Modern Technologies in Industrial Engineering

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Constantin Carausu, Viorel Cohal, Ioan Doroftei,
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Preface

The main objectives of ModTech International Conference - Modern Technologies in Industrial Engineering are to bring together representatives of technology manufacturers, of various state institutions, universities, industry, professional associations, to debate and exchange experiences on important Conference topics. Another main objective of ModTech International Conference consists of providing a good networking opportunity to all these groups.

The ModTech2013 International Conference became a major conference to exchange the new ideas of science and technology among Europe, Asia and USA researchers and scientists and provide a forum to present their new results focused on the main topics of the conference. It is held in Sinaia in Romania from June 27 to 29 hosted by Professional Association in Modern Manufacturing Technologies, ModTech, as main organizer, Silesian University of Technology, Gliwice, Poland and Maritime University of Constanta, Romania as co-organizers.

On the first edition of the ModTech2013 International Conference 414 abstracts were received, 373 of which were accepted. 110 researchers from 18 countries participated, namely from: Japan, USA, Germany, South Korea, Russia, Italy, Romania, Poland, Portugal, Spain, France, Slovakia, Republic of Moldova, Croatia, Serbia, Turkey, Greece and Tunisia.

In addition to the authors that were present at the conference, researchers from Switzerland, India, Slovenia, Uzbekistan, Belgium, Finland, Mexico and Vietnam also send papers. In all, authors from 26 various countries worldwide.

As concerns the representatives of the Romanian universities, business entities /research institutes, the authors come from 17 prestigious universities and from 10 business entities or research institutes. The foreign authors represent 34 universities worldwide and 13 research institutes.

The main publication of ModTech2013 International Conference were as follow: International Journal of Materials & Product Technology, Indian Journal of Engineering & Materials Sciences, Materials Science-Poland, International Journal of Modern Manufacturing Technologies and Advanced Materials Research-AMR" by Trans Tech Publications Inc. (TTP).

Dumitru Nedelcu
Conference President

G. Maritime Engineering and Navigation: Maritime Engineering and Technologies, Maritime Transport and Economics, Maritime Education: **President: Prof. Violeta-Vali Ciucur**, Constanta Maritime University, Constanta, Romania; **Vice President: Prof. Emil Oanta**, Constanta Maritime University, Constanta, Romania

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Each type of positioning and orientation system has its advantages and disadvantages, and there is a system that can replace other types in all circumstances. The method described in [1] are an advantage by eliminating errors due to slipping wheels of the mobile platforms and therefore it motoda with another global localization method can form a powerful odometer.

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KINEMATIC MODELLING AND VR SIMULATION OF A 3DOF MEDICAL PARALLEL ROBOT WITH ONE DECOUPLED MOTION

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Keywords: parallel robots, medical robot, kinematic modelling, VR simulation.

Abstract.

The robot studied in the paper has a 3DOF parallel structure of type 1PRRR+2PRPaR, with two coupled motions and one decoupled motion, composed by a mobile platform connected to the fixed base by three kinematic chains (one open kinematic chain of Prismatic – Revolute – Revolute – Revolute type and two kinematic chains of Prismatic – Revolute – Parallelogram – Revolute type). An analytical kinematic modelling of the parallel robot of type 1PRRR+2PRPaR is firstly presented in this paper, followed by a numerical simulation of the closed-form kinematic model and by a Virtual Reality (VR) application with control aspects. An innovative user interface for high-level control of the parallel 1PRRR+2PRPaR type robot is developed in MATLAB - Simulink and SimMechanics environment.

Introduction

In the last couple of decades parallel robots have been studied and developed from theoretical view point and also for practical applications. The advantages offered by parallel manipulators (PMs) are high stiffness, excellent load-to-weight ratio, positioning accuracy and good dynamic behavior [1]. The parallel robots are mechanisms with closed kinematics chains, composed by a mobile platform (the end-effector) with *n* degrees of freedom, connected to the fixed base by two or more kinematical chains called limbs or legs. A simple or a complex kinematics chain can be associated with each limb [2].

Jin et al. [3] studied the kinematic design of a family of partially decoupled parallel manipulators (DPMs) with 3-limb symmetrical structure, in which 3-DOF spatial motion composed by a vertical translation and two horizontal rotations can be independently controlled. The concept of group decoupling (GD) is introduced for classification and synthesis of decoupled motion PMs.

Also, a kinematical analyze is made by Stan et al. [4], where a kinematics analysis and control of a 3DOF parallel robot is presented. A kinematical modeling of a 3DOF medical parallel robot is detailed in [5].

