Serial, Anthropomorphic, Spatial, Mechatronic Systems can be Studied More Simply in a Plan

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Abstract: The mobile, mechatronic, robotic, serial, spatial, anthropomorphic type systems, which are currently the most used in the machine building industry, can be studied much more simply in a plan instead of the usual spatial study. This not only simplifies the understanding of these systems (including from a didactic point of view) but also facilitates computational methods, moving from matrix analytical methods to more simple classical methods. Usage is done by conversion, so nothing is lost from the essence of physic-mathematical phenomena. The idea of moving from spatial to planar study has been centered over time on all major mechanisms when it was possible, precisely for ease of calculation and working methods, but also for a better understanding of physical phenomena. The vast majority of classical mechanisms can be treated as they move in most cases into a master plan. This is the case with known mechanical transmissions, classic motors of all types, working mechanisms, engine or lucrative cars, etc. In anthropomorphic robots, the method is no longer used because they work clearly in a well-defined space. We used the idea to divide this space into a main work plan that can rotate around a main axis so that the study of all movements is done in the workplan and then the rotations of these parameters corresponding to the rotation of the work plane around the main axis of rotation. The physical-mathematical methods are greatly simplified in this way, from matrix difficult calculations to simple, classical analytical calculation methods.

Keywords: Anthropomorphic Robots, Kinematics, 3D calculation, 2D calculation

Introduction

The mobile, mechatronic, robotic, serial, spatial, anthropomorphic type systems, which are currently the most used in the machine building industry, can be studied much more simply in a plan instead of the usual spatial study. This not only simplifies the understanding of these systems (including from a didactic point of view), but also facilitates computational methods, moving from matrix analytical methods to more simple classical methods. Usage is done by conversion, so nothing is lost from the essence of physic-mathematical phenomena. The idea of moving from spatial to planar study has been centered over time on all major mechanisms when it was possible, precisely for ease of calculation and working methods, but also for a better understanding of physical phenomena. The vast majority of classical mechanisms can be treated as they move in most cases into a master plan. This is the case with known mechanical transmissions, classic motors of all types, working mechanisms, engine or lucrative cars, etc. In anthropomorphic robots, the method is no longer used because they work clearly in a well-defined space. We used the idea to divide this space into a main work plan that can rotate around a main axis so that the study of all movements is done in the workplan and then the
rotations of these parameters corresponding to the rotation of the work plane around the main axis of rotation. The physical-mathematical methods are greatly simplified in this way, from matrix difficult calculations to simple, classical analytical calculation methods.

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 et al., 2000; 2001; Antonescu, 1993; 2003; Antonescu and Mitracă, 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 (2001; 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 et al., 1998; Modler and Wadewitz, 2001; Modler, 1979; Neumann, 1979; 2001; Stoica, 1977; Petrescu and Petrescu, 2011c-d; Petrescu, 2012d-e; Petrescu, 2016; Petrescu et al., 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).

**Materials and Methods**

Figure 1 shows the geometric-kinematic scheme of a base structure 3R.

From this platform you can study by adding any other modern n-R scheme.

![Fig. 1: The geometric-kinematic scheme of a base structure 3R](image-url)
The platform (system) of Fig. 1 has three degrees of mobility, made by three actuators (electric motors) or actuators. The first electric motor trains the entire system in a rotation motion around a vertical axis O0z0. The motor (actuator) number 1 is mounted on the fixed member (bay, 0) and drives the mobile element 1 in a rotation motion around a vertical axis. On the mobile element 1, then all the other components (components) of the system are built.

There follows a planar (vertical) cinematic chain consisting of two movable elements and two kinematic motor couplings. It is the movable kinematic elements 2 and 3, the assembly 2,3 being moved by the second actuator mounted in the coupling A fixed on the element 1. Thus the second electric motor fixed by the element 1 will drive the element 2 in a relative rotation relative to element 1, but automatically it will move the entire kinematic chain 2-3.

The last actuator (electric motor) fixed by element 2 in B will rotate element 3 (relative to 2).

The rotation \( \phi_{10} \) made by the first actuator is also relative (between elements 1 and 0) and absolute (between elements 1 and 0).

The rotation \( \phi_{20} \) of the second actuator is also relative (between elements 2 and 1) and absolute (between elements 2 and 0) due to the positioning of the system.

The rotation \( \phi_{30} \) of the third actuator is only relative (between elements 3 and 2), the corresponding absolute (between elements 3 and 0) being a function of \( \phi_{32} \) and \( \phi_{20} \).

The kinematic chain 2-3 (made up of moving kinematic elements 2 and 3) is a planar cinematic chain that falls into one plane or one or more parallel planes. It is a special cinematic system that will be studied separately. The kinematic coupler A (O2) and B (O3) become the first fixed coupler and the second movable coupler, both of which are C5 cinematic couplers, of rotation.

