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INVERSE AND DIRECT GEOMETRICAL MODEL OF A NEW SURGICAL ROBOT WITH FIVE DEGREES OF FREEDOM

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Abstract*: In recent years, parallel robots have been used in many applications covering human-systems interaction, medical tasks and rehabilitation. This paper presents the innovative development of a surgical parallel robot designed for laparoscopic camera positioning in the surgical field. This research presents the structural synthesis of a parallel robot with linear and rotary active joints. The robot has five degrees of freedom and two guiding kinematics chains of the platform. The algorithm of the geometrical model of the parallel mechanism, designed for minimal invasive surgery is established. Some conclusions are drawn pointing out the advantages of the structure.*
Key words*: surgical robot, five freedom degrees*

1. INTRODUCTION

Robotic-assisted surgery is a new trend in medicine, which aims to help the surgeon and patient. These advantages include off-loading of the routine tasks and reduction of the number of human assistants in the operating room [1].
On a worldwide level there exist today several robotics systems developed for minimal invasive surgery (MIS). Jaspers et al. [2] have published a detailed presentation of all camera and instrument holders for MIS. AESOP robotic arm was the first robotic manipulator of laparoscopes used in MIS dating from 1993 [3]. After AESOP, Computer Motion created Zeus Surgical Robot with three robotic arms attached to the side of the operating table. Another robotic system is the ENDOASSIST which is a console positioned alongside the patient, controlled by an association of foot and head activation through infrared technology [4].
The LAPMAN [3] is a dynamic laparoscope holder guided by a joystick clipped onto the laparoscopic instruments under the operator's index finger. It has been tested successfully in pilot studies in laparoscopic gynaecologic surgery [5].
The DA VINCI robotic system is a robotic platform designed to enable complex surgery using minimally invasive approach. The da Vinci system consist of an ergonomic surgeon's console, a patient-side cart with four interactive robotic arms, a high-performance three dimension high definition vision system [6]. This robotic system has been approved to be used on human patients and although it brings many benefit, some drawback are reported [7] which encourage further researches in this field.
Another robot designed for minim invasive surgery is PARAMIS, which has been developed at Technical University of Cluj-Napoca, Romania and it used for laparoscope camera positioning [8]. The control input allows the user to give commands in for the positioning of the laparoscope using different interfaces: joystick, microphone, keyboard, mouse and haptic device [14].
The actual robotic systems also have some drawbacks such as: they are large and cumbersome, occupying large volumes around the operating table and above the patient; the

surgeon's console ergonomics imposes a very high number of training hours [13]; the surgeon relies only on visual feedback losing the tactile facilities; the current systems are limited to certain types of surgery and the market price is prohibitive.

The most fundamental requirements for the success of medical robots are:

- safety
- compactness in size and lightness
- simple operation in order to improve the learning curve of the young surgeons
- easy sterilization

This paper presents the study of a parallel robot architecture. The structure is constituted of a parallel structure with five degrees of mobility and two guiding kinematics chains of the platform. After the description of the medical system it is presented the structural synthesis of the equations corresponding to the inverse and direct geometrical models.

The final part is focused on the benefits of parallel mechanisms and conclusion of this research.

2. GEOMETRIC ANALYSIS

2.1. Description of the mechanical system

The architecture of a parallel mechanism is shown in figure 1, which is composed of a fixed base and two guiding kinematics chains of the platform. All kinematics chains are connected by two shafts from the fixed base. The movement of parallel robot are archived by using a rotational motor and four linear motors, as seen in the figure 2. The rotational motor is positioned on the fixed base and moves the splined shaft with the first active coordinate q_1. The next active coordinates q_2, q_3, q_4, q_5 are actuated by linear motors, which slide on two ball screws.

2.2. Structural synthesis of the parallel mechanism with five degrees of mobility

In this section are established the relation for the structural synthesis of parallel mechanisms with five degrees of mobility. The mechanism contain the following joints: screw joints, rotary joints, cylindrical joints and spherical joints.

