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Inverse Kinematics of a Stewart Platform

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Abstract: The development and diversification of machines and mechanisms with applications in all fields require new scientific researches for the systematization and improvement of existing mechanical systems by creating new mechanisms adapted to modern requirements, which involve increasingly complex topological structures. The modern industry, the practice of designing and building machinery is increasingly based on the results of scientific and applied research. Each industrial achievement has backed theoretical and experimental computer-assisted research, which solves increasingly complex problems with advanced computing programs using an increasingly specialized software. The robotization of technological processes determines and influences the emergence of new industries, applications under special environmental conditions, the approach of new types of technological operations, manipulation of objects in the alien space, teleoperators in the top disciplines like medicine, robots covering a whole field greater service provision in our modern, computerized society. Movable, robotic, mechatronic mechanical systems have entered nearly all industrial spheres. Today, we can no longer conceive of industrial production without these extremely useful systems. They are still said to steal from people's jobs. Even so, it should be made clear that these systems create value, work in difficult, repetitive, non-pausing, high-quality work, without getting tired, without getting sick, without salary and producing value who are paid and people left without jobs, so that they can work elsewhere in more pleasant, more advantageous conditions, with the necessary breaks. Mechanical systems in motion type parallel structures are solid, fast and accurate. Between mobile systems parallel the best known and used system is that of a Stewart platforms, as being and the oldest system, quickly, solid and accurate. The paper presents a few main elements of the Stewart platforms. In the case where a motto element consists of a structure composed of two elements in a relative movement from the point of view of the train of propulsion and especially in the dynamic calculations, it is more convenient to represent the motto element as a single moving item. The paper presents an exact, original analytical geometry method for determining the kinematic and dynamic parameters of a parallel mobile structure. Compared with other methods already known, the presented method has the great advantage of being an exact analytical method of calculation and not one iterative-approximately.

Keywords: Stewart Platform, Mechanism, Robots, Mechatronics, Mechanical Systems, Parallel Systems

Introduction

Humanoid robots are now used as research tools in several scientific fields.

Researchers must understand the structure and behavior of the human body (biomechanics) to build and study humanoid robots. On the other hand, the tentative simulation of the human body leads to a better understanding of it. Human knowledge is a field of study that focuses on how people learn from sensory information to acquire their motor skills and abilities. This knowledge is used to develop computational models of human behavior and have been improved over time.

It has been suggested that advanced robotics will facilitate growth even among ordinary people.

Although the original purpose of humanoid research was to build a better orthosis and prosthesis for human beings, knowledge was transferred between the two disciplines. Examples include electrode adjustment legs for neuromuscular disorders, ankle protector foot, real biopsy and forearm biopsy (Aversa *et al*., 2017 a-e; 2016 a-o).

In addition to research, robot humanoids are developed to carry out human activities such as personal assistance, where they can help sick and elderly and dirty or dangerous people. Typical works, such as a yacht or a machine line worker, are also suitable for humanoids. "Essentially, because they can use tools and manipulate equipment and vehicles designed to train people, these humanoids could work theoretically, any cargo can be a human being as long as it has the software itself, but the complexity of the procedure is unbearable.

They are also more popular for providing entertainment. For example, Ursula, female females, sings, plays music, dancing and speaks to audiences in Universal Studios. More attention Disney is committed to using animatrons, robots that look, move and talk like human beings in some thematic shows.

These animatrons look so realistic that it can be difficult to decipher the remote if they are or are not actually people. Although they look realistic, they still do not have cognitive or natural autonomy. The various humanoid robots and possible applications in everyday life are presented in an independent documentary film called Plug and Pray, which was released in 2010.

Humanoid robots, especially artificial intelligence algorithms, could be useful for a dangerous future mission and/or at a high distance to scan the space without having to return and return to the ground after the mission.

A sensor is a device that measures an attribute of the world. Being one of the three primitives of robotics (besides planning and control), detection plays an important role in identifying sequential paradigms.

The sensors can be classified based on the physical process that operates with or depending on the type of measurement information it provides for that output.

The proprioceptive sensors sense the position, orientation and speed of the humanoid rubber body.

In addition, people do not use their own proprioceptive sensors (such as Touch, muscle extension, limb position) to help humanoid-oriented robots. Uses accelerometers to measure acceleration, from which speed can be calculated by integration; tilt sensors for tilt measurement; a force sensor placed on the arms and legs to measure the contact force with the robot environment; position sensors, indicating the current position of the robot (whose speed can be calculated by deriving motion laws) or even speed sensors. Array keys can be used to provide data about what has been done. The hue of the hand uses a range of 34 touches arranged under the polyurethane skin on each finger. Touch sensors also provide information about the forces and torques transferred between the robot and the other objects.

The vision refers to data processing in any way that uses the electromagnetic spectrum to produce an image. In robots, humanoids are used to recognize objects and determine their properties (they put sensors to work more than similarly to the eyes of human beings). Most humanoid robots use CCD cameras as sensors.

Sensors allow humanoid robots to hear the sounds and sounds of the environment and perform human ear functions. Microphones are usually used for this task.

Actuators are the engines responsible for motion and robot.

Humanoid robots are built to mimic the human body so that it can use actuation mechanisms that perform movements such as muscles and joints, albeit with a different structure. To achieve the same effect as human motion, humanoid robots use the main rotating servomotor. They can be either electric, pneumatic, hydraulic, piezoelectric, ultrasound. Hydraulic and electrical actuators have a very rigid behavior and can only be made to act in a manner compatible with the use of relatively complex control strategies. While sealing gasket components are more suited for high speeds and reduced loads, the hydraulic works well at low speed and high load.

The piezoelectric actuator elements generate a high force when applied to the voltage. They can be used for ultra-fine positioning and for generating and handling forces or high pressure in static and dynamic situations.

Ultrasonic actuators are designed to produce micrometric movements at ultra-sonic frequencies (over 20 kHz). These are useful for vibration control applications, fast positioning and switching.

The pneumatic actuators operate on the basis of gas compressibility. As they are swollen, they extend along the axis and, as they deflate, they contract. If one end is fixed, the other will move in a linear trajectory. These components are designed for low loads and low/medium loads. Components of the pneumatic actuator include claw cylinders, pneumatic motors, stepping and pneumatic muscles.

In planning and control, the essential difference between humanoids and other types of robots (such as industrial ones) is that the robot movement must be human consumption, as it is, using, in particular, the locomotive of the foot, the beep lever. Planning the ideal for normal human movements should lead to the minimization of energy consumption, as is the case with the human body. For this reason, studies on the dynamics and control of these types of structures are becoming increasingly important.

The issue of moving and stabilizing the surface of robots is very important. Keeping the robot center of gravity in the center of the camp to ensure a stable position can be chosen as a control objective. To maintain the dynamic balance during the walk and a robot needs information about the contact force and the movement to the real and desired. The solution to this problem is based on a major concept, Zero Point Time (Zero Point Time).

Another feature of humanoid robots is that they move, gather information (using sensors) into the "real world" and interact with them. They do not remain like other manipulating robots working in highly structured environments. To enable humanoids to travel in complex environments, planning and control must focus on collision detection, planning and how to avoid obstacles.

Humanoids do not yet have the characteristics of the human body. These include structures with variable flexibility to provide security (for robots and for humans) and redundancy movements, i.e., more degrees of freedom and availability, both at the level. Although these characteristics are desirable for humanoid robots, they will bring more complexity and new planning and control issues. The purpose of treating the whole body with these problems and addressing adequate coordination of many degrees of freedom, for example, to accomplish more tasks simultaneously, while in the next order, a priority.