The Virtual Reality (VR) immerses the user in a three-dimensional (3D) environment that can be actively interacted and explored. Virtual reality environment tool is used by many researchers in design, development and manufacturing of the robotic industry [6].

Using the virtual reality simulation with a virtual robot, a three dimensional design and the real-time behavior of the robot can be observed; that fact is relatively new and allows testing the robot before accomplishment a physical implementation. In this way, resources (money and time) can be saved and various problems can be solved from the design stage.

This paper presents the kinematical modeling of a parallel robot of type 1PRRR+2PPPaR [7] and the necessary steps for developing the virtual environment for kinematic simulation, starting from the SolidWorks model [8].

Description and kinematical modeling of 1PRRR+2PRPaR parallel robot

The parallel robot of type 1PRRR+2PRPaR (1Prismatic, Revolute, Revolute + 2Prismatic, Revolute, Parallelogram, Revolute) has 3 degrees of freedom (DOF) with one decoupled motion along X axis and two coupled motions (see Fig. 1).

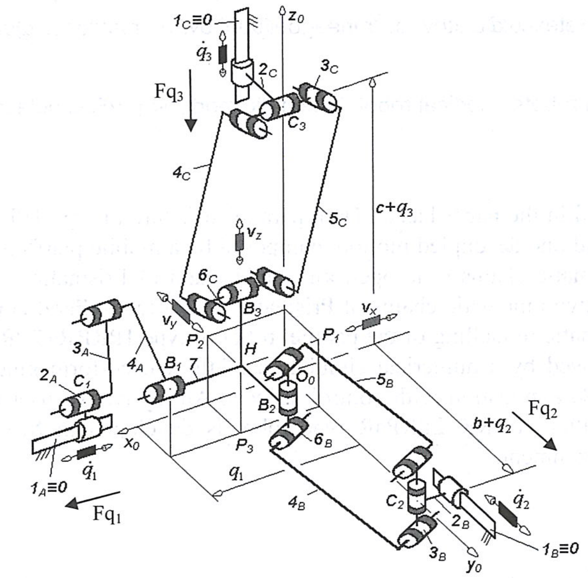
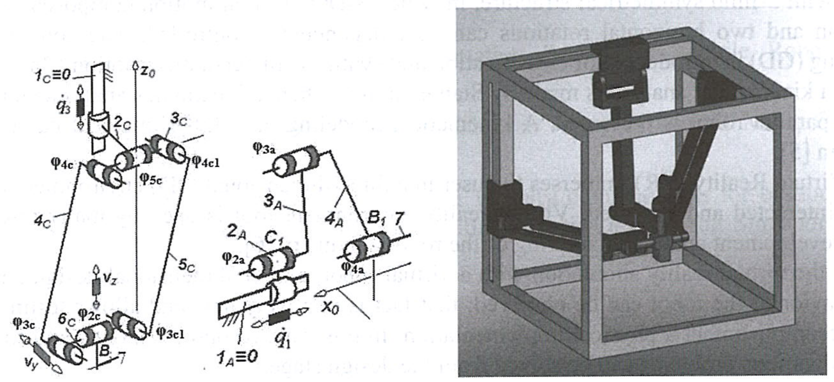


Fig. 1 Kinematic structure of parallel robot of type 1PRRR+2PRPaR [7]

This parallel robot is composed by a mobile platform 7 connected to the base by three kinematic chains A, B and C:

- A: simple open kinematic chain with one active prismatic joint (q1) and three passive revolute joints (φ2a, φ3a and φ4a) – see Fig. 2,b;
- B and C: complex kinematic chains of parallelogram type with one active prismatic joint (q2 and respectively q3) and six passive revolute joints (φ2i, φ3i, φ3i1, φ4i, φ4i1, and φ5i – where i = b,c) – see Fig. 2,a.



a b c

Fig. 2 Parametrization of the 1PRRR+2PRPaR parallel robot (a and b) and its CAD model (c)

Direct and inverse kinematic model of 1PRRR+2PRPaR parallel robot

The direct geometrical (Eq. 1) and the kinematical model (Eq. 2) have been derived to compute the mobile platform displacement (x_h, y_h, z_h) and velocity (V_{xh}, V_{yh}, V_{zh}) in function of drivers' motion.

$$\begin{cases} x_h = q_1 - l_{7a} \\ y_h = l_{3a}\cos(\varphi_{2a}) + l_{4a}\cos(\varphi_{2a}+\varphi_{3a}), \\ z_h = l_{3a}\sin(\varphi_{2a}) + l_{4a}\sin(\varphi_{2a}+\varphi_{3a}) \end{cases} \quad (1)$$

$$\begin{bmatrix} v_{xh} \\ v_{yh} \\ v_{zh} \end{bmatrix} = J_h \cdot \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \\ \dot{q}_3 \end{bmatrix}, \quad (2)$$

where: J_h is the robot Jacobian.

