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Speeds and Accelerations in Direct Kinematics to the MP3R Systems

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Abstract: Today, robots and mechatronic systems are constantly playing an essential role in our lives, being a key link in the automotive industry, without which it can no longer be conceived. If the robots initially started in the machine building industry to the imperious demands of the car king to have a growing production fast and steadily, helping the logarithmic progression of automotive construction, today robots and automation have rapidly penetrated all areas of the machine building industry, due to their ability to produce fast, long, quality, without pauses, country illnesses, at an innate pace, far outweighing man in this chapter. Additionally, robots can work in toxic, dangerous, airless environments, such as in space or underwater, at high pressures, or in potentially dangerous places. There is no question of removing robots from industrial work today. On the contrary, there is a fierce competition in the acquisition, construction, implementation and maintenance of as many robotic mechanical systems due to their high working capacity but also because they have a high reliability and a high quality of the operations performed. In this study we will treat the kinematicity of anthropomorphic robots, as they are today the most widespread robots in the global industry, due to their huge work capabilities and rapid adaptation to any working conditions. It will highlight the speeds and accelerations of these moving mechanical systems in direct kinematics.

Keywords: Mechanism, Robots, Mechatronics, Mechanical Systems, Serial Systems, Kinematics, Direct Kinematics, Velocities, Accelerations

Introduction

The humanoids robots are used now as a tool for research in several scientific fields.

Researchers need to understand the structure of the human body and behavior (biomechanics) to build and to study robots humanoids. On the other hand, the attempt simulation of the human body leads to a greater understanding of it. Human knowledge is a field of study, which is focused on the way in that people learn from sensory information in order to acquire the skills and insightful motor. Such knowledge are used to develop models for the calculation of human behavior and have been improved in time.

It has been suggested that robotics highly advanced will facilitate its increase even in ordinary people.

With all that the original purpose of humanoid research has been to build a better orthosis and prosthesis for human beings, knowledge has been transferred between the two disciplines. Some examples are Prosthesis footswitch with electrical adjustment for impaired neuromuscular, orthosis ankle-foot, biological realistic prosthesis leg and forearm prosthesis (Aversa *et al*., 2017a-e; 2016a-o).

In addition to the research, robots humanoids are developed to perform human activities, such as personal assistance, where they would be able to help places of work diseased and the elderly and dirty or dangerous.

Workplaces ordinary, such as to be a yacht or a worker of a production line of cars are also suitable for the humanoids." In essence, as they can use tools and operate the equipment and vehicles designed to human form, those humanoids could carry out, theoretically, any load a human being may, as long as they have the software itself. However, the complexity to do this is deceptively big.

Today, robots and mechatronic systems are constantly playing an essential role in our lives, being a key link in the automotive industry, without which it can no longer be conceived. If the robots initially started in the machine building industry to the imperious demands of the car king to have a growing production fast and steadily, helping the logarithmic progression of automotive construction, today robots and automation have rapidly penetrated all areas of the machine building industry, due to their ability to produce fast, long, quality, without pauses, country illnesses, at an innate pace, far outweighing man in this chapter.

Additionally, robots can work in toxic, dangerous, airless environments, such as in space or underwater, at high pressures, or in potentially dangerous places.

There is no question of removing robots from industrial work today. On the contrary, there is a fierce competition in the acquisition, construction, implementation and maintenance of as many robotic mechanical systems due to their high working capacity but also because they have a high reliability and a high quality of the operations performed.

In this study we will treat the kinematicity of anthropomorphic robots, as they are today the most widespread robots in the global industry, due to their huge work capabilities and rapid adaptation to any working conditions. It will highlight the speeds and accelerations of these moving mechanical systems in direct kinematics.

Today the moving mechanical systems are utilized in almost all vital sectors of humanity (Reddy *et al*., 2012). The robots are able to process integrated circuits (Aldana *et al*., 2013) sizes micro and nano, on which the man they can be seen only with electron microscopy (Lee, 2013). Dyeing parts in toxic environments, working in chemical and radioactive environments (Padula and Perdereau, 2013; Perumaal and Jawahar, 2013), or at depths and pressures at the deep bottom of huge oceans, or conquest of cosmic space and visiting some new exoplanets, are with robots systems possible (Dong *et al*., 2013) and were turned into from the dream in reality (Garcia *et al*., 2007), because of use of mechanical platforms sequential gearbox (Cao *et al*., 2013; Petrescu *et al*., 2009). The man will be able to carry out its mission supreme (Tang *et al*., 2013; Tong *et al*., 2013), conqueror of new galaxies (de Melo *et al*., 2012), because of mechanical systems sequential gear-box (robotics systems) (Garcia-Murillo *et al*., 2013).

Robots were developed and diversified (Lin *et al*., 2013), different aspects (He *et al*., 2013), but today, they start to be directed on two major categories: systems serial (Liu *et al*., 2013; Petrescu and Petrescu, 2011b) and parallel systems (Petrescu and Petrescu, 2012c). Parallel systems are more solid (Tabaković *et al*., 2013; Wang *et al*., 2013) but more difficult to designed and handled and for this reason, the serial systems were those which have developed the most. In medical operations or radioactive environments are preferred mobile systems parallel, because of their high accuracy positioning.

As examples of such combined mechanisms, several kinematic schemes of gears and gears can be observed, presented by Kojevnikov (1969), (AUTORENKOLLEKTIV, 1968), Şaskin (1963; 1971), Maros (1958), Rehwald and Luck (200; 2001), Antonescu (1993; 2003; Antonescu and Mitrache, 1989).