The structural synthesis calculation uses the following symbols [2]:

- M-degree of mobility (d.o.m)
- F-mechanism family
- N-number of mobile elements
- C_i - number of "i" class joints

The number of common constraints for all mechanism elements represents the mechanism family, F [9]. The figure presented below, show the architectural structure of the parallel mechanism with five degrees of mobility.

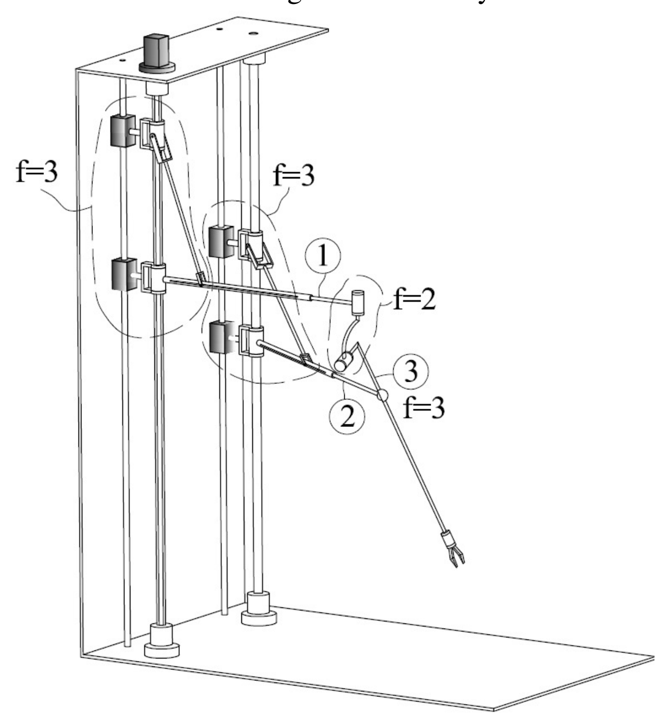

Figure 1. Structural synthesis scheme

The number of degrees of mobility is determined using the next equation [10]:

$$M = (6-F)\cdot N - (5-F)\cdot C_5 - (4-F)\cdot C_4 - (3-F)\cdot C_3 - (2-F)\cdot C_2 - (1-F)\cdot C_2 \quad (1)$$

For the mechanism presented in figure 1 the number of degrees of mobility result from the relation presented below:

$$M = 6N - 5C_5 - 4C_4 - 3C_3 \quad (2)$$

Where:

$$N = 3;\ C_5 = 0;\ C_4 = 1;\ C_3 = 3; \quad (3)$$

From equation (1) it results:

$$M = 6N - 4C_4 - 3C_3 \quad (4)$$

$M = 6 \cdot 3 - 4 \cdot 1 - 3 \cdot 3 = 18 - 4 - 9 = 5$ d.o.m

The numbers of mobile elements are determinates from equation (4):

$$N = \frac{M + 4C_4 + 3C_3}{6}$$

$$N = \frac{5 + 4 \cdot 4 + 3 \cdot 3}{6} = \frac{18}{3} = 3 \quad \text{mobile elements}$$

2.3. Inverse geometric algorithm

For the inverse geometric problem of the parallel mechanism, the position and orientation coordinates X_E, Y_E, Z_E, ψ, θ are given and the coordinates of the active joints q_1, q_2, q_3, q_4, q_5 are unknown. In this case the problem consists in solving a system of five equations with five unknowns [11].

The constant geometrical parameters are shows in figure 2, presented below.

