The anthropomorphic robots are part of the classical series of mechatronic systems, being in the form of arms and having at least three space rotation, to which other components may eventually be added, thus lengthening the entire kinematic chain. You can also add all the planetary or spatial rotating arms or others that are translating. At the end we always have the end effector element that can be a manipulator, that is, a hand to grasp the objects, in which case one can speak of a prehensive device, that is a gripping device that today imitates very well a human hand even if it is one mechanical, may also be a painting, cutting or welding device, or one for machining. The base support and schematics of all anthropomorphic robots remain the 3R space system. It has been presented in other works and studied matrix spatially, or more simply in a plan, but in this case, it is necessary to move from the working plane to the real space, or vice versa, passage that we will present in this study (Antonescu and Petrescu, 1985; 1989; Antonescu *et al.*, 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001; Aversa *et al.*, 2017a; 2017b; 2017c; 2017d; 2017e; 2016a; 2016b; 2016c; 2016d; 2016e; 2016f; 2016g; 2016h; 2016i; 2016j; 2016k; 2016l; 2016m; 2016n; 2016o; Berto *et al.*, 2016a; 2016b; 2016c; 2016d; Cao *et al.*, 2013; Dong *et al.*, 2013; Comanescu, 2010; Franklin, 1930; He *et al.*, 2013; Lee, 2013; Lin *et al.*, 2013; Liu *et al.*, 2013; Mirsayar *et al.*, 2017; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu, 2011; 2015a; 2015b; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e; 2011; 2012a; 2012b; 2013a; 2013b; 2016a; 2016; 2016c; Petrescu *et al.*, 2009; 2016; ; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; 2017r; 2017s; 2017t; 2017u; 2017v; 2017w; 2017x; 2017y; 2017z; 2017aa; 2017ab; 2017ac; 2017ad; 2017ae).

Materials and Methods

Figure 1 shows the kinematic diagram of the planar chain and Fig. 2 shows the kinematic scheme of the space chain.

The transition from the plane to the space movement will then be continued.

The x_2Oy_2 plane dimensions will be projected onto the $zO\rho$ axes. Thus, the length on the horizontal vertical axis Oy will be projected onto the spatial vertical axis Oz by adding the constant a_1 φ and the length of the horizontal plan axis Ox will be projected on the horizontal spatial axis $O\rho$ by adding the constant d_1, according to the relations given by the system (1):

$$\begin{cases} \rho_{M'} = d_1 + x_M^P \\ z_M = a_1 + y_M^P \end{cases} \tag{1}$$

Projections of point M on planar axes will be marked with the higher P (Plan) index to distinguish them from the corresponding space axes.

Due to the fact that the vertical projection plane is removed from the $O\rho$ axis with a constant distance $a_2 + a_3$, (the vertical working plane does not project directly on the $O\rho$ axis, but on an axis parallel to it distal to the length $a_2 + a_3$) the projection of the M point on the horizontal plane of the space will not fall in M 'but at the point M'' (Fig. 2).

Therefore, the projections of M on the axes Ox and Oy will not be those of point M' but those of point M'', according to the relations given by the system (2):

$$\begin{cases} x_M = \rho_{M'} \cdot \cos\varphi_{10} + (a_2 + a_3) \cdot \cos\left(\varphi_{10} + \dfrac{\pi}{2}\right) \\ y_M = \rho_{M'} \cdot \sin\varphi_{10} + (a_2 + a_3) \cdot \sin\left(\varphi_{10} + \dfrac{\pi}{2}\right) \end{cases} \tag{2}$$

We want to remove the angle of 90°C from the relations (2), which had an important explanatory role in the understanding of the phenomenon, to see how the equation of transition from plane to spatial axes is written, here (in the horizontal plane of space) about a rotation, whose relations should not be automatically detained, but deduced logically, which is why we will immediately move from the logically determined system (2) to the convenient system (3), which will now be obtained from (2) the angle of 90°C from the trigonometric relations:

$$\begin{cases} x_M = \rho_{M'} \cdot \cos\varphi_{10} - (a_2 + a_3) \cdot \sin\varphi_{10} \\ y_M = \rho_{M'} \cdot \sin\varphi_{10} + (a_2 + a_3) \cdot \cos\varphi_{10} \end{cases} \tag{3}$$