The main problems with plane and spatial gears and gears refer to kinematic analysis and geometric-kinematic synthesis under certain conditions imposed by technological processes, (Bruja and Dima, 2011), (Buda and Mateucă, 1989), (Luck and Modler, 1995), Niemeyer (2000), Tutunaru (1969), Popescu (1977), (Braune, 2000), (Dudita, 1989), Lichtenheldt (1995), Lederer (1993), Lin (1999), Modler and Wadewitz (1998, 2001; Modler, 1979), Neumann (1979; 2001), Stoica (1977), (Petrescu and Petrescu, 2011c-d; Petrescu, 2012d-e); (Petrescu, 2016; 2017a-q; Aversa *et al*., 2017a-e; 2016a-o; Mirsayar *et al*., 2017; Petrescu and Petrescu, 2016a-c; 2013a-d; 2012a-d; 2011a-b; Petrescu, 2012a-c; 2009; Petrescu and Calautit, 2016a-b; Petrescu *et al*., 2016a-b; Maros, 1958; Modler and Wadewitz, 2001; Manolescu, 1968; Margine, 1999). Serial, mechanical and mobile systems have rapidly and steadily penetrated almost all industrial areas due to their flexibility, reliability, simple implementation and adaptability to various types of mechanical machining in the automotive industry. In addition, they occupy less space and volume compared to parallel systems and are easier to manufacture and implement, but also much cheaper. Serial systems have been noticed since the beginnings of robotics and mechatronics due to their flexibility, their work dynamics and the dynamics of their implementation. In addition, there are useful, reliable systems with high efficiency and productivity, economic and industrial.

Materials and Methods

Figure 1 shows such an industrial, basic, serial, anthropomorphic mechatronic system. The fixed coordinate system was denoted by $x_0O_0y_0z_0$.

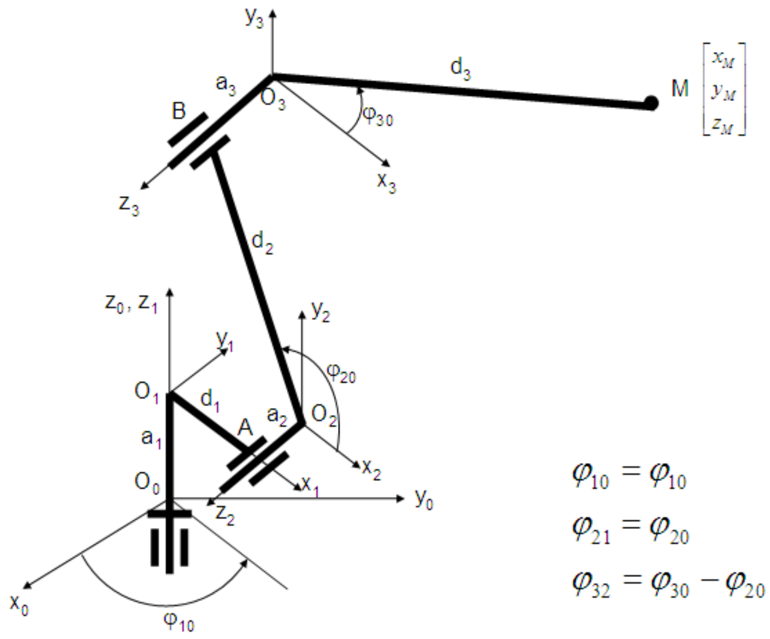

Fig. 1: An industrial, basic, serial, anthropomorphic mechatronic system

The mobile systems (rigidized) of the three mobile elements (1, 2, 3) have indices 1, 2 and 3. Their orientation has been chosen conveniently. It starts from the already known matrix relation of speeds (1):

$$\begin{aligned} X_{0M} &= A_{01} + T_{01} \cdot X_{1M} = A_{01} + T_{01} \cdot (A_{12} + T_{12} \cdot X_{2M}) \\ &= A_{01} + T_{01} \cdot A_{12} + T_{01} \cdot T_{12} \cdot X_{2M} \\ &= A_{01} + T_{01} \cdot A_{12} + T_{01} \cdot T_{12} \cdot (A_{23} + T_{23} \cdot X_{3M}) \\ &= A_{01} + T_{01} \cdot A_{12} + T_{01} \cdot T_{12} \cdot A_{23} + T_{01} \cdot T_{12} \cdot T_{23} \cdot X_{3M} \end{aligned} \tag{1}$$

This is written in simplified form (2):

$$X_{0M} = A_{01} + P_1 + P_2 + T_{03} \cdot X_{3M} \tag{2}$$

Where:

$$A_{01} = \begin{bmatrix} 0 \\ 0 \\ a_1 \end{bmatrix} \tag{3}$$

$$P_1 = \begin{bmatrix} d_1 \cdot \cos\phi_{10} - a_2 \cdot \sin\phi_{10} \\ d_1 \cdot \sin\phi_{10} + a_2 \cdot \cos\phi_{10} \\ 0 \end{bmatrix} \tag{4}$$

$$P_2 = \begin{bmatrix} d_2 \cdot \cos\phi_{10} \cdot \cos\phi_{20} - a_3 \cdot \sin\phi_{10} \\ d_2 \cdot \sin\phi_{10} \cdot \cos\phi_{20} + a_3 \cdot \cos\phi_{10} \\ d_2 \cdot \sin\phi_{20} \end{bmatrix} \tag{5}$$

$$T_{03} = \begin{bmatrix} \cos\phi_{10} & 0 & \sin\phi_{10} \\ \sin\phi_{10} & 0 & -\cos\phi_{10} \\ 0 & 1 & 0 \end{bmatrix} \tag{6}$$

$$X_{3M} = \begin{bmatrix} x_{3M} \\ y_{3M} \\ z_{3M} \end{bmatrix} = \begin{bmatrix} d_3 \cdot \cos\phi_{30} \\ d_3 \cdot \sin\phi_{30} \\ 0 \end{bmatrix} \tag{7}$$