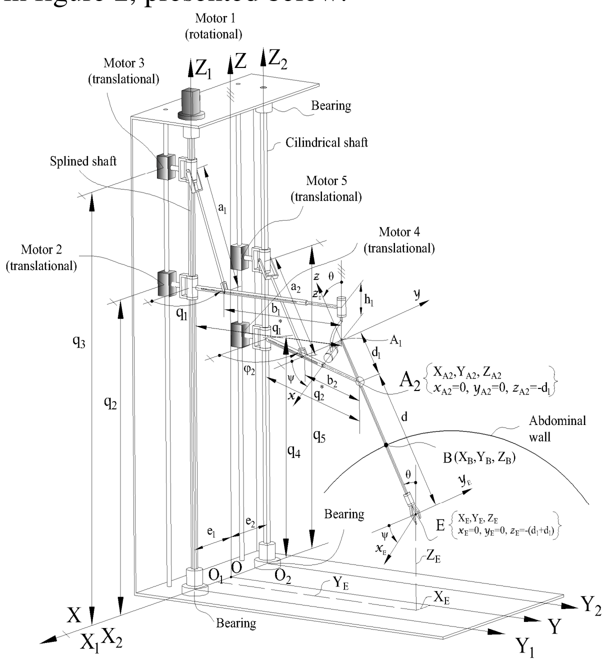

Figure 2. Kinematic scheme

The input data for inverse geometric algorithm model are:

$X_E, Y_E, Z_E, \psi, \theta, \varphi = 0;$

$h_1, d, d_1, e_1, e_2, b_1, b_2, a_1, a_2$

Following relations presents the inverse kinematics algorithm.

Cartesian coordinate of the point E belonging of the end effector's can be determinate by the relation:

(5)

$$\begin{bmatrix} X_E \\ Y_E \\ Z_E \\ 1 \end{bmatrix} = \begin{bmatrix} C\alpha' & C\alpha'' & C\alpha''' & X_{A_1} \\ C\beta' & C\beta'' & C\beta''' & Y_{A_1} \\ C\gamma' & C\gamma'' & C\gamma''' & Z_{A_1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x_E \\ y_E \\ z_E \\ 1 \end{bmatrix} \quad (9)$$

(6) In equation (9) the angles given by the fixed coordinate system OXYZ and the coordinate (7) system attached to the end-effector can be determinate by the next equation:

	ox	oy	oz
OX	α'	α''	α'''
OY	β'	β''	β'''
OZ	γ'	γ''	γ'''

(10)

The coordinates of point E are:

$$\begin{bmatrix} X_E \\ Y_E \\ Z_E \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & X_{A_1} \\ 0 & 1 & 0 & Y_{A_1} \\ 0 & 0 & 1 & Z_{A_1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} C\psi & -S\psi & 0 & 0 \\ S\psi & C\psi & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot$$

$$\cdot \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C\theta & -S\theta & 0 \\ 0 & S\theta & C\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x_E \\ y_E \\ z_E \\ 1 \end{bmatrix} \quad (11)$$

The relation can be written as follows:

$$\begin{bmatrix} X_E \\ Y_E \\ Z_E \\ 1 \end{bmatrix} = \begin{bmatrix} C\psi & -S\psi C\theta & S\psi S\theta & X_{A_1} \\ S\psi & C\psi S\theta & -C\psi S\theta & Y_{A_1} \\ 0 & S\theta & C\theta & Z_{A_1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x_E \\ y_E \\ z_E \\ 1 \end{bmatrix} \quad (12)$$

The following relations give the value of guiding angle cosines:

$C\alpha' = C\psi$	$C\alpha'' = -S\psi C\theta$	$C\alpha''' = S\psi S\theta$
$C\beta' = S\psi$	$C\beta'' = C\psi S\theta$	$C\beta''' = -C\psi S\theta$
$C\gamma' = 0$	$C\gamma'' = S\theta$	$C\gamma''' = C\theta$

(13)

The coordinates of the point A_1 are:

$$\begin{cases} X_{A_1} = q_1^* C q_1 \\ Y_{A_1} = q_1^* S q_1 \\ Z_{A_1} = q_2 - h_1 \end{cases} \quad (14)$$

Where:

(8) $$q_1^* = b_1 + \sqrt{a_1^2 - (q_3 - q_2)^2} \quad (15)$$

Using relation (15) results:

$$\begin{cases} X_{A_1} = e_1 + [b_1 + \sqrt{a_1^2 - (q_3 - q_2)^2}] C q_1 \\ Y_{A_1} = [b_1 + \sqrt{a_1^2 - (q_3 - q_2)^2}] S q_1 \\ Z_{A_1} = q_2 - h_1 \end{cases} \quad (16)$$