The automatic screwdriver with automatic screwdriver is automatically with anthropomorphic arms: extremely flexible in all aspects; they allow to twist different planes and have a high conversion factor. When changing the product or production mode, the arm can be used in a variety of applications.

Industrial anthropomorphic robots have become the most widespread and most used. These are the most widespread on the planet because they have been well implemented and are more easily designed, built and implemented than other types of robots and manipulators. The most common is the structure with a base consisting of three rotary elements, 3R. It is a space saving space, mechanically structured, mobile, three-degree, easy to project and with high mobility. There are great advantages that he has established in the world of industrial robots and has been generalized. Like all industrial robots and this anthropomorphic structure, it was launched in the automotive industry, which has ordered and produced almost all modern industrial robots. The main advantages of such a structure are large mobility, a wider workspace, dynamic, fast and acceptable precision for industrial operations, combined with the most common daily work.

When it comes to reliability and stability, the excessive anthropomorphic structure can not cope with the tasks, it is successfully replaced by parallel structures.

Today, mechanical motion systems are used in almost all vital sectors of humanity (Reddy *et al*., 2012). Robots have the ability to process integrated circuits (Aldana *et al*., 2013) with micro and nano dimensions, which man can only see in electronic microscopy (Lee, 2013). (Padula and Perdereau, 2013; Perumaal and Jawahar, 2013) or deep depths and pressures in deep deep oceans or conquest of space and visiting the new exoplanet Cao *et al*. (2007) on the use of the sequential mechanical transmission mechanism, 2013; Petrescu *et al*., 2009). (Garcia-Murillo *et al*., 2013), a conqueror of the new galaxies (de Melo *et al*., 2012), the human being will be able to fulfill his supreme mission (Tang *et al*., 2013). (Lin *et al*., 2013), various aspects (He *et al*., 2013), but today two major categories are addressed: serial systems (Liu *et al*., 2013; Petrescu and Petrescu, 2012c). Parallel systems are more robust (Tabaković *et al*., 2013; Wang *et al*., 2013), but are more difficult to design and manipulate and for this reason, serial systems have been the ones that have developed the most. In medical or radioactive environments, preferred mobile systems are parallel due to their high accuracy positioning.

Movable mechanical systems are solid, fast and accurate parallel structures. Mechanical systems in parallel motion structures are solid, fast and accurate. Between parallel mobile systems, the most known and used system is that of a Stewart platform, being the oldest, fast, solid and accurate system.

A Gough-Stewart platform is a parallel robot that has six prismatic actuators, usually with winches, electric or hydraulic servo motors attached in pairs to three positions on the base plate of the platform, placed on a top plate. The devices placed on the upper plate can be moved in the six degrees of freedom in which it is possible for a freely suspended body to move. These are the three linear linear, x, y, z (lateral, longitudinal and vertical) linear movements and the three rotation, rotation and rotation sensors. The terms "six axes" or "6-DOF" (degrees of freedom), the platform is also used "Synergy" (see below).

This specialized aspect of the Six Jacks was first used by Eric E. Gough in the United Kingdom and was operational in 1954, the project being subsequently published in a 1965 document by Dough Stewart written by Gough-Stewart on Wikipedia. Although Stewart Short is now used for this Jack, it would be more appropriate for Eric Gough to call it a Gough/Stewart platform. Specifically, the original Stewart platform had a slightly different design. See the references for more details at the end of this article.

In order to ensure that movements are produced by a combination of multiple protection devices, a device is sometimes referred to as a synergy platform because of synergy (mutual interaction between planned power supplies). Geodetic "Hexapod" for Stewart machines used in machine tools, however the term is used for 6-door platforms outside the machine because it simply means "six feet".

The paper presents some of the main elements of Stewart platforms. Start by studying the geometric, cinematic elements of the system and then the dynamic elements.

If a structural motto element consists of two elements in a relatively structural movement, the drive train and especially the dynamic one, it is more convenient to represent the motto element as a single mobile element. In this way there are seven movable elements (the six motto or foot elements, plus the mobile platform 7) and a fixed component. The kinematics of positions is determined by an original method of analytical geometry (Fig. 1). The study of mechanical solids is done by specific calculations.

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*., 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, 1979; Lederer, 1993; Lin, 1999; Modler and Wadewitz, 1998; 2001; Modler, 1979; Neumann, 1979; 2001; Stoica, 1977; Petrescu and Petrescu, 2011 c-d; Petrescu, 2012 d-e; Petrescu, 2016; 2017a-q; Aversa *et al*., 2017 a-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 spatial direction of the unit vectors along the elements 1 and 2 which connect the coupling D of the upper mobile platform 7 by the A and B couplings of the lower fixed platform 0.

The coordinates of the six unitary vectors of type 1-6 engines (variable length) are given by the relational system (1) if these lengths of the single vectors are given by the system (2) and the real lengths of the six mottoes (variables) (3):

$$\begin{cases} \alpha_1 = \frac{x_D - x_A}{l_1}; \beta_1 = \frac{y_D - y_A}{l_1}; \gamma_1 = \frac{z_D - z_A}{l_1} \\ \alpha_2 = \frac{x_D - x_B}{l_2}; \beta_2 = \frac{y_D - y_B}{l_2}; \gamma_2 = \frac{z_D - z_B}{l_2} \\ \alpha_3 = \frac{x_E - x_B}{l_3}; \beta_3 = \frac{y_E - y_B}{l_3}; \gamma_3 = \frac{z_E - z_B}{l_3} \\ \alpha_4 = \frac{x_E - x_C}{l_4}; \beta_4 = \frac{y_E - y_C}{l_4}; \gamma_4 = \frac{z_E - z_C}{l_4} \\ \alpha_5 = \frac{x_F - x_C}{l_5}; \beta_5 = \frac{y_F - y_C}{l_5}; \gamma_5 = \frac{z_F - z_C}{l_5} \\ \alpha_6 = \frac{x_F - x_A}{l_6}; \beta_6 = \frac{y_F - y_A}{l_6}; \gamma_6 = \frac{z_F - z_A}{l_6} \end{cases} \quad (1)$$

$$\begin{cases} \overline{L_1} = \alpha_1 \cdot \overline{i} + \beta_1 \cdot \overline{j} + \gamma_1 \cdot \overline{k}; \overline{L_2} = \alpha_2 \cdot \overline{i} + \beta_2 \cdot \overline{j} + \gamma_2 \cdot \overline{k} \\ \overline{L_3} = \alpha_3 \cdot \overline{i} + \beta_3 \cdot \overline{j} + \gamma_3 \cdot \overline{k}; \overline{L_4} = \alpha_4 \cdot \overline{i} + \beta_4 \cdot \overline{j} + \gamma_4 \cdot \overline{k} \\ \overline{L_5} = \alpha_5 \cdot \overline{i} + \beta_5 \cdot \overline{j} + \gamma_5 \cdot \overline{k}; \overline{L_6} = \alpha_6 \cdot \overline{i} + \beta_6 \cdot \overline{j} + \gamma_6 \cdot \overline{k} \end{cases} \quad (2)$$