Matrix relation (2) is derived and the expression (8) is obtained:

$$\begin{aligned} \dot{X}_{0M} &= \dot{A}_{01} + \dot{P}_1 + \dot{P}_2 + \dot{T}_{03} \cdot X_{3M} + T_{03} \cdot \dot{X}_{3M} \\ &= \dot{P}_1 + \dot{P}_2 + \dot{T}_{03} \cdot X_{3M} + T_{03} \cdot \dot{X}_{3M} \\ &= \dot{P}_{12} + \dot{T}_{03} \cdot X_{3M} + T_{03} \cdot \dot{X}_{3M} \end{aligned} \tag{8}$$

Because:

$$\dot{A}_{01} = \begin{bmatrix} 0 \\ 0 \\ \dot{a}_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} = 0 \tag{9}$$

$$\dot{P}_1 = \begin{bmatrix} -d_1 \cdot \sin\phi_{10} \cdot \omega_{10} - a_2 \cdot \cos\phi_{10} \cdot \omega_{10} \\ d_1 \cdot \cos\phi_{10} \cdot \omega_{10} - a_2 \cdot \sin\phi_{10} \cdot \omega_{10} \\ 0 \end{bmatrix} \tag{10}$$

$$\dot{P}_2 = \begin{bmatrix} -d_2 \cdot \sin\phi_{10} \cdot \omega_{10} \cdot \cos\phi_{20} - d_2 \cdot \cos\phi_{10} \\ \cdot \sin\phi_{20} \cdot \omega_{20} - a_3 \cdot \cos\phi_{10} \cdot \omega_{10} \\ d_2 \cdot \cos\phi_{10} \cdot \omega_{10} \cdot \cos\phi_{20} - d_2 \cdot \sin\phi_{10} \\ \cdot \sin\phi_{20} \cdot \omega_{20} - a_3 \cdot \sin\phi_{10} \cdot \omega_{10} \\ d_2 \cdot \cos\phi_{20} \cdot \omega_{20} \end{bmatrix} \quad (11)$$

$$\dot{T}_{03} = \begin{bmatrix} -\sin\phi_{10} \cdot \omega_{10} & 0 & \cos\phi_{10} \cdot \omega_{10} \\ \cos\phi_{10} \cdot \omega_{10} & 0 & \sin\phi_{10} \cdot \omega_{10} \\ 0 & 0 & 0 \end{bmatrix} \quad (12)$$

$$\dot{X}_{3M} = \begin{bmatrix} \dot{x}_{3M} \\ \dot{y}_{3M} \\ \dot{z}_{3M} \end{bmatrix} = \begin{bmatrix} -d_3 \cdot \sin\phi_{30} \cdot \omega_{30} \\ d_3 \cdot \cos\phi_{30} \cdot \omega_{30} \\ 0 \end{bmatrix} \quad (13)$$

$$\dot{P}_{12} = \dot{P}_1 + \dot{P}_2 = \begin{bmatrix} -d_1 \sin\phi_{10}\omega_{10} - a_2 \cos\phi_{10}\omega_{10} - a_3 \cos\phi_{10}\omega_{10} \\ -d_2 \sin\phi_{10}\omega_{10} \cos\phi_{20} - d_2 \cos\phi_{10} \sin\phi_{20}\omega_{20} \\ d_1 \cos\phi_{10}\omega_{10} - a_2 \sin\phi_{10}\omega_{10} - a_3 \sin\phi_{10}\omega_{10} \\ +d_2 \cos\phi_{10}\omega_{10} \cos\phi_{20} - d_2 \sin\phi_{10} \sin\phi_{20}\omega_{20} \\ d_2 \cos\phi_{20}\omega_{20} \end{bmatrix} \quad (14)$$

Next, determine the two matrix products (15 and 16) of relation (8).

$$\dot{T}_{03} \cdot X_{3M} = \begin{bmatrix} -\sin\phi_{10} \cdot \omega_{10} & 0 & \cos\phi_{10} \cdot \omega_{10} \\ \cos\phi_{10} \cdot \omega_{10} & 0 & \sin\phi_{10} \cdot \omega_{10} \\ 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} d_3 \cdot \cos\phi_{30} \\ d_3 \cdot \sin\phi_{30} \\ 0 \end{bmatrix} = \begin{bmatrix} -d_3 \cdot \sin\phi_{10} \cdot \omega_{10} \cdot \cos\phi_{30} \\ d_3 \cdot \cos\phi_{10} \cdot \omega_{10} \cdot \cos\phi_{30} \\ 0 \end{bmatrix} \quad (15)$$

$$T_{03} \cdot \dot{X}_{3M} = \begin{bmatrix} \cos\phi_{10} & 0 & \sin\phi_{10} \\ \sin\phi_{10} & 0 & -\cos\phi_{10} \\ 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} -d_3 \cdot \sin\phi_{30} \cdot \omega_{30} \\ d_3 \cdot \cos\phi_{30} \cdot \omega_{30} \\ 0 \end{bmatrix} = \begin{bmatrix} -d_3 \cdot \cos\phi_{10} \cdot \sin\phi_{30} \cdot \omega_{30} \\ -d_3 \cdot \sin\phi_{10} \cdot \sin\phi_{30} \cdot \omega_{30} \\ d_3 \cdot \cos\phi_{30} \cdot \omega_{30} \end{bmatrix} \quad (16)$$

We can now determine $\dot{X}_{0M}$:

$$\dot{X}_{0M} = \begin{bmatrix} (-d_1 \sin\phi_{10}\omega_{10} - a_2 \cos\phi_{10}\omega_{10} - a_3 \cos\phi_{10}\omega_{10} - d_2 \sin\phi_{10}\omega_{10} \cos\phi_{20} - \\ -d_2 \cos\phi_{10} \sin\phi_{20}\omega_{20} - d_3 \sin\phi_{10}\omega_{10} \cos\phi_{30} - d_3 \cos\phi_{10} \sin\phi_{30}\omega_{30}) \\ (d_1 \cos\phi_{10}\omega_{10} - a_2 \sin\phi_{10}\omega_{10} - a_3 \sin\phi_{10}\omega_{10} + d_2 \cos\phi_{10}\omega_{10} \cos\phi_{20} - \\ -d_2 \sin\phi_{10} \sin\phi_{20}\omega_{20} + d_3 \cos\phi_{10}\omega_{10} \cos\phi_{30} - d_3 \sin\phi_{10} \sin\phi_{30}\omega_{30}) \\ (d_2 \cos\phi_{20}\omega_{20} + d_3 \cos\phi_{30}\omega_{30}) \end{bmatrix} \quad (17)$$