In matrix form the coordinates of the point A_1 are given by the next relations:

$$\begin{bmatrix} X_{A_1}-X_E \\ Y_{A_1}-Y_E \\ Z_{A_1}-Z_E \end{bmatrix} = \begin{bmatrix} C\alpha' & C\alpha'' & C\alpha''' \\ C\beta' & C\beta'' & C\beta''' \\ C\gamma' & C\gamma'' & C\gamma''' \end{bmatrix} \cdot \begin{bmatrix} x_{A_1}-x_E \\ y_{A_1}-y_E \\ z_{A_1}-z_E \end{bmatrix} \quad (17)$$

$$\begin{bmatrix} X_{A_1} \\ Y_{A_1} \\ Z_{A_1} \end{bmatrix} = \begin{bmatrix} X_E \\ Y_E \\ Z_E \end{bmatrix} + \begin{bmatrix} C\alpha' & C\alpha'' & C\alpha''' \\ C\beta' & C\beta'' & C\beta''' \\ C\gamma' & C\gamma'' & C\gamma''' \end{bmatrix} \cdot \begin{bmatrix} x_{A_1}-x_E \\ y_{A_1}-y_E \\ z_{A_1}-z_E \end{bmatrix} \quad (18)$$

From figure 2 results:

$$x_{A_1}=0 \qquad y_{A_1}=0 \qquad z_{A_1}=0 \quad (19)$$

Using (19) in (18) it results:

$$\begin{bmatrix} X_{A_1} \\ Y_{A_1} \\ Z_{A_1} \end{bmatrix} = \begin{bmatrix} X_E \\ Y_E \\ Z_E \end{bmatrix} - \begin{bmatrix} C\alpha' & C\alpha'' & C\alpha''' \\ C\beta' & C\beta'' & C\beta''' \\ C\gamma' & C\gamma'' & C\gamma''' \end{bmatrix} \cdot \begin{bmatrix} x_E \\ y_E \\ z_E \end{bmatrix} \quad (20)$$

It using the value of the guiding angle cosines given by relation (13) result:

$$\begin{bmatrix} X_{A_1} \\ Y_{A_1} \\ Z_{A_1} \end{bmatrix} = \begin{bmatrix} X_E \\ Y_E \\ Z_E \end{bmatrix} - \begin{bmatrix} C\psi & -S\psi C\theta & S\psi S\theta \\ S\psi & C\psi S\theta & -C\psi S\theta \\ 0 & S\theta & C\theta \end{bmatrix} \cdot \begin{bmatrix} x_E \\ y_E \\ z_E \end{bmatrix} \quad (21)$$

Relations (20) and (21) can be written:

$$\begin{cases} X_{A_1} = X_E - x_E \cdot C\alpha' + y_E \cdot C\alpha'' - z_E \cdot C\alpha''' \\ Y_{A_1} = Y_E - x_E \cdot C\beta' - y_E \cdot C\beta'' + z_E \cdot C\beta''' \\ Z_{A_1} = Z_E - x_E \cdot C\gamma' - y_E \cdot C\gamma'' - z_E \cdot C\gamma''' \end{cases} \quad (22)$$

$$\begin{cases} X_{A_1} = X_E - x_E \cdot C\psi + y_E \cdot S\psi \cdot C\theta - z_E \cdot S\psi \cdot S\theta \\ Y_{A_1} = Y_E - x_E \cdot S\psi - y_E \cdot C\psi C\theta + z_E \cdot C\psi S\theta \\ Z_{A_1} = Z_E - y_E \cdot S\theta - z_E \cdot C\psi S\theta \end{cases} \quad (23)$$

Comparing relations (14) and (22) it results the following system of equations:

$$\begin{cases} e_1 + q_1^* \cdot Cq_1 = X_E - x_E \cdot C\alpha' - y_E \cdot C\alpha'' - z_E \cdot C\alpha''' \\ q_1^* \cdot Sq_1 = Y_E - x_E \cdot C\beta' - y_E \cdot C\beta'' - z_E \cdot C\beta''' \\ q_2^* - h_1 = Z_E + x_E \cdot C\gamma' - y_E \cdot C\gamma'' - z_E \cdot C\gamma''' \end{cases} \quad (24)$$

where q_2^* is given by relation (15):