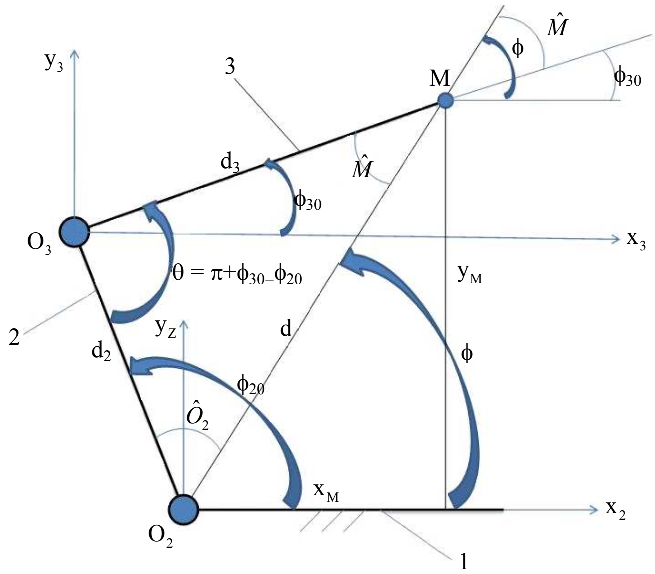

Fig. 1: The kinematic scheme of the plan chain

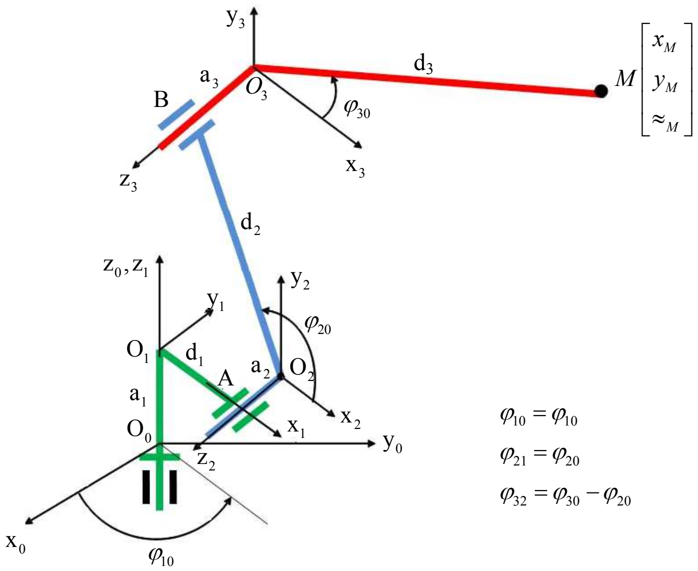

Fig. 2: The kinematic scheme of the spatial chain

Perhaps the method used may seem rather difficult, but compared to spatial matrix methods, it is extremely straightforward and direct, contributing to transforming the space movement into a flat, much easier to understand and studied movement.

In the system (4) we centralize all the transition relations from the plane to the spatial movement:

$$\begin{cases} x_M = \left(d_1 + x_M^P\right) \cdot \cos\varphi_{10} - (a_2 + a_3) \cdot \sin\varphi_{10} \\ y_M = \left(d_1 + x_M^P\right) \cdot \sin\varphi_{10} + (a_2 + a_3) \cdot \cos\varphi_{10} \\ z_M = a_1 + y_M^P \end{cases} \quad (4)$$

Replacing in (4) the values of x_M^P and y_M^P obtaining the system of absolute spatial Equation 5:

$$\begin{cases} x_M = \left(d_1 + d_2 \cdot \cos\varphi_{20} + d_3 \cdot \cos\varphi_{30}\right) \cdot \cos\varphi_{10} - (a_2 + a_3) \cdot \sin\varphi_{10} \\ y_M = \left(d_1 + d_2 \cdot \cos\varphi_{20} + d_3 \cdot \cos\varphi_{30}\right) \cdot \sin\varphi_{10} + (a_2 + a_3) \cdot \cos\varphi_{10} \\ z_M = a_1 + d_2 \cdot \sin\varphi_{20} + d_3 \cdot \sin\varphi_{30} \end{cases} \quad (5)$$

For simpler determination of speeds and accelerations in the system (4) from which it departs, it is denoted $a_2 + a_3$ by a, so that (4) acquires the simplified aspect (6):

$$\begin{cases} x_M = \left(d_1 + x_M^P\right) \cdot \cos\varphi_{10} - a \cdot \sin\varphi_{10} \\ y_M = \left(d_1 + x_M^P\right) \cdot \sin\varphi_{10} + a \cdot \cos\varphi_{10} \\ z_M = a_1 + y_M^P \end{cases} \tag{6}$$