Results

Follows, the acceleration relations. The relationship (8) is derived and the expression (18) is obtained:

$$\begin{aligned} \ddot{X}_{0M} &= \ddot{P}_{12} + \ddot{T}_{03} \cdot X_{3M} + \dot{T}_{03} \cdot \dot{X}_{3M} + \dot{T}_{03} \cdot \dot{X}_{3M} + T_{03} \cdot \ddot{X}_{3M} \\ &= \ddot{P}_{12} + \ddot{T}_{03} \cdot X_{3M} + 2 \cdot \dot{T}_{03} \cdot \dot{X}_{3M} + T_{03} \cdot \ddot{X}_{3M} \end{aligned} \quad (18)$$

Where:

$$\ddot{P}_{12} = \ddot{P}_1 + \ddot{P}_2 = \begin{bmatrix} (-d_1 \cos\phi_{10}\omega_{10}^2 + a_2 \sin\phi_{10}\omega_{10}^2 \\ +a_3 \sin\phi_{10}\omega_{10}^2 - d_2 \cos\phi_{10}\omega_{10}^2 \cos\phi_{20} \\ +d_2 \sin\phi_{10}\omega_{10} \sin\phi_{20}\omega_{20} + d_2 \sin\phi_{10}\omega_{10} \sin\phi_{20}\omega_{20} \\ -d_2 \cos\phi_{10} \cos\phi_{20}\omega_{20}^2) \\ (-d_1 \sin\phi_{10}\omega_{10}^2 - a_2 \cos\phi_{10}\omega_{10}^2 \\ -a_3 \cos\phi_{10}\omega_{10}^2 - d_2 \sin\phi_{10}\omega_{10}^2 \cos\phi_{20} - \\ -d_2 \cos\phi_{10}\omega_{10} \sin\phi_{20}\omega_{20} - d_2 \cos\phi_{10}\omega_{10} \sin\phi_{20}\omega_{20} \\ -d_2 \sin\phi_{10} \cos\phi_{20}\omega_{20}^2) \\ (-d_2 \sin\phi_{20}\omega_{20}^2) \end{bmatrix} \quad (19)$$

The fairly simple form of the matrix $\ddot{P}_{12}$ is due to the fact that the three angular speeds of the actuators were considered constant (as is normal).

$$\ddot{T}_{03} = \begin{bmatrix} -\cos\phi_{10} \cdot \omega_{10}^2 & 0 & -\sin\phi_{10} \cdot \omega_{10}^2 \\ -\sin\phi_{10} \cdot \omega_{10}^2 & 0 & \cos\phi_{10} \cdot \omega_{10}^2 \\ 0 & 0 & 0 \end{bmatrix} \quad (20)$$

$$\ddot{X}_{3M} = \begin{bmatrix} -d_3 \cdot \cos\phi_{30} \cdot \omega_{30}^2 \\ -d_3 \cdot \sin\phi_{30} \cdot \omega_{30}^2 \\ 0 \end{bmatrix} \quad (21)$$

$$2 \cdot \dot{T}_{03} \cdot \dot{X}_{3M} = \begin{bmatrix} 2 \cdot d_3 \cdot \sin\phi_{10} \cdot \omega_{10} \cdot \sin\phi_{30} \cdot \omega_{30} \\ -2 \cdot d_3 \cdot \cos\phi_{10} \cdot \omega_{10} \cdot \sin\phi_{30} \cdot \omega_{30} \\ 0 \end{bmatrix} \quad (22)$$

$$\ddot{T}_{03} \cdot X_{3M} = \begin{bmatrix} -\cos\phi_{10} \cdot \omega_{10}^2 & 0 & -\sin\phi_{10} \cdot \omega_{10}^2 \\ -\sin\phi_{10} \cdot \omega_{10}^2 & 0 & \cos\phi_{10} \cdot \omega_{10}^2 \\ 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} d_3 \cdot \cos\phi_{30} \\ d_3 \cdot \sin\phi_{30} \\ 0 \end{bmatrix} = \begin{bmatrix} -d_3 \cdot \cos\phi_{10} \cdot \omega_{10}^2 \cdot \cos\phi_{30} \\ -d_3 \cdot \sin\phi_{10} \cdot \omega_{10}^2 \cdot \cos\phi_{30} \\ 0 \end{bmatrix} \quad (23)$$

$$T_{03} \cdot \ddot{X}_{3M} = \begin{bmatrix} \cos\phi_{10} & 0 & \sin\phi_{10} \\ \sin\phi_{10} & 0 & -\cos\phi_{10} \\ 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} -d_3 \cdot \cos\phi_{30} \cdot \omega_{30}^2 \\ -d_3 \cdot \sin\phi_{30} \cdot \omega_{30}^2 \\ 0 \end{bmatrix} = \begin{bmatrix} -d_3 \cdot \cos\phi_{10} \cdot \cos\phi_{30} \cdot \omega_{30}^2 \\ -d_3 \cdot \sin\phi_{10} \cdot \cos\phi_{30} \cdot \omega_{30}^2 \\ -d_3 \cdot \sin\phi_{30} \cdot \omega_{30}^2 \end{bmatrix} \quad (24)$$

The matrix of the impedance acceleration matrices is obtained according to the rotations and angular speeds of the three actuators, with $\omega_{10} = ct$, $\omega_{20} = ct$, $\omega_{30} = ct$.