From the first two relations of system (24) results:

$$(q_1^*)^2 = (X_E - x_E \cdot C\alpha' - y_E \cdot C\alpha'' - z_E \cdot C\alpha''' - e_1)^2 + (Y_E + x_E \cdot C\beta' - y_E \cdot C\beta'' - z_E \cdot C\beta''')^2 \quad (25)$$

$$q_1^* = +\sqrt{(X_E - x_E \cdot C\alpha^I - y_E \cdot C\alpha^{II} - z_E \cdot C\alpha^{III} - e_1)^2 + (Y_E - x_E \cdot C\beta^I - y_E \cdot C\beta^{II} - z_E \cdot C\beta^{III})^2} \quad (26)$$

From figure 2 result the coordinates of point E in relation with mobile system connected by the end-effector Axyz:

$$x_E = 0 \qquad y_E = 0 \qquad z_E = -(d_1 + d) \quad (27)$$

Using value of the coordinates x_E, y_E, z_E it results:

$$\begin{cases} q_1^* \cdot Cq_1 = X_E - z_E \cdot C\alpha''' - e_1 \\ q_1^* \cdot Sq_1 = Y_E - z_E \cdot C\beta''' \\ q_2^* - h_1 = Z_E - z_E \cdot C\gamma''' \end{cases} \quad (28)$$

Variable length q_1^* is:

$$q_1^* = \sqrt{(X_E - z_E \cdot C\alpha''' - e_1)^2 + (Y_E - z_E \cdot C\beta''')^2} \quad (29)$$

From the first two relations of the system of equations (28) result:

$$u_1 = Sq_1 = \frac{Y_E - z_E \cdot C\beta'''}{q_1^*} \qquad w_1 = Cq_1 = \frac{X_E - z_E \cdot C\alpha''' - e_1}{q_1^*} \quad (30)$$

The coordinate of the first active joint is:

$$q_1 = \operatorname{atan2}(Y_E - z_E \cdot C\beta''', X_E - z_E \cdot C\alpha''' - e_1) \quad (31)$$

For the second active joint it results:

$$q_2 = h_1 + Z_E - z_E \cdot C\gamma''' \quad (32)$$

The third active joint has the expression:

$$q_3 = q_2 + \sqrt{a_1^2 - (q_1^* - b_1)^2} \quad (33)$$

In order to determine the position of q_4, the coordinates of point A_2, placed in spherical joint of the parallel mechanism are calculated:

$$X_{A_2} = X_E + d \cdot C\alpha''' \qquad Y_{A_2} = Y_E + d \cdot C\beta''' \qquad Z_{A_2} = Z_E + d \cdot C\gamma''' \quad (34)$$

Relation (20) can be written:

$$\begin{cases} X_{A_2} - e = q_2^* \cdot C\varphi_2 \\ Y_{A_2} = q_2^* \cdot S\varphi_2 \\ Z_{A_2} = q_4 \end{cases} \quad (35)$$

From the third equation of the system (35) result the value of the fourth active joint:

$$q_4 = Z_{A_2} \quad (36)$$

By squaring and adding first two relations of system (35) results:

$$q_2^* = +\sqrt{(X_{A_2} - e_2)^2 + Y_{A_2}} \quad (37)$$

The equation of the last active joint q_5 is:

$$q_5 = q_4 + \sqrt{a_2^2 - (q_2^* - b_2)^2} \quad (38)$$

The relation (38) can be written as follows:

$$q_5 = q_4 + \sqrt{a_2^2 - \left[-b_2 + \sqrt{(X_{A_2} - e_2)^2 + Y_{A_2}}\right]^2} \quad (39)$$

2.4. Direct geometric algorithm

The objective of the direct geometric model is to define a mapping from the known set of the actuated joints coordinates to the unknown position of the laparoscope [10]. For the forward geometric problem of the parallel mechanism, coordinates of the active joints q_1, q_2, q_3, q_4, q_5 are known, and the position coordinates and orientation angles X_E, Y_E, Z_E, ψ, θ of the end-effector's are unknown.