$$\begin{cases} \overline{l_1} = l_1 \cdot \overline{L_1} = \alpha_1 \cdot l_1 \cdot \overline{i} + \beta_1 \cdot l_1 \cdot \overline{j} + \gamma_1 \cdot l_1 \cdot \overline{k} \\ \overline{l_2} = l_2 \cdot \overline{L_2} = \alpha_2 \cdot l_2 \cdot \overline{i} + \beta_2 \cdot l_2 \cdot \overline{j} + \gamma_2 \cdot l_2 \cdot \overline{k} \\ \overline{l_3} = l_3 \cdot \overline{L_3} = \alpha_3 \cdot l_3 \cdot \overline{i} + \beta_3 \cdot l_3 \cdot \overline{j} + \gamma_3 \cdot l_3 \cdot \overline{k} \\ \overline{l_4} = l_4 \cdot \overline{L_4} = \alpha_4 \cdot l_4 \cdot \overline{i} + \beta_4 \cdot l_4 \cdot \overline{j} + \gamma_4 \cdot l_4 \cdot \overline{k} \\ \overline{l_5} = l_5 \cdot \overline{L_5} = \alpha_5 \cdot l_5 \cdot \overline{i} + \beta_5 \cdot l_5 \cdot \overline{j} + \gamma_5 \cdot l_5 \cdot \overline{k} \\ \overline{l_6} = l_6 \cdot \overline{L_6} = \alpha_6 \cdot l_6 \cdot \overline{i} + \beta_6 \cdot l_6 \cdot \overline{j} + \gamma_6 \cdot l_6 \cdot \overline{k} \end{cases} \quad (3)$$

$$\begin{cases} \alpha_1 \cdot l_1 = x_D - x_A; \dot{\alpha}_1 \cdot l_1 + \alpha_1 \cdot \dot{l}_1 = \dot{x}_D; \dot{\alpha}_1 = \frac{\dot{x}_D - \alpha_1 \cdot \dot{l}_1}{l_1} \\ \beta_1 \cdot l_1 = y_D - y_A; \dot{\beta}_1 \cdot l_1 + \beta_1 \cdot \dot{l}_1 = \dot{y}_D; \dot{\beta}_1 = \frac{\dot{y}_D - \beta_1 \cdot \dot{l}_1}{l_1} \\ \gamma_1 \cdot l_1 = z_D - z_A; \dot{\gamma}_1 \cdot l_1 + \gamma_1 \cdot \dot{l}_1 = \dot{z}_D; \dot{\gamma}_1 = \frac{\dot{z}_D - \gamma_1 \cdot \dot{l}_1}{l_1} \end{cases} \quad (4)$$

$$\begin{cases} x_D = x_A + \alpha_1 \cdot l_1; y_D = y_A + \beta_1 \cdot l_1; z_D = z_A + \gamma_1 \cdot l_1 \\ x_{G_1} = x_A + \alpha_1 \cdot a_1; y_{G_1} = y_A + \beta_1 \cdot a_1; z_{G_1} = z_A + \gamma_1 \cdot a_1 \end{cases} \quad (5)$$

Figure 2, a motor element (motor 1) is represented in an instant position because a motor element consists of a structure composed of two relative cross members but which, from the point of view of the propulsion train and in particular the dynamic calculations considered be a variable length element. The three equations of the first relationship in the system (1) defining the engine element 1 are derived and transmitted to the system (4). These are also written in system 5 together with the engine center of gravity Equations 1.

The latter separate in the system (6) that is derived in the system (7):

$$\begin{cases} x_{G_1} = \dfrac{a_1 \cdot x_D + (l_1 - a_1) \cdot x_A}{l_1} \\ y_{G_1} = \dfrac{a_1 \cdot y_D + (l_1 - a_1) \cdot y_A}{l_1} \\ z_{G_1} = \dfrac{a_1 \cdot z_D + (l_1 - a_1) \cdot z_A}{l_1} \end{cases} \tag{6}$$

$$\begin{cases} l_1 \cdot x_{G_1} = a_1 \cdot x_D + (l_1 - a_1) \cdot x_A; \dot{l}_1 \cdot x_{G_1} + l_1 \cdot \dot{x}_{G_1} = \\ = \dot{a}_1 \cdot x_D + a_1 \cdot \dot{x}_D + (\dot{l}_1 - \dot{a}_1) \cdot x_A \\ \dot{x}_{G_1} = \dfrac{\dot{a}_1 \cdot x_D + a_1 \cdot \dot{x}_D - \dot{l}_1 \cdot x_{G_1} + (\dot{l}_1 - \dot{a}_1) \cdot x_A}{l_1} \\ \dot{y}_{G_1} = \dfrac{\dot{a}_1 \cdot y_D + a_1 \cdot \dot{y}_D - \dot{l}_1 \cdot y_{G_1} + (\dot{l}_1 - \dot{a}_1) \cdot y_A}{l_1} \\ \dot{z}_{G_1} = \dfrac{\dot{a}_1 \cdot z_D + a_1 \cdot \dot{z}_D - \dot{l}_1 \cdot z_{G_1} + (\dot{l}_1 - \dot{a}_1) \cdot z_A}{l_1} \end{cases} \tag{7}$$

The kinetic energy of the mechanism (relation 8) is written because the translation of the center of gravity of each engine element already contains the effect of a different rotation.

Each engine element (rod) will be studied as a single kinematic element with varying length with mass and constant position and variable center of gravity. Each movement of an engine element is one of spatial rotation:

$$\begin{cases} E_c = \dfrac{m_1}{2} \cdot \left(\dot{x}_{G_1}^2 + \dot{y}_{G_1}^2 + \dot{z}_{G_1}^2\right) + \dfrac{m_2}{2} \cdot \left(\dot{x}_{G_2}^2 + \dot{y}_{G_2}^2 + \dot{z}_{G_2}^2\right) \\ + \dfrac{m_3}{2} \cdot \left(\dot{x}_{G_3}^2 + \dot{y}_{G_3}^2 + \dot{z}_{G_3}^2\right) + \dfrac{m_4}{2} \cdot \left(\dot{x}_{G_4}^2 + \dot{y}_{G_4}^2 + \dot{z}_{G_4}^2\right) \\ + \dfrac{m_5}{2} \cdot \left(\dot{x}_{G_5}^2 + \dot{y}_{G_5}^2 + \dot{z}_{G_5}^2\right) + \dfrac{m_6}{2} \cdot \left(\dot{x}_{G_6}^2 + \dot{y}_{G_6}^2 + \dot{z}_{G_6}^2\right) \\ + \dfrac{m_7}{2} \cdot \left(\dot{x}_S^2 + \dot{y}_S^2 + \dot{z}_S^2\right) + \dfrac{J_{7SN}}{2} \cdot \omega_{7SN}^2 \end{cases} \tag{8}$$

According to the system model (7), the weight centers of the six rods are then determined (see Equations 9). Known speeds are known, whether given, measured, or required, all velocities must therefore be known as value when the dynamic calculation process begins. The same happens with all the hardships, which are also known, being already given or obtained through several weighing processes. The moment of mass or mechanical inertia calculated or determined along the N axis can be determined by calculation, calculated with an approximate formula (10):

Fixed platform positions are determined by systems 11-13 and those of the mobile platform are determined by system relationships 14-52. The system 53 then determines the lengths of the six motto elements. Only original geometrical analytical relations already described are used.