$$\ddot{X}_{0M} = \begin{bmatrix} (-d_1 \cos\phi_{10}\omega_{10}^2 + a_2 \sin\phi_{10}\omega_{10}^2 \\ +a_3 \sin\phi_{10}\omega_{10}^2 - d_2 \cos\phi_{10}\omega_{10}^2 \cos\phi_{20} + \\ +2d_2 \sin\phi_{10}\omega_{10} \sin\phi_{20}\omega_{20} - d_2 \cos\phi_{10} \cos\phi_{20}\omega_{20}^2 \\ +2d_3 \sin\phi_{10}\omega_{10} \sin\phi_{30}\omega_{30} - \\ -d_3 \cos\phi_{10}\omega_{10}^2 \cos\phi_{30} - d_3 \cos\phi_{10} \cos\phi_{30}\omega_{30}^2) \\ \\ (-d_1 \sin\phi_{10}\omega_{10}^2 - a_2 \cos\phi_{10}\omega_{10}^2 \\ -a_3 \cos\phi_{10}\omega_{10}^2 - d_2 \sin\phi_{10}\omega_{10}^2 \cos\phi_{20} - \\ -2d_2 \cos\phi_{10}\omega_{10} \sin\phi_{20}\omega_{20} - d_2 \sin\phi_{10} \cos\phi_{20}\omega_{20}^2 \\ -2d_3 \cos\phi_{10}\omega_{10} \sin\phi_{30}\omega_{30} - \\ -d_3 \sin\phi_{10}\omega_{10}^2 \cos\phi_{30} - d_3 \sin\phi_{10} \cos\phi_{30}\omega_{30}^2) \\ \\ (-d_2 \sin\phi_{20}\omega_{20}^2 - d_3 \sin\phi_{30}\omega_{30}^2) \end{bmatrix} \quad (25)$$

Discussion

Today, robots and mechatronic systems are constantly playing an essential role in our lives, being a key link in the automotive industry, without which it can no longer be conceived. If the robots initially started in the machine building industry to the imperious demands of the car king to have a growing production fast and steadily, helping the logarithmic progression of automotive construction, today robots and automation have rapidly penetrated all areas of the machine building industry, due to their ability to produce fast, long, quality, without pauses, country illnesses, at an innate pace, far outweighing man in this chapter. Additionally, robots can work in toxic, dangerous, airless environments, such as in space or underwater, at high pressures, or in potentially dangerous places. There is no question of removing robots from industrial work today. On the contrary, there is a fierce competition in the acquisition, construction, implementation and maintenance of as many robotic mechanical systems due to their high working capacity but also because they have a high reliability and a high quality of the operations performed. In this study, we will treat the kinematics of anthropomorphic robots, as they are today the most widespread robots in the global industry, due to their huge work capabilities and rapid adaptation to any working conditions. It will highlight the speeds and accelerations of these moving mechanical systems in direct kinematics.

Conclusion

Serial, mechanical and mobile systems have rapidly and steadily penetrated almost all industrial areas due to their flexibility, reliability, simple implementation and adaptability to various types of mechanical machining in the automotive industry. In addition, they occupy less space and volume compared to parallel systems and are easier to manufacture and implement, but also much cheaper. Serial systems have been noticed since the beginnings of robotics and mechatronics due to their flexibility, their work dynamics and the dynamics of their implementation. In addition, there are useful, reliable systems with high efficiency and productivity, economic and industrial.

The paper presents an exact, original analytical method for determining the direct kinematic parameters of a serial mobile structure.

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Author's Contributions

All the authors contributed equally to prepare, develop and carry out this manuscript.

Ethics

This article is original. Authors declare that are not ethical issues that may arise after the publication of this manuscript.

References

Aldana, N.D., C.L. Trujillo and J.G. Guarnizo, 2013. Active and reactive power flow regulation for a grid connected vsc based on fuzzy controllers. Revista Facultad de Ingeniería, 66: 118-130.

Antonescu, P., 2003. Mecanisms. Ed. Printech, Bucureşti.

Antonescu, P., 1993. Synthesis of manipulators. Lito UPB, Bucureşti.

Antonescu, P. and M. Mitrache, 1989. Contributions to the synthesis of the mechanisms used as windscreen wipers. SYROM'89, Bucharest.

Autorenkollektiv, J., 1968. Getriebetechnik-VEB. Verlag Technik, Berlin.

Aversa, R., R.V.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2017a. Nano-diamond hybrid materials for structural biomedical application. Am. J. Biochem. Biotechnol.

Aversa, R., R.V. Petrescu, B. Akash, R.B. Bucinell and J.M. Corchado *et al.*, 2017b. Kinematics and forces to a new model forging manipulator. Am. J. Applied Sci., 14: 60-80.

Aversa, R., R.V. Petrescu, A. Apicella, I.T.F. Petrescu and J.K. Calautit *et al.*, 2017c. Something about the V engines design. Am. J. Applied Sci., 14: 34-52.

Aversa, R., D. Parcesepe, R.V.V. Petrescu, F. Berto and G. Chen *et al.*, 2017d. Process ability of bulk metallic glasses. Am. J. Applied Sci., 14: 294-301.

Aversa, R., R.V.V. Petrescu, B. Akash, R.B. Bucinell and J.M. Corchado *et al.*, 2017e. Something about the balancing of thermal motors. Am. J. Eng. Applied Sci., 10: 200.217. DOI: 10.3844/ajeassp.2017.200.217

Aversa, R., F.I.T. Petrescu, R.V. Petrescu and A. Apicella, 2016a. Biomimetic FEA bone modeling for customized hybrid biological prostheses development. Am. J. Applied Sci., 13: 1060-1067. DOI: 10.3844/ajassp.2016.1060.1067

Aversa, R., D. Parcesepe, R.V. Petrescu, G. Chen and F.I.T. Petrescu *et al.*, 2016b. Glassy amorphous metal injection molded induced morphological defects. Am. J. Applied Sci., 13: 1476-1482.