The input data for the direct kinematics algorithm are:

$$\begin{array}{l} q_1, q_2, q_3, q_4, q_5 \\ h_1, d, d_1, e_1, e_2, b_1, b_2, a_1, a_2 \end{array} \quad (40)$$

The next relations present the direct geometric algorithm.

The start point of this algorithm consists in determination of the point A_1 coordinates:

$$\begin{array}{l} X_{A_1} = e_1 + \left[b_1 + \sqrt{a_1^2 - (q_2 - q_2)^2}\right] \cdot Cq_1 \\ Y_{A_1} = \left[b_1 + \sqrt{a_1^2 - (q_2 - q_2)^2}\right] \cdot Sq_1 \\ Z_{A_1} = q_2 - h_1 \end{array} \quad (41)$$

Because the point A_1 is placed on the A_1z axis result the coordinates of the point E in relation with the system coordinates of point A_1:

$$x_E = 0,\ y_E = 0,\ z_E = -(d_1 + d) \quad (42)$$

Using relation (42) the coordinates of point A_1 can be determined by the next system:

$$\begin{cases} X_{A_1} = X_E + (e_1 + d) \cdot S\psi \cdot S\theta \\ Y_{A_1} = Y_E - (e_1 + d) \cdot C\psi \cdot S\theta \\ Z_{A_1} = Z_E + (e_1 + d) \cdot C\theta \end{cases} \quad (43)$$

Knowing the coordinates of point A_1, result from (31):

$$\begin{cases} X_E \cdot S\psi \cdot S\theta = X_{A_1} \\ Y_E + z_E \cdot C\psi \cdot S\theta = Y_{A_1} \\ Z_E + z_E \cdot C\theta = Z_{A_1} \end{cases} \quad (44)$$

The coordinate of A_2 can be written:

$$\begin{array}{l} X_{A_2} = X_E + d \cdot S\psi S\theta \\ Y_{A_2} = Y_E - d \cdot C\psi S\theta \\ Z_{A_2} = Z_E + d \cdot C\theta \end{array} \quad (45)$$

The coordinates of point A_2 can be determined by the figure 2:

$$\begin{cases} X_{A_2} - e_2 = q_2^* \cdot C\varphi_2 \\ Y_{A_2} = q_2^* \cdot S\varphi_2 \\ Z_{A_2} = q_4 \end{cases} \quad (46)$$

Where variable distance of q_2^* is given by the next relation:

$$q_2^* = b_2 + \sqrt{a_1^2 - (q_5 - q_4)^2} \quad (47)$$

From the first two equations of the system (46) results:

$$(X_{A_2} - e_2)^2 + Y_{A_2}{}^2 = (q_2^*)^2 \quad (48)$$

The equations (48) can be written:

$$(X_E + d \cdot S\psi S\theta - e_2)^2 + (Y_E - d \cdot C\psi S\theta)^2 = (q_2^*) \quad (49)$$

Using last relation of the system (33) results:

$$Z_E + d \cdot C\theta = q_4 \quad (50)$$

The equations (44), (45), (50) form a system with five unknows $X_E, Y_E, Z_E, \psi, \theta$:

$$\begin{cases} X_E + (d_1 + d) \cdot S\psi S\theta = X_{A_1} \\ Y_E - (d_1 + d) \cdot C\psi \cdot S\theta = Y_{A_1} \\ Z_E + (d_1 + d) \cdot C\theta = Z_{A_1} \\ (X_E + d \cdot S\psi S\theta - e_2)^2 + (Y_E - d \cdot C\psi S\theta)^2 = (q_2^*) \\ Z_E + d \cdot C\theta = q_4 \end{cases} \quad (51)$$

From the system (51) it results:

$$d_1 \cdot C\theta = Z_{A_1} - q_4 \quad (52)$$

$$w_2 = C\theta = \frac{Z_{A_1} - q_4}{d_1} \quad (53)$$

$$u_2 = S\theta = +\sqrt{1 - w_1^2}\ ; \qquad 0 \le \theta \le \pi,\ S\theta \ge 0 \quad (54)$$