$$\begin{cases} \begin{cases} \dot{x}_{G_1} = \dfrac{\dot{a}_1 \cdot (x_D - x_A) + a_1 \cdot \dot{x}_D + \dot{l}_1 \cdot (x_A - x_{G_1})}{l_1} \\ \dot{y}_{G_1} = \dfrac{\dot{a}_1 \cdot (y_D - y_A) + a_1 \cdot \dot{y}_D + \dot{l}_1 \cdot (y_A - y_{G_1})}{l_1} \\ \dot{z}_{G_1} = \dfrac{\dot{a}_1 \cdot (z_D - z_A) + a_1 \cdot \dot{z}_D + \dot{l}_1 \cdot (z_A - z_{G_1})}{l_1} \end{cases} \\ \begin{cases} \dot{x}_{G_2} = \dfrac{\dot{a}_2 \cdot (x_D - x_B) + a_2 \cdot \dot{x}_D + \dot{l}_2 \cdot (x_B - x_{G_2})}{l_2} \\ \dot{y}_{G_2} = \dfrac{\dot{a}_2 \cdot (y_D - y_B) + a_2 \cdot \dot{y}_D + \dot{l}_2 \cdot (y_B - y_{G_2})}{l_2} \\ \dot{z}_{G_2} = \dfrac{\dot{a}_2 \cdot (z_D - z_B) + a_2 \cdot \dot{z}_D + \dot{l}_2 \cdot (z_B - z_{G_2})}{l_2} \end{cases} \\ \begin{cases} \dot{x}_{G_3} = \dfrac{\dot{a}_3 \cdot (x_E - x_B) + a_3 \cdot \dot{x}_E + \dot{l}_3 \cdot (x_B - x_{G_3})}{l_3} \\ \dot{y}_{G_3} = \dfrac{\dot{a}_3 \cdot (y_E - y_B) + a_3 \cdot \dot{y}_E + \dot{l}_3 \cdot (y_B - y_{G_3})}{l_3} \\ \dot{z}_{G_3} = \dfrac{\dot{a}_3 \cdot (z_E - z_B) + a_3 \cdot \dot{z}_E + \dot{l}_3 \cdot (z_B - z_{G_3})}{l_3} \end{cases} \\ \begin{cases} \dot{x}_{G_4} = \dfrac{\dot{a}_4 \cdot (x_E - x_C) + a_4 \cdot \dot{x}_E + \dot{l}_4 \cdot (x_C - x_{G_4})}{l_4} \\ \dot{y}_{G_4} = \dfrac{\dot{a}_4 \cdot (y_E - y_C) + a_4 \cdot \dot{y}_E + \dot{l}_4 \cdot (y_C - y_{G_4})}{l_4} \\ \dot{z}_{G_4} = \dfrac{\dot{a}_4 \cdot (z_E - z_C) + a_4 \cdot \dot{z}_E + \dot{l}_4 \cdot (z_C - z_{G_4})}{l_4} \end{cases} \\ \begin{cases} \dot{x}_{G_5} = \dfrac{\dot{a}_5 \cdot (x_F - x_C) + a_5 \cdot \dot{x}_F + \dot{l}_5 \cdot (x_C - x_{G_5})}{l_5} \\ \dot{y}_{G_5} = \dfrac{\dot{a}_5 \cdot (y_F - y_C) + a_5 \cdot \dot{y}_F + \dot{l}_5 \cdot (y_C - y_{G_5})}{l_5} \\ \dot{z}_{G_5} = \dfrac{\dot{a}_5 \cdot (z_F - z_C) + a_5 \cdot \dot{z}_F + \dot{l}_5 \cdot (z_C - z_{G_5})}{l_5} \end{cases} \\ \begin{cases} \dot{x}_{G_6} = \dfrac{\dot{a}_6 \cdot (x_F - x_A) + a_6 \cdot \dot{x}_F + \dot{l}_6 \cdot (x_A - x_{G_6})}{l_6} \\ \dot{y}_{G_6} = \dfrac{\dot{a}_6 \cdot (y_F - y_A) + a_6 \cdot \dot{y}_F + \dot{l}_6 \cdot (y_A - y_{G_6})}{l_6} \\ \dot{z}_{G_6} = \dfrac{\dot{a}_6 \cdot (z_F - z_A) + a_6 \cdot \dot{z}_F + \dot{l}_6 \cdot (z_A - z_{G_6})}{l_6} \end{cases} \end{cases} \tag{9}$$

10.3844/jmrsp.2018.45.59

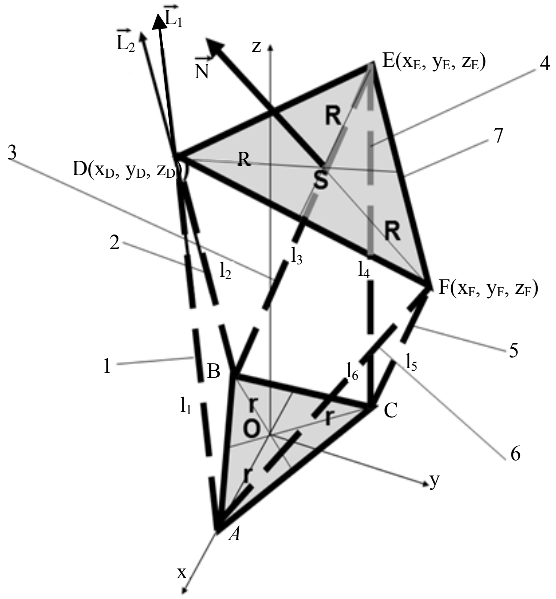

Fig. 1: The structure and geometry of a Stewart platform

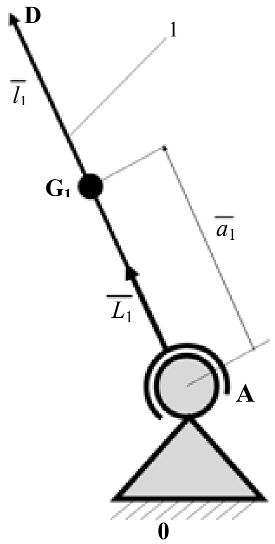

Fig. 2: The basic structure of a motto element

$$J_{7SN} = \frac{\frac{1}{2}m_p \cdot R_T^2 + \frac{1}{2}m_p \cdot r_T^2}{2} = \frac{m_p}{4}\cdot\left(R_T^2 + r_T^2\right) = \frac{m_p}{4}\cdot\left[R_T^2 + \left(\frac{1}{2}R_T\right)^2\right] = \frac{m_p}{4}\cdot R_T^2\cdot\left(1+\frac{1}{4}\right) = \frac{5}{16}\cdot m_p \cdot R_T^2 = \frac{5}{16}\cdot m_p\cdot R^2 \tag{10}$$

$$\begin{cases} x = r \\ y = z = 0 \end{cases} \tag{11}$$

$$\begin{cases} x_B = -\frac{1}{2}\cdot r \\ y_B = -\frac{\sqrt{3}}{2}\cdot r \\ z_B = 0 \end{cases} \tag{12}$$

$$\begin{cases} x_C = -r\cdot\sin 30^0 = -\frac{1}{2}\cdot r \\ y_C = r\cdot\cos 30^0 = \frac{\sqrt{3}}{2}\cdot r \\ z_C = 0 \end{cases} \tag{13}$$

$$\begin{cases} (x_D - x_F)^2 + (y_D - y_F)^2 + (z_D - z_F)^2 = 3\cdot R^2 \\ (x_D - x_E)^2 + (y_D - y_E)^2 + (z_D - z_E)^2 = 3\cdot R^2 \\ (x_E - x_F)^2 + (y_E - y_F)^2 + (z_E - z_F)^2 = 3\cdot R^2 \end{cases} \tag{14}$$

$$\begin{cases} (x_D - x_S)^2 + (y_D - y_S)^2 + (z_D - z_S)^2 = R^2 \\ (x_E - x_S)^2 + (y_E - y_S)^2 + (z_E - z_S)^2 = R^2 \\ (x_F - x_S)^2 + (y_F - y_S)^2 + (z_F - z_S)^2 = R^2 \end{cases} \tag{15}$$