Aversa, R., R.V. Petrescu, F.I.T. Petrescu and A. Apicella, 2016c. Smart-factory: Optimization and process control of composite centrifuged pipes. Am. J. Applied Sci., 13: 1330-1341.

Aversa, R., F. Tamburrino, R.V. Petrescu, F.I.T. Petrescu and M. Artur *et al.*, 2016d. Biomechanically inspired shape memory effect machines driven by muscle like acting NiTi alloys. Am. J. Applied Sci., 13: 1264-1271.

Aversa, R., E.M. Buzea, R.V. Petrescu, A. Apicella and M. Neacsa *et al.*, 2016e. Present a mechatronic system having able to determine the concentration of carotenoids. Am. J. Eng. Applied Sci., 9: 1106-1111.

Aversa, R., R.V. Petrescu, R. Sorrentino, F.I.T. Petrescu and A. Apicella, 2016f. Hybrid ceramo-polymeric nanocomposite for biomimetic scaffolds design and preparation. Am. J. Eng. Applied Sci., 9: 1096-1105.

Aversa, R., V. Perrotta, R.V. Petrescu, C. Misiano and F.I.T. Petrescu *et al.*, 2016g. From structural colors to super-hydrophobicity and achromatic transparent protective coatings: Ion plating plasma assisted TiO2 and SiO2 Nano-film deposition. Am. J. Eng. Applied Sci., 9: 1037-1045.

Aversa, R., R.V. Petrescu, F.I.T. Petrescu and A. Apicella, 2016h. Biomimetic and evolutionary design driven innovation in sustainable products development. Am. J. Eng. Applied Sci., 9: 1027-1036.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016i. Mitochondria are naturally micro robots-a review. Am. J. Eng. Applied Sci., 9: 991-1002.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016j. We are addicted to vitamins C and E-A review. Am. J. Eng. Applied Sci., 9: 1003-1018.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016k. Physiologic human fluids and swelling behavior of hydrophilic biocompatible hybrid ceramo-polymeric materials. Am. J. Eng. Applied Sci., 9: 962-972.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016l. One can slow down the aging through antioxidants. Am. J. Eng. Applied Sci., 9: 1112-1126.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016m. About homeopathy or ≪Similia similibus curentur≫. Am. J. Eng. Applied Sci., 9: 1164-1172.

Aversa, R., R.V. Petrescu, A. Apicella and F.I.T. Petrescu, 2016n. The basic elements of life's. Am. J. Eng. Applied Sci., 9: 1189-1197.

Aversa, R., F.I.T. Petrescu, R.V. Petrescu and A. Apicella, 2016o. Flexible stem trabecular prostheses. Am. J. Eng. Applied Sci., 9: 1213-1221.

Braune, R., 2000. Bewegungsdesign – Eine Kernkompetenz des Getriebe Technikers. 1st Edn., VDI – Verlag, Dusseldorf.

Bruja, A. and M. Dima, 2001. Synthesis of kinematics of harmonics reducers with rigid front element. Sixth Simp. Nat. Construction Machinery, 1: 53-59.

Buda, L. and C. Mateucă, 1989. Functional, cinematic and cinetostatic analysis of the lifting mechanism of the passenger carriages. SYROM'89, Bucharest, 4: 59-66.

Cao, W., H. Ding, Z. Bin and C. Ziming, 2013. New structural representation and digital-analysis platform for symmetrical parallel mechanisms. Int. J. Adv. Robotic Sys. DOI: 10.5772/56380

Dong, H., N. Giakoumidis, N. Figueroa and N. Mavridis, 2013. Approaching behaviour monitor and vibration indication in developing a General Moving Object Alarm System (GMOAS). Int. J. Adv. Robotic Sys. DOI: 10.5772/56586

Dudita, F.L., 1989. Articulated, inventive, cinematic mechanisms. Technical Publishing House, Bucharest.

Garcia, E., M.A. Jimenez, P.G. De Santos and M. Armada, 2007. The evolution of robotics research. Robotics Automation Magazine, IEEE, 14: 90-103.

Garcia-Murillo, M., J. Gallardo-Alvarado and E. Castillo-Castaneda, 2013. Finding the generalized forces of a series-parallel manipulator. IJARS. DOI: 10.5772/53824

He, B., Z. Wang, Q. Li, H. Xie and R. Shen, 2013. An analytic method for the kinematics and dynamics of a multiple-backbone continuum robot. IJARS. DOI: 10.5772/54051

Kojevnikov, S.N., 1969. Teoria mehanizmov i maşin. Izd. Maşinostroenie, Moskva.

Lederer, P., 1993. Dynamische synthese der ubertragungs-funktion eines Kurvengetriebes. Mech. Mach. Theory 28: 23-29. DOI: 10.1016/0094-114X(93)90043-U

Lee, B.J., 2013. Geometrical derivation of differential kinematics to calibrate model parameters of flexible manipulator. Int. J. Adv. Robotic Sys. DOI: 10.5772/55592

Lichtenheldt, W., 1995. Konstruktionslehre der Getriebe. Akademie – Verlag Berlin.

Lin, S., 1999. Getriebesynthese Nach Unscharfen Lagenvorgaben Durch Positionierung Eines vorbestimmten Getriebes. 1st Edn., VDI-Verlag, Düsseldorf, sseldorf, ISBN-10: 3183313014, pp: 132.

Lin, W., B. Li, X. Yang and D. Zhang, 2013. Modelling and control of inverse dynamics for a 5-DOF parallel kinematic polishing machine. Int. J. Adv. Robotic Sys. DOI: 10.5772/54966

Liu, H., W. Zhou, X. Lai and S. Zhu, 2013. An efficient inverse kinematic algorithm for a PUMA560-structured robot manipulator. IJARS. DOI: 10.5772/56403

Luck, K. and K.H. Modler, 1995. Getriebetechnik – Analyse, Synthese, Optimierung. 2. Aufl. Berlin/ Heidelberg/ New York, Springer.