Where:

$$S\theta = +\sqrt{1 - \left(\frac{Z_{A_1} - q_4}{d_1}\right)^2} \quad (55)$$

$$u_2 = S\theta = \frac{\sqrt{d_1^2 - (Z_{A_1} - q_4)^2}}{d_1} \quad (56)$$

From the system (51) result the values of coordinates X_E, Y_E, Z_E:

$$X_E = X_{A_1} - (d_1 + d) \cdot u \cdot S\psi \quad (57)$$

$$Y_E = Y_{A_1} + (d_1 + d) \cdot u \cdot C\psi \quad (58)$$

$$Z_E = q_4 - d \cdot C\theta \quad (59)$$

The equations of the cartesian coordinates X_E, Y_E, are used in the fourth expresion of system (51). It results:

$$a = 2d_1 \cdot u_2 \cdot Y_{A_1}$$
$$b = -2d_1 \cdot u_2 \cdot \left(X_{A_1} - e_2\right)$$
$$c = \left(q_2^*\right)^2 - \left(X_{A_1} - e_2\right)^2 - Y_{A_1}^2 - d_1^2 \cdot u_2^2 \qquad (60)$$

The value of the ψ angle of the laparoscope is give by the next equation:

$$\psi = \text{atan2}\left(c\ ,\ \pm\sqrt{a^2 + b^2 - c^2}\right) - \text{atan2}(a, b) \qquad (61)$$

2.5. Numerical results

In order to validate the equations obtained it developed an algorithm in MATLAB software, for the inverse and direct geometric model [12]. For numerical calculus the linear dimension are expressed in meters and the angle in degrees.

For the beginning, the geometrical parameters of the robot are chosen as follows:

h_1=0.154 [m]

d=0.609 [m]	d_1=0.200 [m]
e_1=0.300 [m]	e_2=0.300 [m]
b_1=0.605 [m]	b_2=0.605 [m]
a_1=0.536 [m]	a_2=0.536 [m]

(62)

The coordinates of end-effector are chosen from the inner of robot workspace. The parameters witch determines the position and orientation chosen are:

X_E=0.8 [m]
Y_E=1.1 [m]
Z_E=0.08 [m]
ψ=10°
θ=20° (63)

Using the algorithm of the inverse geometrical model, the coordinates of the active joints are:

q_1=56.48406675°
q_2=0.994211330 [m]
q_3=1.364497517 [m]
q_4=0.652272806 [m]
q_5=0.960934722 [m] (64)

These coordinates are introduced in the direct geometric model. Using the algorithm of the direct model are validate the values of end-effectors coordinates. The coordinates of the laparoscope position are:

X_E=0.8000 [m]
Y_E=1.1000 [m]
Z_E=0.0800 [m]
ψ=10.0000°
θ=20.0000° (65)

The numerical results show that the geometrical model equations are corrected and can pass the kinematics model for calculation velocity and acceleration of this robot.

3. ADVANTAGES OF PARALLEL ROBOTS IN SURGICAL APPLICATIONS

The parallel robots has many advantages in contrast with the bulky serial robots, the compact and lightweight parallel architectures simplify the relocation of the robot in the operating room, save necessary space, and allow easy sterilization by covering the robot with a closed drape. The parallel robots provide accuracy with lower price when compared to similar serial robots with the same accuracy level. Some accuracy levels may not be achieved with serial robots. This level of accuracy is very important for minim invasive surgery.

4. CONCLUSIONS

The paper presents the concept of an advanced parallel robot designed for medical application. The relations presented give the equations for the inverse and direct geometric models. The dimensions of this manipulator can be determined by minimizing the overall size while keeping the structure away from the singular positions. Unlike other robots designed for minim invasive surgery, this robot can position the laparoscope without support on the abdominal wall. The design of this robot allows a large working space. Also, this robot can have attached an orientation system designed for active surgical instruments. Then, two parallel robots would act as the right hand and left hand of the surgeon and the third one can be used for laparoscopic camera positioning in surgery field. Regarding the research in this domain there should be organized ethical boards who will study the future problems [15].