The inverse geometric model allows obtaining the liaison between geometrical parameters (q1, q2, q3) and (xh, yh, zh) – eq. 3 for 1PRRR+2PRPaR parallel robot (with notations presented in Fig. 1 and 2):

$$\begin{cases} q_1 = x_h + l_{7a} \\ q_2 = \sqrt{l_{4b}^2 - z_h^2 - x_h^2} + l_{7b} + y_h \\ q_3 = \sqrt{l_{4c}^2 - x_h^2 - y_h^2} + l_{7c} + z_h \end{cases} \quad (3)$$

Deriving the eq. 3, the inverse kinematical model (eq. 4) is obtained:

$$\begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \\ \dot{q}_3 \end{bmatrix} = J_h^{-1} \cdot \begin{bmatrix} v_{xh} \\ v_{yh} \\ v_{zh} \end{bmatrix}, \quad (4)$$

where J_h^{-1} is the inverse Jacobian matrix of the 1PRRR+2PRPaR parallel robot:

$$J_h^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ -\dfrac{x_h}{\sqrt{l_{4b}^2 - z_h^2 - x_h^2}} & 1 & -\dfrac{z_h}{\sqrt{l_{4b}^2 - z_h^2 - x_h^2}} \\ -\dfrac{x_h}{\sqrt{l_{4c}^2 - x_h^2 - y_h^2}} & -\dfrac{y_h}{\sqrt{l_{4c}^2 - x_h^2 - y_h^2}} & 1 \end{bmatrix}. \quad (5)$$

Virtual Reality tools for parallel robot prototyping

An interface for high-level control of robot manipulators is presented in this section and is based on a virtual reality approach in order to provide the user with an interactive 3D graphical representation of the parallel robot.

The actuators and the control algorithm were modeled in Simulink. The dynamic model of the mechanical structure was imported from SolidWorks using SimMechanics from MATLAB/ Simulink.

In fig. 3 is presented the complete model with VR of the parallel robot.