Manolescu, N.I., 1968. Problems of machine theory and machines. EDP, Bucharest.

Margine, A.L., 1999. Contributions to the geometric-kinematical and dynamic synthesis of planetary gears with cylindrical gears. PhD Thesis, U.P.B.

de Melo, F.L., S.F. Reis Alves and J.M. Rosário, 2012. Mobile robot navigation modelling, control and applications. Int. Rev. Modelling Simul., 5: 1059-1068.

Mirsayar, M.M., V.A. Joneidi, R.V.V. Petrescu, F.I.T. Petrescu and F. Berto, 2017. Extended MTSN criterion for fracture analysis of soda lime glass. Eng. Fracture Mechan., 178: 50-59. DOI: 10.1016/j.engfracmech.2017.04.018

Modler, K.H. and C. Wadewitz, 2001. Synthese von Raderkoppelgetriebe als Vorschaltgetriebe mit definierter Ungleichformigkeit.Wissenschaftliche Zeitschrift, TU-Dresden Nr.

Modler, K.H. and C. Wadewitz, 1998. Trepte, U., Rechnergestutzte Synthese von Raderkoppelgetrieben als Vorschaltgetriebe zur Erzeugung nichtlinearer Antriebsbewegungen. Bericht zum DFG – Vorhaben Mo 537/5 – 1. TU Dresden.

Modler, K.H., 1979. Reakisierung von pilgerschritten durch zweiraderkoppel-getriebe. Dynamik und Getribetechnik.

Neumann, R., 1979. Einstellbare Raderkoppelgetriebe. Dynamik und Getribe-technik, A, Dresda.

Neumann, R., 2001. Dreiraderkoppel – schrittgetriebe mit zahnradern oder zahnriemen. SYROM'2001, Bucureşti, 3: 321-324.

Niemeyer, J., 2000. Das IGM – Getriebelexikon – Wissensverarbeitung in der Getriebetechnik mit Hilfe der Internet – Technologie. In: IMG – Kolloquium Getriebetechnik, Forschung and Lehre 1972-2000, Dittrich, G. (Ed.), Mainz, Aachen, pp: 53-66.

Padula, F. and V. Perdereau, 2013. An on-line path planner for industrial manipulators. Int. J. Adv. Robotic Sys. DOI: 10.5772/55063

Perumaal, S. and N. Jawahar, 2013. Automated trajectory planner of industrial robot for pick-and-place task. IJARS. DOI: 10.5772/53940

Petrescu, F.I.T., 2016 Valorisation of Romanian-Romanian Engineering Tradition. 1st Edn., Create Space Publisher, USA.

Petrescu, F.I. and R.V. Petrescu, 2011a. Memories about Flight. 1st Edn., CreateSpace, pp: 652.

Petrescu, F.I. and R.V. Petrescu, 2011b. Mechanical Systems, Serial and Parallel – Course (in romanian). 1st Edn., LULU Publisher, London, UK, pp: 124.

Petrescu, F.I.T. and R.V. Petrescu, 2011c. Planetary Trains. 1st Edn., CreateSpace, USA, pp: 204.

Petrescu, F.I. and R.V. Petrescu, 2011d. Dynamics of Distribution Mechanisms. 1st Edn., Create Space Publisher, USA, pp: 188.

Petrescu, R.V. and F.I.T. Petrescu, 2012a. Northrop. 1st Edn., Books on Demand. pp: 142.

Petrescu, F.I. and R.V. Petrescu, 2012b. New Aircraft II. 1st Edn., Books on Demand, pp: 138.

Petrescu, F.I. and R.V. Petrescu, 2012c. Mecatronica-sisteme seriale si paralele. 1st Edn., Create Space Publisher, USA, pp: 128.

Petrescu, F.I. and R.V. Petrescu, 2012d. Kinematics of the planar quadrilateral mechanism. Engevista, 14: 345-348.

Petrescu, R.V. and F.I. Petrescu, 2013a. Lockheed Martin. 1st Edn., CreateSpace, pp: 114.

Petrescu, R.V. and F.I. Petrescu, 2013b. Northrop. 1st Edn., CreateSpace, pp: 96.

Petrescu, R.V. and F.I. Petrescu, 2013c. The Aviation History or New Aircraft I Color. 1st Edn., CreateSpace, pp: 292.

Petrescu, F.I. and R.V. Petrescu, 2013d. Cinematics of the 3R Dyad, Engevista, 15: 118-124.

Petrescu, F.I. and R.V. Petrescu, 2016a. Parallel moving mechanical systems kinematics. ENGE-VISTA, 18: 455-491.

Petrescu, F.I. and R.V. Petrescu, 2016b. Direct and inverse kinematics to the anthropomorphic robots. ENGEVISTA, 18: 109-124.

Petrescu, F.I. and R.V. Petrescu, 2016c. Dynamic cinematic to a structure 2R. Revista Geintec-Gestao Inovacao E Tecnol., 6: 3143-3154.

Petrescu, F.I.T. and J.K. Calautit, 2016a. About Nano fusion and dynamic fusion. Am. J. Applied Sci., 13: 261-266.

Petrescu, F.I. and J.K. Calautit, 2016b. About the light dimensions. Am. J. Applied Sci., 13: 321-325. DOI: 10.3844/ajassp.2016.321.325

Petrescu, F.I.T., 2009. New aircraft. Proceedings of the 3rd International Conference on Computational Mechanics, Oct. 29-30, Brasov, Romania.

Petrescu, F.I.T., 2012a. Cold Nuclear Fusion. 1st Edn., Create Space, USA, pp: 80.

Petrescu, F.I.T., 2012b. Particle Annihilation-A source of renewable energy?

Petrescu, F.I.T., 2012c. Particle annihilation-a source of renewable energy? Infinite Energy.

Petrescu, F.I., 2012d. Basis of Analysis and Optimization of Rigid Memory Systems - Course and Applications. 1st Edn., Create Space Publisher, USA, pp: 164.