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6. REFERENCES

1. Nabil, Simaan., *Analysis and Synthesis of Parallel Robots for Medical Applications*, research thesis, Haifa, Israel, (1999).
2. Jaspers, JE., Breedveld, P., Herder, JL., Grimbergen, CA., *Camera and instrument holders and their clinical value in minimally invasive surgery*., 14(3):145-52 Surg Laparosc Endosc Percutan Tech.,'04.
3. Pisla, Doina., Plitea, Nicolae., Vaida, Calin., Hesselbach, J., Raatz, A., et all., *PARAMIS parallel robot for laparoscopic surgery*, Chirurgia, No.5, pp. 677 -41, 683, Cluj, Romania, (2010).
4. Aiono, S., Gilbert, JM., Soin, B., Finlay, PA.., Gordan A., *Controlled trial of the introduction of a robotic camera assistant (EndoAssist) for laparoscopic cholecystectomy.* Surg Endosc. 2002; 16(9):1267-70. Epub (2002).
5. Polet, R., Donnez, J., *Using a Laparoscope Manipulator (LapMan) in Laparoscopic Gynecological Surgery*, Surgical Technology International XVII, Belgium, Universal Medical Press (2007).
6. Bruno, Dieter., Chris, Threat., *da Vinci Prostatectomy (Robotically Assisted Radical Prostatectomy),* 3351 El Camino. Real, Suite 101 Atherton, CA 94027n (650) 306-1016
7. Plitea, Nicolae., Vlad, Liviu., Popescu, Irinel., Pisla, Doina., et all., *E-learning platform for hepatic robotic minimally invasive surgery using parallel structures,* Acta Technica Napocensis, No: 51, Vol. III, (2008).
8. Vaida, Calin., *Contributii la realizarea si modelarea cinematico-dinamica a robotilor paraleli pentru chirurgia minim invaziva,* PhD. Thesis, Cluj-Napoca, Romania, (2008)
9. Plitea, Nicolae., Hesselbach, J., Pisla, Doina., et all, *Innovative development of parallel robots and microrobots,* Acta Technica Napocensis, No: 49, Vol.V, 2006
10. Plitea, Nicolae., Pisla, Doina., Negrean Iuliu., Arghir, Mariana et all., *Innovative development of parallel microrobots with four degree of freedom,* Acta Technica Napocensis, No: 50 Vol.IV, (2007).
11. Kanann, Daniel., Wenger, Philippe., Chablat, Damien., *Workspace and Kinematic Analysis of the VERNE machine,* AIM, Zürich, Suisse, (2007)
12. http://www.mathworks.com/products/matlab/
13. Graur, Florin., Scurtu, Liviu., Furcea, Luminita., Plitea, Nicolae., et all., *Training Platform for Robotic Assisted Liver Surgery - the Surgeon Point of View*, Eucomes Proceedings, Cluj, Romania, (2010)
14. Graur, Florin., Pisla, Doina., Scurtu, Liviu., et all., Liver 3D Reconstruction Modalities *- The First Step Toward a Laparoscopic Liver Surgery Simulator*, IFMBE Proceedings, 26, 251-257 (2009)
15. Graur, Florin., Frunza, M., Elisei, R., Furcea, L., Scurtu, L., et all., *Ethics in Robotic Surgery and Telemedicine,* Eucomes Proceedings, Cluj, Romania, 2010

MODELAREA GEOMETRICĂ DIRECTĂ ŞI INVERSĂ A UNUI NOU ROBOT CHIRURGICAL CU CINCI GRADE DE LIBERTATE

Abstract: În ultimii ani, robotii paraleli sunt utilizati in multe aplicații care acoperă interacțiunea umană, printre care medicina şi reabilitarea. Lucrarea prezintă *dezvoltarea inovativă a unui robot chirurgical paralel conceput pentru poziționarea camerei laparoscopice în câmpul operator. Această lucrare prezintă sinteză structurală a unui robot paralel cu motoare liniare si de rotație. Robotul are cinci grade de libertate şi două lanțuri cinematice de ghidare a platformei. Algoritmul* *modelului geometric al mecanismului paralel conceput chirurgiei minim invazive este determinat. Câteva concluzii sunt trase subliniind avantajele acestei structurii.*

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