In order to determine the degree of mobility of the planar kinematic chain 2-3, the structural formula given by relation (1), where \( m \) represents the number of movable elements of the planar kinematic chain, in our case \( m = 2 \) (with respect to the two moving kinematic elements 2 and 3) and C5 represents the number of fifth order kinematic couplings, in the present case C5 = 2 (with the A and B or O2 or O3 couplings):

\[
M_4 = 3 \cdot m - 2 \cdot C_4 = 3 \cdot 2 - 2 \cdot 2 = 6 - 4 = 2 \tag{1}
\]

The kinematic chain 2-3 having the degree of mobility 2 must be driven by two motors.

It is preferred that the two actuators are two electric, DC, or alternating motors. The action can also be done with other engines. Hydraulic, pneumatic, sonic, etc.

The schematic diagram of the planar kinematic chain 2-3 (Fig. 2) resembles its kinematic scheme.

Results; Direct Kinematics of the Plan 2-3

Figure 3 shows the kinematic diagram of the open 2-3 chain (Petrescu, 2014).

The kinematic parameters \( \phi_{20} \) and \( \phi_{30} \) are known in kinematics and must be determined by analyzing the parameters \( x_M \) and \( y_M \), which represent the scaled coordinates of the point M (endefactor M).

The \( d_2 + d_3 \) vectors are projected onto the Cartesian axis system considered fixed, xOy, identical to x2O2y2. The system of scalar equations is obtained (2):

\[
\begin{align*}
x_M &= x_2 + x_3 = \cos \phi_{20} + \cos \phi_{30} = d \cdot \cos \phi \\
y_M &= y_2 + y_3 = \sin \phi_{20} + \sin \phi_{30} = d \cdot \sin \phi
\end{align*} \tag{2}
\]

After determining the cartesian coordinates of the M point using the relations given by the system (2), the parameters of the angle can be obtained immediately using the relations established within the system (3):

\[
\begin{align*}
d^2 &= x_M^2 + y_M^2 \\
d &= \sqrt{x_M^2 + y_M^2} \\
\cos \phi &= \frac{x_M}{d} \\
\sin \phi &= \frac{y_M}{d} \\
\phi &= \text{sign}(\sin \phi) \cdot \arccos(\cos \phi)
\end{align*} \tag{3}
\]
Fig. 3: The kinematic scheme of the planar kinematic chain 2-3 bound to element 1 considered fixed

The system (2) is written more concise in the time-dependent form (4), resulting in the speed system (5), which derives from time, in turn generates the acceleration system (6):

\[
\begin{align*}
\phi_{30} &= \omega_{30} = ct; \theta = ct \Rightarrow \sin \omega_{30} = ct \\
\text{Is considered} \quad e_{30} = \dot{\theta} = e_{30} = 0
\end{align*}
\]

Relationships (3) are also derived and the velocity (8) and acceleration (9) systems are obtained:

\[
\begin{align*}
\dot{x}_{M} &= x_{M} + y_{M} \\
2 \cdot \ddot{d} &= 2 \cdot \ddot{x}_{M} + 2 \cdot y_{M} - y_{M} \\
\text{d} &= \frac{x_{M} - \ddot{x}_{M}}{y_{M} - \ddot{y}_{M}} \\
\text{d} &= \frac{\cos \phi}{\sin \phi} \\
\text{d} &= \frac{\sin \phi}{\cos \phi} \\
\dot{\phi} &= \dot{y}_{M} - \cos \phi \cdot \dot{x}_{M} - \sin \phi \\
\ddot{\phi} &= \frac{y_{M} \cdot \cos \phi - \dot{x}_{M} \cdot \sin \phi}{d}
\end{align*}
\]
\[
\begin{align*}
\dot{d}^2 &= x_{M}^2 + y_{M}^2 \\
2 \cdot d \cdot \dot{d} &= 2 \cdot x_{M} \cdot \dot{x}_{M} + 2 \cdot y_{M} \cdot \dot{y}_{M} \\
\dot{d} \cdot \dot{d} &= x_{M} \cdot \ddot{x}_{M} + y_{M} \cdot \ddot{y}_{M} \\
d^2 + d \cdot \dot{d} &= \dot{x}_{M}^2 + x_{M} \cdot \dot{x}_{M} + \dot{y}_{M}^2 + y_{M} \cdot \dot{y}_{M} - \ddot{d}^2 \quad d 
\end{align*}
\]