$$\overline{DS}\cdot\bar{N} = 0 \tag{16}$$

$$\begin{cases} (x_D - x_S)\cdot\alpha + (y_D - y_S)\cdot\beta + (z_D - z_S)\cdot\gamma = 0 \\ (x_E - x_S)\cdot\alpha + (y_E - y_S)\cdot\beta + (z_E - z_S)\cdot\gamma = 0 \\ (x_F - x_S)\cdot\alpha + (y_F - y_S)\cdot\beta + (z_F - z_S)\cdot\gamma = 0 \end{cases} \tag{17}$$

$$\begin{cases} (x_D - x_S)\cdot\alpha + (y_D - y_S)\cdot\beta = (z_S - z_D)\cdot\gamma \\ (x_D - x_S)^2 + (y_D - y_S)^2 = R^2 - (z_D - z_S)^2 \end{cases} \tag{18}$$

$$\begin{cases} x = x_D - x_S \\ y = y_D - y_S \\ \theta = (z_S - z_D)\cdot\gamma \\ L^2 = R^2 - (z_D - z_S)^2 \end{cases} \tag{19}$$

$$\begin{cases} \alpha\cdot x + \beta\cdot y = \theta \\ x^2 + y^2 = L^2 \end{cases} \tag{20}$$

$$\begin{cases} x = \frac{\theta - \beta\cdot y}{\alpha} x^2 = \frac{\theta^2 + \beta^2\cdot y^2 - 2\cdot\theta\cdot\beta\cdot y}{\alpha^2} \\ \theta^2 + \beta^2\cdot y^2 - 2\cdot\theta\cdot\beta\cdot y + \alpha^2\cdot y^2 = \alpha^2\cdot L^2 \\ (\alpha^2 + \beta^2)\cdot y^2 - 2\cdot\theta\cdot\beta\cdot y - (\alpha^2\cdot L^2 - \theta^2) = 0 \end{cases} \tag{21}$$

$$\begin{cases} y_{1,2} = \dfrac{\theta \cdot \beta \pm \sqrt{\theta^2 \cdot \beta^2 + (\alpha^2 + \beta^2) \cdot (\alpha^2 \cdot L^2 - \theta^2)}}{\alpha^2 + \beta^2} \\ y_{1,2} = \dfrac{\theta \cdot \beta \pm \alpha \cdot \sqrt{(\alpha^2 + \beta^2) \cdot L^2 - \theta^2}}{\alpha^2 + \beta^2} \\ x_{1,2} = \dfrac{\theta - \beta \cdot y}{\alpha} = \dfrac{\theta}{\alpha} - \dfrac{\beta}{\alpha} \cdot y_{1,2} \end{cases} \tag{22}$$

$$\begin{cases} y = \dfrac{\theta \cdot \beta - \alpha \cdot \sqrt{(\alpha^2 + \beta^2) \cdot L^2 - \theta^2}}{\alpha^2 + \beta^2} y_D = y + y_S \\ x = \dfrac{\theta - \beta \cdot y}{\alpha} = \dfrac{\theta}{\alpha} - \dfrac{\beta}{\alpha} \cdot y x_D = x + x_S \\ \Rightarrow D(x_D, y_D, z_D) \end{cases} \tag{23}$$

$$\begin{cases} (x_E - x_S) \cdot \alpha + (y_E - y_S) \cdot \beta + (z_E - z_S) \cdot \gamma = 0 \\ (x_E - x_S)^2 + (y_E - y_S)^2 + (z_E - z_S)^2 = R^2 \\ (x_E - x_D)^2 + (y_E - y_D)^2 + (z_E - z_D)^2 = 3 \cdot R^2 \end{cases} \tag{24}$$

$$\begin{cases} x_E^2 + x_S^2 - 2 \cdot x_S \cdot x_E + y_E^2 + y_S^2 - \\ -2 \cdot y_S \cdot y_E + z_E^2 + z_S^2 - 2 \cdot z_S \cdot z_E = R^2 \\ x_E^2 + x_D^2 - 2 \cdot x_D \cdot x_E + y_E^2 + y_D^2 - \\ -2 \cdot y_D \cdot y_E + z_E^2 + z_D^2 - 2 \cdot z_D \cdot z_E = 3 \cdot R^2 \\ \text{---} \\ x_D^2 - x_S^2 + 2 \cdot (x_S - x_D) \cdot x_E + y_D^2 - y_S^2 + \\ +2 \cdot (y_S - y_D) \cdot y_E + z_D^2 - z_S^2 + \\ +2 \cdot (z_S - z_D) \cdot z_E = 2 \cdot R^2 \end{cases} \tag{25}$$

$$\begin{cases} 2 \cdot (x_S - x_D) \cdot x_E + 2 \cdot (y_S - y_D) \cdot y_E \\ +2 \cdot (z_S - z_D) \cdot z_E = 2 \cdot R^2 + x_S^2 + y_S^2 \\ +z_S^2 - x_D^2 - y_D^2 - z_D^2 \\ \alpha \cdot x_E + \beta \cdot y_E + \gamma \cdot z_E \\ = \alpha \cdot x_S + \beta \cdot y_S + \gamma \cdot z_S \end{cases} \tag{26}$$

$$z_E = \frac{\alpha}{\gamma} \cdot x_S + \frac{\beta}{\gamma} \cdot y_S + z_S - \frac{\alpha}{\gamma} \cdot x_E - \frac{\beta}{\gamma} \cdot y_E \tag{27}$$

$$y_E = k_1 + k_2 \cdot x_E \tag{28}$$

$$\begin{cases} k_1 = \Big[2 \cdot R^2 + x_S^2 + y_S^2 + z_S^2 - x_D^2 - y_D^2 - z_D^2 - \\ -2 \cdot (z_S - z_D) \cdot \dfrac{\alpha}{\gamma} \cdot x_S - 2 \cdot (z_S - z_D) \cdot \dfrac{\beta}{\gamma} \cdot y_S - 2 \cdot (z_S - z_D) \cdot z_S \Big] : \\ : \left[2 \cdot (y_S - y_D) - 2 \cdot (z_S - z_D) \cdot \dfrac{\beta}{\gamma} \right] \\ k_2 = \dfrac{(x_D - x_S) + (z_S - z_D) \cdot \dfrac{\alpha}{\gamma}}{(y_S - y_D) - (z_S - z_D) \cdot \dfrac{\beta}{\gamma}} \end{cases} \tag{29}$$

$$z_E = k_3 - k_4 \cdot x_E \tag{30}$$

$$\begin{cases} k_3 = \dfrac{\alpha}{\gamma} \cdot x_S + \dfrac{\beta}{\gamma} \cdot y_S + z_S - \dfrac{\beta}{\gamma} \cdot k_1 \\ k_4 = \dfrac{\alpha}{\gamma} + \dfrac{\beta}{\gamma} \cdot k_2 \end{cases} \tag{31}$$

$$\begin{cases} x_E^2 - 2 \cdot x_S \cdot x_E + (k_1 + k_2 \cdot x_E)^2 \\ -2 \cdot y_S \cdot (k_1 + k_2 \cdot x_E) + (k_3 - k_4 \cdot x_E)^2 \\ -2 \cdot z_S \cdot (k_3 - k_4 \cdot x_E) = R^2 - x_S^2 - y_S^2 - z_S^2 \end{cases} \tag{32}$$