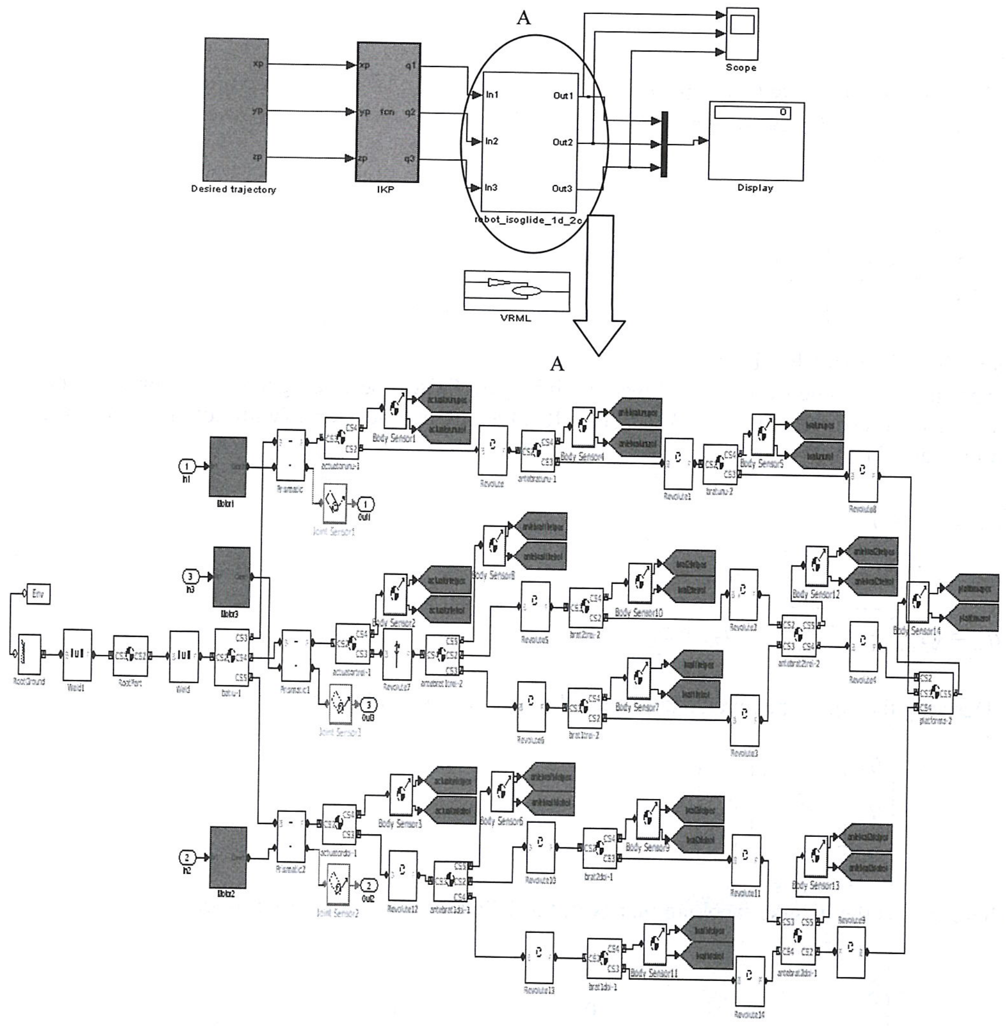


Fig. 3 The complete model for 1PRRR+2PRPaR parallel robot with VR

Virtual Reality Toolbox for MATLAB makes more realistic renderings of bodies possible. Arbitrary virtual worlds can be designed with Virtual Reality Modeling Language (VRML), and interfaced to the SimMechanics model. The user simply describes the geometric properties of the robot first. Then, in order to move any part of the robot through 3D input devices, the inverse kinematics is automatically calculated in real time. The interface was also designed to provide the user decision capabilities when problems such as singularities are encountered.

In particular, the interface allows user to understand the behaviour of an existing robot, and to investigate the performance of a newly designed structures without the need and the cost associated with the hardware implementation.

SimMechanics offers the possibility to visualize and animate the robot. The visualization tool can also be used to animate the motion of the system during simulation. The bodies of the robot can be represented as convex hulls (fig. 4).

The models obtained allow the opening for a control strategy implementation.

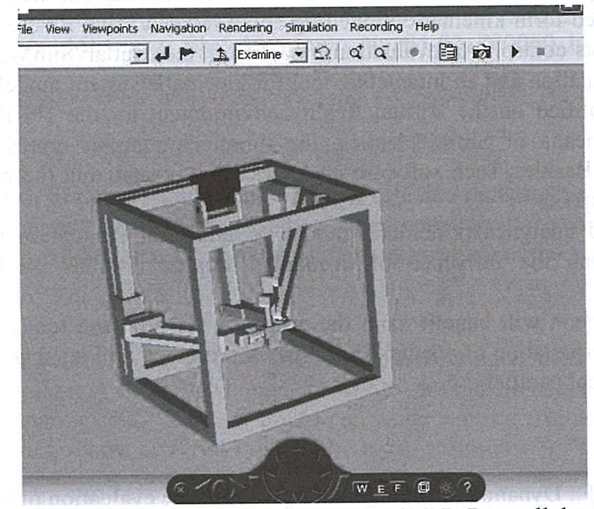


Fig. 4 Virtual Reality model of 1PRRR+2PRPaR parallel robot

Simulation Results

For testing the obtained model, it has been chosen a linear trajectory between two defined points, considering a movement low in Cartesian space of fifth degree polynomial type. The simulation is done by numerical simulation of the analytical model and by numerical simulation of the CAD model from Fig. 2.c.

Regarding the displacements (Fig. 5), it can be noted that for the same desired displacement of the end-effector, the required displacements in motor joints q2 and q3 are bigger.