The scaling speeds and the O3 point accelerations are then determined by successive derivation of the system (10), in which the \(d\cdot \cos \phi\) or \(d\cdot \sin \phi\) products are replaced by the respective positions, xO3 or yO3, which thus become variables (see relations 11 and 12):

\[
\begin{align*}
\dot{x}_{O3} &= -d \cdot \sin \phi \cdot \omega_{O3} = -y_{O3} \cdot \omega_{O3} \\
\dot{y}_{O3} &= d \cdot \cos \phi \cdot \omega_{O3} = x_{O3} \cdot \omega_{O3} \\
\dot{x}_{O3} &= -d \cdot \cos \phi \cdot \omega_{O3} = -x_{O3} \cdot \omega_{O3} \\
\dot{y}_{O3} &= -d \cdot \sin \phi \cdot \omega_{O3} = -y_{O3} \cdot \omega_{O3} 
\end{align*}
\]

The scalar speeds and accelerations of the O3 point were made according to the initial positions (scaling) and the absolute angular velocity of the element 2. The angular velocity was considered constant.

Discussion

The technique of determining velocities and accelerations according to positions is extremely useful in the study of system dynamics, vibrations and noise caused by the system. This technique is common in studying system vibrations. The vibrations of the scalar positions of point O3 are known and the vibrations of the speeds and accelerations of that point as well as other points of the system are readily determined as a function of the known scaling positions of the O3 point. It is also possible to calculate the local noise levels at different points of the system as well as the overall noise level generated by the system with a sufficiently large approximation compared to the noise obtained by experimental measurements with the appropriate equipment. The study of system dynamics can also be developed by this technique.

The absolute speed of the O3 point (speed module) is given by the relationship (13):

\[
v_{O3} = \sqrt{x_{O3}^2 + y_{O3}^2} = \sqrt{d^2 \cdot \omega_{O3}^2 \cdot \sin^2 \phi + d^2 \cdot \omega_{O3}^2 \cdot \cos^2 \phi} = \sqrt{d^2 \cdot \omega_{O3}^2} = d \cdot \omega_{O3}
\]

The absolute acceleration of the O3 point for constant angular velocity is given by the relationship (14):

\[
a_{O3} = \sqrt{x_{O3}^2 + y_{O3}^2} = \sqrt{d^2 \cdot \omega_{O3}^2 \cdot \cos^2 \phi + d^2 \cdot \omega_{O3}^2 \cdot \sin^2 \phi} = \sqrt{d^2 \cdot \omega_{O3}^2} = d \cdot \omega_{O3}^2
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\]
\begin{align}
\dot{x}_u &= (\ddot{y}_{io} - \dot{y}_{iu}) \cdot \dot{\theta} - \ddot{y}_{i} \cdot \omega_{o2} \\
\dot{y}_u &= (\ddot{x}_{iu} - \dot{x}_{iu} \cdot \dot{\theta}) + \ddot{\gamma}_{o} \\
\dot{y}_{i} &= (x_{iu} - x_{iu} \cdot \dot{\theta}) + \ddot{x}_{iu} \cdot \omega_{o2} \\
\dot{x}_{iu} &= (y_{iu} - y_{iu} \cdot \dot{\theta}) + (\omega_{o2} + \ddot{\gamma}_{o}) \\
\dot{\gamma}_{o} &= \left(\ddot{x}_{iu} - \dot{x}_{iu} \cdot \dot{\theta} \cdot \ddot{\gamma}_{o} + \dot{\gamma}_{o} \cdot \dddot{\gamma}_{o} \right) - x_{iu} \cdot \omega_{o2} \\
\dot{\omega}_{o2} &= \left(\ddot{y}_{iu} - \dot{y}_{iu} \cdot \dot{\theta} \cdot \ddot{\omega}_{o2} + \dot{\omega}_{o2} \cdot \dddot{\omega}_{o2} \right) - y_{iu} \cdot \omega_{o2} \\
\dot{x}_{iu} &= (x_{iu} - x_{iu} \cdot \dot{\theta}) \cdot (\ddot{x}_{iu} + \dddot{\gamma}_{o}) \\
\dot{y}_{iu} &= (y_{iu} - y_{iu} \cdot \dot{\theta}) \cdot (\ddot{y}_{iu} + \dddot{\omega}_{o2}) \\
\dot{\gamma}_{o} &= (\ddot{x}_{iu} - \dot{x}_{iu} \cdot \dot{\theta}) \cdot (\ddot{y}_{iu} + \dddot{\omega}_{o2}) \\
\dot{\omega}_{o2} &= (\ddot{y}_{iu} - \dot{y}_{iu} \cdot \dot{\theta}) \cdot (\ddot{y}_{iu} + \dddot{\omega}_{o2}) \\
\end{align} 
\quad (17)

Conclusion

The mobile, mechatronic, robotic, serial, spatial, anthropomorphic type systems, which are currently the most used in the machine building industry, can be studied much more simply in a plan instead of the usual spatial study.

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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.

References


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