$$\begin{cases} (1 + k_2^2 + k_4^2) \cdot x_E^2 \\ -2 \cdot (x_S - k_1 \cdot k_2 + k_2 \cdot y_S + k_3 \cdot k_4) \cdot x_E \\ +k_1^2 - 2 \cdot k_1 \cdot y_S + k_3^2 - 2 \cdot k_3 \cdot z_S \\ -R^2 + x_S^2 + y_S^2 + z_S^2 = 0 \end{cases} \tag{33}$$

$$\begin{cases} a_1 = 1 + k_2^2 + k_4^2 \\ b_1 \equiv -\dfrac{b}{2} = x_S - k_1 \cdot k_2 + k_2 \cdot y_S + k_3 \cdot k_4 \\ c_1 = k_1^2 \, 2 \cdot k_1 \cdot y_S + k_3^2 \, 2 \cdot k_3 \cdot z_S \, R^2 + x_S^2 + y_S^2 + z_S^2 \end{cases} \tag{34}$$

$$a_1 \cdot x_E^2 - 2 \cdot b_1 \cdot x_E + c_1 = 0 \tag{35}$$

$$x_{E_{1,2}} = \frac{b_1 \pm \sqrt{b_1^2 - a_1 \cdot c_1}}{a_1} \tag{36}$$

$$\begin{cases} x_E = \dfrac{b_1}{a_1} - \sqrt{\left(\dfrac{b_1}{a_1}\right)^2 - \dfrac{c_1}{a_1}} \\ y_E = k_1 + k_2 \cdot x_E \\ z_E = k_3 - k_4 \cdot x_E \end{cases} \tag{37}$$

$$\begin{cases} (x_F - x_S) \cdot \alpha + (y_F - y_S) \cdot \beta + (z_F - z_S) \cdot \gamma = 0 \\ (x_F - x_S)^2 + (y_F - y_S)^2 + (z_F - z_S)^2 = R^2 \\ (x_F - x_D)^2 + (y_F - y_D)^2 + (z_F - z_D)^2 = 3 \cdot R^2 \\ (x_F - x_E)^2 + (y_F - y_E)^2 + (z_F - z_E)^2 = 3 \cdot R^2 \end{cases} \tag{38}$$

$$\begin{cases} x_F^2 + x_D^2 - 2 \cdot x_D \cdot x_F + y_F^2 + y_D^2 - 2 \cdot y_D \cdot y_F \\ +z_F^2 + z_D^2 - 2 \cdot z_D \cdot z_F = 3 \cdot R^2 \\ x_F^2 + x_E^2 - 2 \cdot x_E \cdot x_F + y_F^2 + y_E^2 - 2 \cdot y_E \cdot y_F \\ +z_F^2 + z_E^2 - 2 \cdot z_E \cdot z_F = 3 \cdot R^2 \end{cases} \tag{39}$$

$$\begin{cases} x_D^2 - x_E^2 + 2 \cdot (x_E - x_D) \cdot x_F \\ +y_D^2 - y_E^2 + 2 \cdot (y_E - y_D) \cdot y_F \\ +z_D^2 - z_E^2 + 2 \cdot (z_E - z_D) \cdot z_F = 0 \end{cases} \tag{40}$$

$$\begin{cases} 2\cdot(x_E x_D)\cdot x_F + 2\cdot(y_E y_D)\cdot y_F + \\ +2\cdot(z_E - z_D)\cdot z_F = \\ = x_E^2 - x_D^2 + y_E^2 - y_D^2 + z_E^2 - z_D^2 \end{cases} \quad (41)$$

$$\begin{cases} x_F^2 + x_S^2 - 2\cdot x_S\cdot x_F + y_F^2 + y_S^2 - \\ -2\cdot y_S\cdot y_F + z_F^2 + z_S^2 - 2\cdot z_S\cdot z_F = R^2 \\ x_F^2 + x_D^2 - 2\cdot x_D\cdot x_F + y_F^2 + y_D^2 - \\ -2\cdot y_D\cdot y_F + z_F^2 + z_D^2 - 2\cdot z_D\cdot z_F = 3\cdot R^2 \end{cases} \quad (42)$$

$$\begin{cases} x_D^2 - x_S^2 + 2\cdot(x_S - x_D)\cdot x_F + y_D^2 - y_S^2 \\ +2\cdot(y_S - y_D)\cdot y_F + z_D^2 - z_S^2 \\ +2\cdot(z_S - z_D)\cdot z_F = 2\cdot R^2 \end{cases} \quad (43)$$

$$\begin{cases} 2\cdot(x_S - x_D)\cdot x_F + 2\cdot(y_S - y_D)\cdot y_F \\ +2\cdot(z_S - z_D)\cdot z_F \\ = 2\cdot R^2 + x_S^2 - x_D^2 + y_S^2 - y_D^2 + z_S^2 - z_D^2 \end{cases} \quad (44)$$

$$\begin{cases} 2(x_E - x_D)x_F + 2(y_E - y_D)y_F + 2(z_E - z_D)z_F \\ = x_E^2 - x_D^2 + y_E^2 - y_D^2 + z_E^2 - z_D^2 \\ 2(x_S - x_D)x_F + 2(y_S - y_D)y_F + 2(z_S - z_D)z_F \\ = 2R^2 + x_S^2 - x_D^2 + y_S^2 - y_D^2 + z_S^2 - z_D^2 \\ \alpha\cdot x_F + \beta\cdot y_F + \gamma\cdot z_F = \alpha\cdot x_S + \beta\cdot y_S + \gamma\cdot z_S \end{cases} \quad (45)$$

$$\begin{cases} a_{11}\cdot x_F + a_{12}\cdot y_F + a_{13}\cdot z_F = b_1 \\ a_{21}\cdot x_F + a_{22}\cdot y_F + a_{23}\cdot z_F = b_2 \\ a_{31}\cdot x_F + a_{32}\cdot y_F + a_{33}\cdot z_F = b_3 \end{cases} \quad (46)$$

$$\begin{cases} a_{11} = 2\cdot(x_E - x_D); a_{12} = 2\cdot(y_E - y_D); \\ a_{13} = 2\cdot(z_E - z_D); \\ b_1 = x_E^2 - x_D^2 + y_E^2 - y_D^2 + z_E^2 - z_D^2; \\ a_{21} = 2\cdot(x_S - x_D); a_{22} = 2\cdot(y_S - y_D); \\ a_{23} = 2\cdot(z_S - z_D); \\ b_2 = 2\cdot R^2 + x_S^2 - x_D^2 + y_S^2 - y_D^2 + z_S^2 - z_D^2; \\ a_{31} = \alpha;\ a_{32} = \beta;\ a_{33} = \gamma; \\ b_3 = \alpha\cdot x_S + \beta\cdot y_S + \gamma\cdot z_S \end{cases} \quad (47)$$

$$\Delta = \begin{vmatrix} a_{11}\, a_{12}\, a_{13} \\ a_{21}\, a_{22}\, a_{23} \\ a_{31}\, a_{32}\, a_{33} \end{vmatrix} = a_{11}\cdot(a_{22}\cdot a_{33} - a_{23}\cdot a_{32}) \\ +a_{12}\cdot(a_{23}\cdot a_{31} - a_{21}\cdot a_{33}) + a_{13}\cdot(a_{21}\cdot a_{32} - a_{22}\cdot a_{31}) \quad (48)$$