The spatial positioning system (6) is derived from time and the spatial velocity system (7) is obtained:

$$\begin{cases} \dot{x}_M = \dot{x}_M^P \cdot \cos\varphi_{10} - \left(d_1 + x_M^P\right) \cdot \sin\varphi_{10} \cdot \dot{\varphi}_{10} - a \cdot \cos\varphi_{10} \cdot \dot{\varphi}_{10} \\ \dot{y}_M = \dot{x}_M^P \cdot \sin\varphi_{10} + \left(d_1 + x_M^P\right) \cdot \cos\varphi_{10} \cdot \dot{\varphi}_{10} - a \cdot \sin\varphi_{10} \cdot \dot{\varphi}_{10} \\ \dot{z}_M = \dot{y}_M^P \end{cases} \tag{7}$$

The space velocity system (7) derives from time and the spatial acceleration system (8) is obtained, which is restricted to the shape (9):

$$\begin{cases} \ddot{x}_M = \ddot{x}_M^P \cdot \cos\varphi_{10} - \dot{x}_M^P \cdot \sin\varphi_{10} \cdot \dot{\varphi}_{10} - \dot{x}_M^P \cdot \sin\varphi_{10} \cdot \dot{\varphi}_{10} \\ -\left(d_1 + x_M^P\right) \cdot \cos\varphi_{10} \cdot \dot{\varphi}_{10}^2 + a \cdot \sin\varphi_{10} \cdot \dot{\varphi}_{10}^2 \\ \ddot{y}_M = \ddot{x}_M^P \cdot \sin\varphi_{10} + \dot{x}_M^P \cdot \cos\varphi_{10} \cdot \dot{\varphi}_{10} + \dot{x}_M^P \cdot \cos\varphi_{10} \cdot \dot{\varphi}_{10} \\ -\left(d_1 + x_M^P\right) \cdot \sin\varphi_{10} \cdot \dot{\varphi}_{10}^2 - a \cdot \cos\varphi_{10} \cdot \dot{\varphi}_{10}^2 \\ \ddot{z}_M = \ddot{y}_M^P \end{cases} \tag{8}$$

$$\begin{cases} \ddot{x}_M = \left[\ddot{x}_M^P - \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10}^2\right] \cdot \cos\varphi_{10} \\ -\left(2 \cdot \dot{x}_M^P - a \cdot \dot{\varphi}_{10}\right) \cdot \dot{\varphi}_{10} \cdot \sin\varphi_{10} \\ \ddot{y}_M = \left[\ddot{x}_M^P - \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10}^2\right] \cdot \sin\varphi_{10} \\ +\left(2 \cdot \dot{x}_M^P - a \cdot \dot{\varphi}_{10}\right) \cdot \dot{\varphi}_{10} \cdot \cos\varphi_{10} \\ \ddot{z}_M = \ddot{y}_M^P \end{cases} \tag{9}$$

The space velocity system (7) is restricted to the shape (10), which by using the notations u and v is rewritten in the simplified form (11) and the acceleration system (9) can be restricted to the shape (12), with the notations w, t:

$$\begin{cases} \dot{x}_M = \left(\dot{x}_M^P - a \cdot \dot{\varphi}_{10}\right) \cdot \cos\varphi_{10} - \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10} \cdot \sin\varphi_{10} \\ \dot{y}_M = \left(\dot{x}_M^P - a \cdot \dot{\varphi}_{10}\right) \cdot \sin\varphi_{10} + \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10} \cdot \cos\varphi_{10} \\ \dot{z}_M = \dot{y}_M^P \end{cases} \tag{10}$$

$$\begin{cases} \dot{x}_M = u \cdot \cos\varphi_{10} - v \cdot \sin\varphi_{10} \\ \dot{y}_M = u \cdot \sin\varphi_{10} + v \cdot \cos\varphi_{10} \\ \dot{z}_M = \dot{y}_M^P \\ u = \dot{x}_M^P - a \cdot \dot{\varphi}_{10}; v = \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10} \end{cases} \tag{11}$$

$$\begin{cases} \ddot{x}_M = w \cdot \cos\varphi_{10} - t \cdot \sin\varphi_{10} \\ \ddot{y}_M = w \cdot \sin\varphi_{10} + t \cdot \cos\varphi_{10} \\ \ddot{z}_M = \ddot{y}_M^P \\ w = \ddot{x}_M^P - \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10}^2; t = \left(2 \cdot \dot{x}_M^P - a \cdot \dot{\varphi}_{10}\right) \cdot \dot{\varphi}_{10} \end{cases} \tag{12}$$