Petrescu, F.I., 2012e. Theory of Mechanisms - Course and Applications. 2nd Edn., Create Space Publisher, USA, pp: 284.

Petrescu, R.V.V., R. Aversa, A. Apicella, F. Berto and S. Li *et al.*, 2016a. Ecosphere protection through green energy. Am. J. Applied Sci., 13: 1027-1032.

Petrescu, F.I.T., A. Apicella, R.V.V. Petrescu, S.P. Kozaitis and R.B. Bucinell *et al.*, 2016b. Environmental protection through nuclear energy. Am. J. Applied Sci., 13: 941-946.

Petrescu, F.I.T., A. Apicella, R.V.V. Petrescu, S.P. Kozaitis and R.B. Bucinell *et al.*, 2016b. Environmental protection through nuclear energy. Am. J. Applied Sci., 13: 941-946.

Petrescu, R.V., R. Aversa, B. Akash, R. Bucinell and J. Corchado *et al.*, 2017a. Modern propulsions for aerospace-a review. J. Aircraft Spacecraft Technol., 1: 1-8.

Petrescu, R.V., R. Aversa, B. Akash, R. Bucinell and J. Corchado *et al.*, 2017b. Modern propulsions for aerospace-part II. J. Aircraft Spacecraft Technol., 1: 9-17.

Petrescu, R.V., R. Aversa, B. Akash, R. Bucinell and J. Corchado *et al.*, 2017c. History of aviation-a short review. J. Aircraft Spacecraft Technol., 1: 30-49.

Petrescu, R.V., R. Aversa, B. Akash, R. Bucinell and J. Corchado *et al.*, 2017d. Lockheed martin-a short review. J. Aircraft Spacecraft Technol., 1: 50-68.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017e. Our universe. J. Aircraft Spacecraft Technol., 1: 69-79.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017f. What is a UFO? J. Aircraft Spacecraft Technol., 1: 80-90.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017g. About bell helicopter FCX-001 concept aircraft-a short review. J. Aircraft Spacecraft Technol., 1: 91-96.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017h. Home at airbus. J. Aircraft Spacecraft Technol., 1: 97-118.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017i. Airlander. J. Aircraft Spacecraft Technol., 1: 119-148.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017j. When boeing is dreaming – a review. J. Aircraft Spacecraft Technol., 1: 149-161.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al.*, 2017k. About Northrop Grumman. J. Aircraft Spacecraft Technol., 1: 162-185.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al*., 2017l. Some special aircraft. J. Aircraft Spacecraft Technol., 1: 186-203.

Petrescu, R.V., R. Aversa, B. Akash, J. Corchado and F. Berto *et al*., 2017m. About helicopters. J. Aircraft Spacecraft Technol., 1: 204-223.

Petrescu, R.V., R. Aversa, B. Akash, F. Berto and A. Apicella *et al*., 2017n. The modern flight. J. Aircraft Spacecraft Technol.

Petrescu, R.V., R. Aversa, B. Akash, F. Berto and A. Apicella *et al*., 2017o. Sustainable energy for aerospace vessels. J. Aircraft Spacecraft Technol.

Petrescu, R.V., R. Aversa, B. Akash, F. Berto and A. Apicella *et al*., 2017p. Unmanned helicopters. J. Aircraft Spacecraft Technol.

Petrescu, R.V., R. Aversa, B. Akash, F. Berto and A. Apicella *et al*., 2017q. Project HARP. J. Aircraft Spacecraft Technol.

Petrescu, F.I., B. Grecu, A. Comanescu and R.V. Petrescu, 2009. Some mechanical design elements. Proceeding of the International Conference on Computational Mechanics and Virtual Engineering, (COMEC' 2009), Braşov, pp: 520-525.

Popescu, I., 1977. Design of planar mechanisms. Scrisul Românesc Publishing House of Craiova.

Reddy, P., K.V. Shihabudheen and J. Jacob, 2012. Precise non linear modeling of flexible link flexible joint manipulator. IReMoS, 5: 1368-1374.

Rehwald, W. and K. Luck, 2000. Kosim – Koppelgetriebesimulation: Fortschritt Berichte VDI, Reihe. 1st Edn., VDI Verlag, Dusseldorf.

Rehwald, W. and K. Luck, 2001. Betrachtungen Zur Zahl Der Koppelgetribetypen. Wissenschaftliche Zeitschrift der TU Dresda, 50: 107-115.

Stoica, I.A., 1977. Gear Wheel Interference. 1st Edn., DACIA Publishing House, Cluj-Napoca.

Şaskin, A.G., 1971. Zubciato rîciajnîe mehanizmî. Izd. Maşinostroenie, Moskva.

Şaskin, A.G., 1963. Sintezu zubciato - rîciajnîh mehanizmov s vâstoem. Teoria maşin I mehanizmov, Moskva, 94-95: 88-110.

Tabaković, S., M. Zeljković, R. Gatalo and A. Zivković, 2013. Program suite for conceptual designing of parallel mechanism-based robots and machine tools. Int. J. Adv. Robotic Sys. DOI: 10.5772/56633

Tang, X., D. Sun and Z. Shao, 2013. The structure and dimensional design of a reconfigurable PKM. IJARS. DOI: 10.5772/54696

Tong, G., J. Gu and W. Xie, 2013. Virtual entity-based rapid prototype for design and simulation of humanoid robots. Int. J. Adv. Robotic Sys. DOI: 10.5772/55936

Tutunaru, D., 1969. Rectangular and inverse planar mechanisms. Technical Publishing House, Bucharest.

Wang, K., M. Luo, T. Mei, J. Zhao and Y. Cao, 2013. Dynamics analysis of a three-DOF planar serial-parallel mechanism for active dynamic balancing with respect to a given trajectory. Int. J. Adv. Robotic Sys. DOI: 10.5772/54201

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Petrescu and Petrescu, 2011b