$$\Delta_x = \begin{vmatrix} b_1\, a_{12}\, a_{13} \\ b_2\, a_{22}\, a_{23} \\ b_3\, a_{32}\, a_{33} \end{vmatrix} = b_1\cdot(a_{22}\cdot a_{33} - a_{23}\cdot a_{32}) \\ +a_{12}\cdot(a_{23}\cdot b_3 - b_2\cdot a_{33}) + a_{13}\cdot(b_2\cdot a_{32} - a_{22}\cdot b_3) \quad (49)$$

$$\Delta_y = \begin{vmatrix} a_{11}\, b_1\, a_{13} \\ a_{21}\, b_2\, a_{23} \\ a_{31}\, b_3\, a_{33} \end{vmatrix} = a_{11}\cdot(b_2\cdot a_{33} - a_{23}\cdot b_3) \\ +b_1\cdot(a_{23}\cdot a_{31} - a_{21}\cdot a_{33}) + a_{13}\cdot(a_{21}\cdot b_3 - b_2\cdot a_{31}) \quad (50)$$

$$\Delta_z = \begin{vmatrix} a_{11}\, a_{12}\, b_1 \\ a_{21}\, a_{22}\, b_2 \\ a_{31}\, a_{32}\, b_3 \end{vmatrix} = a_{11}\cdot(a_{22}\cdot b_3 - b_2\cdot a_{32}) \\ +a_{12}\cdot(b_2\cdot a_{31} - a_{21}\cdot b_3) + b_1\cdot(a_{21}\cdot a_{32} - a_{22}\cdot a_{31}) \quad (51)$$

$$\begin{cases} x_F = \dfrac{\Delta_x}{\Delta} \\ y_F = \dfrac{\Delta_y}{\Delta} \\ z_F = \dfrac{\Delta_z}{\Delta} \end{cases} \quad (52)$$

$$\begin{cases} l_1 = \sqrt{(x_D - x_A)^2 + (y_D - y_A)^2 + (z_D - z_A)^2} \\ l_2 = \sqrt{(x_D - x_B)^2 + (y_D - y_B)^2 + (z_D - z_B)^2} \\ l_3 = \sqrt{(x_E - x_B)^2 + (y_E - y_B)^2 + (z_E - z_B)^2} \\ l_4 = \sqrt{(x_E - x_C)^2 + (y_E - y_C)^2 + (z_E - z_C)^2} \\ l_5 = \sqrt{(x_F - x_C)^2 + (y_F - y_C)^2 + (z_F - z_C)^2} \\ l_6 = \sqrt{(x_F - x_A)^2 + (y_F - y_A)^2 + (z_F - z_A)^2} \end{cases} \quad (53)$$

In the case in which is to be understood by the mp, the mobile mass of the platform mobile 7 (obtained by weighing).

Results

Geometry and Inverse Kinematic to a Stewart Platform by a Method of Analytical Geometry-Determination of Positions and Movements

Figure 3 shows the basic geometric model. In order to ease the calculation system, two equilateral triangles inserted into the top and bottom plate circles will be used. As a basic system, the ABC triangle (fixed) with its own fixed axle system, rectangular xOyz, will be considered and for the mobile (upper) platform the equilateral triangle DEF, mobile (locked on top of the mobile platform of the system) will be adopted. The center of the fixed triangle is the point O and the point of the triangle is point S.

Figure 4 presents the parameters of position (Cartesian coordinates space) of the fixed points A, B, C.

For the mobile platform up (DEF) it can be written the equations (14-15) (Fig. 5).

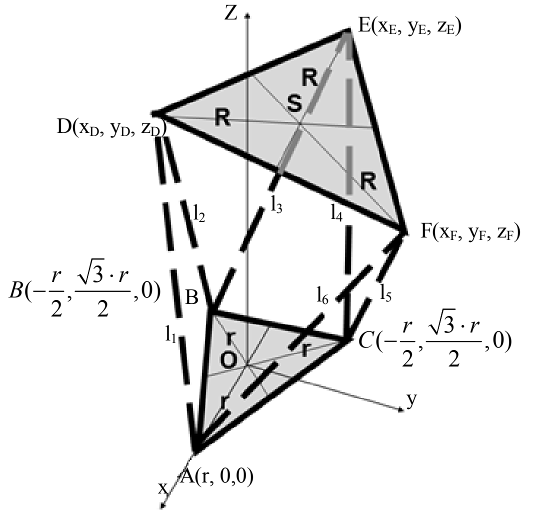

Fig. 3: The basic geometric model

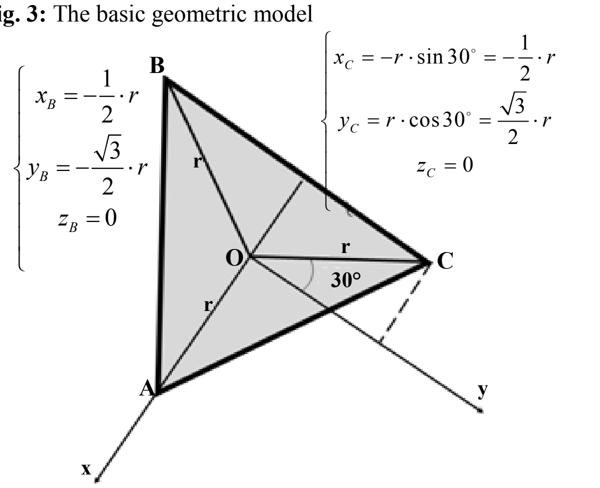

Fig. 4: The determined parameters of position for fixed points A, B, C

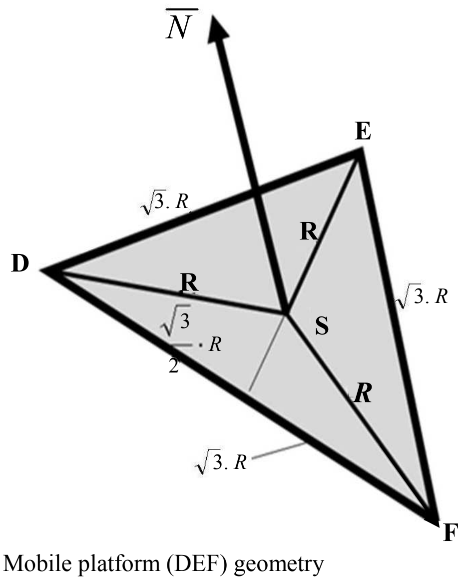

Fig. 5: Mobile platform (DEF) geometry

Repeat the procedure, but this time by writing all the distances between the center S of the mobile triangle and each peak of triangle (DEF) (see relations system 15).

Discussion

Now follows writing general equations of the triangle noted with DEF (Equation 16), where D is any point of the plan, S is a specific point (center) of the plan and the vector N is the vector perpendicular to the DEF plan. The geometric parameters (scalars) (α, β, γ) of the vector N are known. The general equation of a plan says that any right of the plan (included in the plan DEF) scalar multiplied with *N* (the vector perpendicular to the plan DEF) generates the product 0. In other words, the scalar product of vectors DS and SN is 0.

To the point D will assign successively the values of D, E and F and the vector equation of the plan (spatial equation, product scalar 16) will be expressed to the form of three relations (system 17).

One knows all the parameters: x_S, y_S, z_S, α, β, γ. With the help of the systems (17) and (15) may be determined the scalar parameters of a point on the mobile circle, by choosing for example to determine the initial point D (It is necessary for this point D to be known, already positioned). It assumes for example to be known the coordinates of z_D. Then one determines the other two scalar coordinates x_D and y_D from the system (18) out of the first relation from the system (17) and the first expression of the system (15).