Next, we will present the positions, velocities and spatial accelerations, all written down within the system (13):

$$\begin{cases} Positions: \\ x_M = s \cdot \cos\varphi_{10} - a \cdot \sin\varphi_{10} \\ y_M = s \cdot \sin\varphi_{10} + a \cdot \cos\varphi_{10} \\ z_M = a_1 + y_M^P \\ cu \quad s = d_1 + x_M^P; \; a = a_2 + a_3 \\ Velocities: \\ \dot{x}_M = u \cdot \cos\varphi_{10} - v \cdot \sin\varphi_{10} \\ \dot{y}_M = u \cdot \sin\varphi_{10} + v \cdot \cos\varphi_{10} \\ \dot{z}_M = \dot{y}_M^P \\ cu \quad u = \dot{x}_M^P - a \cdot \dot{\varphi}_{10}; \; v = \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10} \\ Accelerations: \\ \ddot{x}_M = w \cdot \cos\varphi_{10} - t \cdot \sin\varphi_{10} \\ \ddot{y}_M = w \cdot \sin\varphi_{10} + t \cdot \cos\varphi_{10} \\ \ddot{z}_M = \ddot{y}_M^P \\ with \quad w = \ddot{x}_M^P - \left(d_1 + x_M^P\right) \cdot \dot{\varphi}_{10}^2; \quad t = \left(2 \cdot \dot{x}_M^P - a \cdot \dot{\varphi}_{10}\right) \cdot \dot{\varphi}_{10} \end{cases} \tag{13}$$

Results

The spatial position vector module of the end effector point M in the fixed Cartesian space system is given by the relation (14):

$$r_M = \sqrt{x_M^2 + y_M^2 + z_M^2} = \sqrt{s^2 + a^2 + \left(a_1 + y_M^P\right)^2} \tag{14}$$

The modulus of the absolute speed vector of point M is obtained with the relation (15):

$$v_M = \sqrt{\dot{x}_M^2 + \dot{y}_M^2 + \dot{z}_M^2} = \sqrt{u^2 + v^2 + \dot{y}_M^{P\,2}} \tag{15}$$

The M-point absolute acceleration vector module is obtained with relation (16):

$$a_M = \sqrt{\ddot{x}_M^2 + \ddot{y}_M^2 + \ddot{z}_M^2} = \sqrt{w^2 + t^2 + \ddot{y}_M^{P\,2}} \tag{16}$$

In the system (17) a recapitulation of the three absolute spatial parameters of the M point: Absolute displacement (or absolute position), absolute speed, absolute acceleration is made:

$$\begin{cases} r_M = \sqrt{x_M^2 + y_M^2 + z_M^2} = \sqrt{s^2 + a^2 + \left(a_1 + y_M^P\right)^2} \\ v_M = \sqrt{\dot{x}_M^2 + \dot{y}_M^2 + \dot{z}_M^2} = \sqrt{u^2 + v^2 + \dot{y}_M^{P\,2}} \\ a_M = \sqrt{\ddot{x}_M^2 + \ddot{y}_M^2 + \ddot{z}_M^2} = \sqrt{w^2 + t^2 + \ddot{y}_M^{P\,2}} \end{cases} \tag{17}$$

Discussion

Simple transition from plan to spatial computing can help us modify our work so that instead of performing all spatial matrices, let's study the planar system, then add the equation of transition from plane to spatial mode and so the same results will be obtained as if we had all the difficult spatial calculations done, practically just in plan, simplified. Man is accustomed to seeing the plan better than space, but especially to judge and reason more easily the plane phenomena than the spatial phenomena.

Conclusion

The anthropomorphic robots are part of the classical series of mechatronic systems, being in the form of arms and having at least three space rotation, to which other components may eventually be added, thus lengthening the entire kinematic chain. You can also add all the planetary or spatial rotating arms or others that are translating.

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Author's Contributions

This section should state the contributions made by each author in the preparation, development and publication of this manuscript.

Ethics

Authors should address any ethical issues that may arise after the publication of this manuscript.

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