One solving the system (18) by introducing the notations (19); from the system (18) using the annotation (19) it obtains the relations system (20), who may be solved successively through the relations (21) which leading to an equation of two degrees having the unknown *y*, whose solution may be given by two expressions: First and second relationship system (22), mean-while with the third expression of system (22) one calculates *x*.

To obtain a correct positioning for the point *D*, initially shall be chosen the negative solution (and if this does not correspond then will be chosen the positive solution). In this mode it can be obtained all the scalar parameters of the point *D* (expressions 23).

Using systems (17, 15, 14) we can go for next equations with those one writes the system (24), in such mode as to have as unknown the only scalar coordinates of point *E*, i.e., x_E, y_E, z_E. New system thus obtained is a non-linear system.

To be solved the system (24) must be first linearised. One rose square the last two system relations and then must to be reduced the second relation from the third. It obtains the third system expression (25), which can be arranged to a more convenient form resulting in the system (26) together with the first expression of the system (24) neat properly.

Using the second relation of the system (26) one explicits z_E, (expression 27), which shall be introduced to first expression system (26) by eliminating parameter z_E and go then to linear relationship (28), having y_E as a function of x_E, whith the coefficients k_1, k_2, which are determined by the relations system (29).

One uses the relations (11) for the point A.

Point B is determined by relations (12).

Point C is determined through the relations (13).

One replaces y_E given by the expression (28) in the relation (27); then it obtains (in this way) a second linear expression between the two parameters z_E and x_E, (relation 30), whit coefficients k_3, k_4, given by the system (31).

Expressions (28) and (30) are simultaneously included in the first relation system (25) and one obtains an equation of second degree in x_E (expression 32), who is listed according to the form (33).

Then, one notes the coefficients of equation (33) second degree in x_E, with a_1, b_1, c_1, (see the expressions of system 34).

Expression (33) becomes the simplified form (35), which supports the real solutions (36).

Now, again in front of two solutions and being required to choose only the correct one. One choose one of them and if the calculation does not match desired position (represented and on a drawing) one choose the other solution. We assume now that the solution will be the negative. Shall one write all the scalar parameters of point *E*, using and expressions (37).

From the systems (17, 15, 14) must choose to use only four expressions (one of 17, one of 15 and two from 14), expressions with which one writes the system (38).

It rose square binomial last two expressions system (38) and relations obtained (39) gather resulting in the equation (40), which may be then arranged convenient to the final form (41).

One repeats the procedure for the torque equations two and three belonging to the system (38) and then one obtains the system with two equations (42), who gathered give relationship (43), who can be used to arrange things properly in the relation-ship (44).

Shall be retained the linear system (45) of three equations with three unknowns, the three equations (41), (44) and the first relationship of the system (38) folded out.

System (45) can be written in the form (46).

All coefficients of the system (46) have been determined through relations (47).

Determinants of the system (46) are written in forms (48-51).

All the system solutions may be given by the expressions (52).

With all known coordinates points *D*, *E*, *F*, as required by the state of the plan DEF and with the choice of point *D*, shall be then determined the lengths required components (engines elements), (see expressions 53).

Applications

In the 1800s Augustine Louis Cauchy, a pioneer in mathematical analysis, studied the stiffness of an articulated octahedron, the ancestor of the hexapod. In 1949, V. E. Gough advanced research and built a parallel mechanism to test tires in various tasks.

A few years later, in 1965, D. Stewart began using a hexadop version for flight simulators. The robot he built will be renamed the "Stewart Platform". Over the years, the hexapod has been enhanced by sophisticated engineers such as *K*. Cappel, Mc Callion, etc.

A Gough-Stewart platform is a parallel robot type that has six prismatic actuators with electric or hydraulic winches mounted in pairs in three positions on the base plate of the platform, passing over the three mounting points on a top plate.

The devices placed on the upper plate can be moved in the six degrees of freedom in which it is possible for a freely suspended body to move.

These are the three linear linear, *x*, *y*, *z* (lateral, longitudinal and vertical) linear movements and the three rotation, rotation and rotation sensors. The terms "six axes" or "6-DOF" (degrees of freedom), the platform is also used as "Synergy".

This specialized aspect of the Six Jacks was first used by Eric *E*. Gough in the United Kingdom and was operational in 1954, later designed to be published in a 1968 Dw Stewart document on the British engineer. Although Stewart Short is now used for this Jack, it would be more appropriate for Eric Gough to call it a Gough/Stewart platform. Specifically, the original Stewart platform had a slightly different design.

To ensure that the movements are produced by a combination of multiple neck movements, such a device is sometimes referred to as a synergic motion platform due to synergy (mutual interaction between the way the sockets are programmed.

Because the device has six outputs, it is often known as a hexapod (six feet). The "hexapod" technology (geodetic technique) was originally for Stewart's machine tools. However, the term is now used for platforms with 6 jacks outside machine tools, as this simply means "six feet".

The system presented may be particularly useful for surgical robots that operate patients; these systems require very good positioning accuracy.

Such high precision positioning systems can be especially useful for the brain, heart, liver, kidneys and various prosthetic operations.

These platforms can precisely position even very heavy weights, such as the modern stationary telescope.

The design of the Stewart platform is widely used in flight simulation, especially in the so-called full flight simulator, for which all 6 degrees of freedom are required. This application was developed by Redifon, whose offer of simulators has become available for Boeing 707, Douglas DC-8, South Aviation Caravelle, Canadair CL-44, Boeing 727, Comet, Vickers Viscount, Vickers Vanguard, Convair CV-990, Lockheed C130 Hercules, Vickers VC10 and Fokker F-27 1962.

In this role, the payload is the pilot response and a visual display system, normally in the order of several channels, to show the visual scene in the crew of the airplane that was trained. The payload weight of a full flight simulator for a large airplane can be up to about 15,000 pounds.

Similar platforms are used in simulators, often mounted in *xy* for large tables, to simulate short-term acceleration over a period of time, can be simulated by tilting the platform and an active research area is how to mix the two.

Eric Gough was a car engineer and worked on Dunlop Dunlop Dunlop Dunlop tires in Birmingham, England. He developed either the Universal Tir-Testing Machine (also known as the Universal Rig) and in 1950 and the platform was operational in 1954. The device was able to mechanically test tires according to the combined loads. Dr. Gough died in 1972, but testing his platform continued to be used by the end of 1980, when the factory was shut down and then demolished. His platform was rescued and transported to the Marine Science Museum in London at Wrought near Swindon.

The AMiBA radio telescope, experimental microwave experimental experiments, is mounted on a hexahedron with six-meter carbon fiber. A hexapod robot is a walker robot whose locomotion is based on three pairs of legs. The study of insect evolution is of particular interest in presenting an alternative to wheel use. The term refers to biological inspirational robots imitating hexapod animals, such as insects in this case.

Hexapod robots are considered more stable than bit robots because in most cases the hexapods are statically stable. For this reason, it does not depend on real-time controllers to stay or go. However, it appears that high speed insects are dependent on dynamic factors.

Insects have been chosen as models because their nervous system is simpler than other animal species.

In addition, complex behaviours can only be attributed to a few neurons and the path between sensory inputs and engine outputs is relatively short.

Insect walking cycle and neural architecture are used to improve the robot location. Instead, biologists use hexapods to test different assumptions.

Conclusion

The paper presents an exact, original analytical geometry method for determining the kinematic and dynamic parameters of a parallel mobile structure.

Compared with other methods already known, the presented method has the great advantage of being an exact analytical method of calculation and not one iterative-approximately.

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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.

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