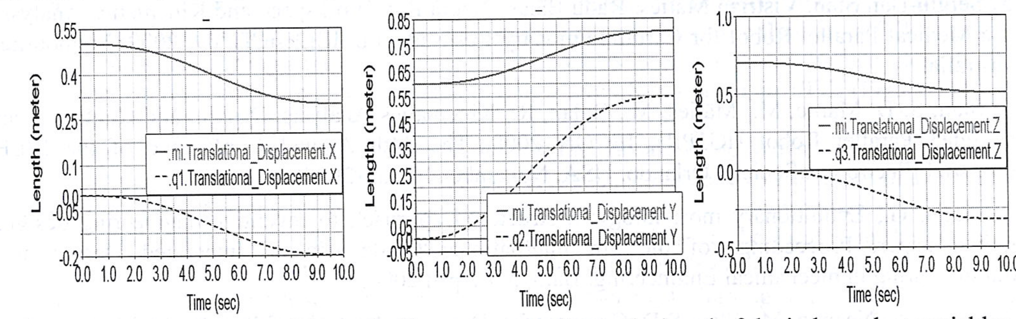


Fig. 5. Displacements of the end-effector (red-continues line) and of the independent variables $q_{1,2,3}$ (blue – dashed line) of the parallel robot of 1PRRR+2PRPaR type

The results obtained by numerical simulation (Fig. 5) reach at the conclusion: to obtain a displacement of 200 mm along each of the three axis, a 1.5-2.5 more displacement for motor q_2 and q_3 are needed, and exactly the same displacement for motor q_1, due at the decoupling motion.

Conclusions

The main advantages of this parallel manipulator are that all the actuators can be attached directly to the base, that closed-form solutions are available for the forward and inverse kinematics, and that the moving platform maintains the same orientation throughout the entire workspace. The paper presents a closed-form kinematic modelling and a novel Virtual Reality Interface for 3 DOF medical parallel robots control. An evaluation model from the Matlab/SimMechanics environment was used for the simulation and an interactive tool for kinematic system modeling and analysis was presented and exemplified on the Virtual Reality environment for the 1PRRR+2PRPaR medical parallel robot. By means of SimMechanics, the robotic system in represented as a block of functional diagrams. Besides, such software packages allow visualizing the motion of mechanical system in 3D virtual space.

With the obtained analytical kinematic model, a numerical simulation is done, on a given trajectory, emphasizing the influence of decoupled/coupled motions on the robot kinematic behaviour.

Especially non-experts will benefit from the proposed visualization tools, as they facilitate the modeling and the interpretation of results. The research presented will lay a good foundation for the development of medical parallel robots.

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Preliminary Ideas on Designing an Unmanned Aerial Vehicle Based on Coanda Effect

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Keywords: Coandă effect, design, unmanned aerial vehicle (UAV)

Abstract. The final goal of this research is to develop a safe and inexpensive flying vehicle. In this paper, only some preliminary ideas on the design of an unmanned aerial vehicle, based on Coandă effect, will be presented. These ideas are concerning the optimization of the aerodyne body profile.

Introduction

An Unmanned Aerial Vehicle (UAV) is an aircraft or other flying vehicle without a human pilot on board. The vehicle flight is controlled autonomously by computers inside the aerial vehicle, or can be guided by a human operator from the ground or inside another vehicle. In the literature this vehicles are named flying robots or aerial robots. The most common UAV's types are: helicopter, airplane and rocket.

Unfortunately, currently UAV's are mainly used in the army for various surveillance and combat actions. They are also known as drones. In order to control the flight we need an inner-loop system to collect and process, with an appropriate algorithm, the information provided by sensors.

Efficient small hovering aerial vehicles tend to be unstable, which makes their stabilization more difficult than large hovering flying vehicles. This can be achieved by equipping the UAVs with various detection devices such as: inertial navigation systems (gyroscopes, accelerometers), cameras, altimeters, distance-measuring equipment (radar, sonar, laser), GPS, magnetic compasses. Choosing the type of sensor used depends on the purpose for which the vehicle is built.

Operation principle of the Coanda effect

Coandă effect is an aerodynamic and hydrodynamic phenomenon discovered by the Romanian scientist Henri Coandă, phenomenon characterized by the tendency of the fluid jet to follow a close convex surface and through the occurrence of depressions on an adjacent surface close to the convex one. He registered two patents related to a new aircraft in France, in 1932, (Figure 1) [2, 3] and a similar one in Romania, in 1936.

Also, in 1956, Henri Coandă registered two lenticular aerodyne patents with no moving mechanical parts, vertically propelled by the power steam, equipped with ejectors that operated following the same Coanda effect. Another unique technical solution was proposed by Coanda in 1970, a cylindrical fuselage supported by four lenticular aerodyne, to be located in the center of pressure of all four forces, these appeared at the la intersection their vertical axes. A model of this idea is on shown at the Museum "Dimitrie Leonida" in Bucharest. Starting from this phenomenon, in the past decade was developed a new class of UAVs based on Coandă effect. The researches were resumed by Robert Collins [4] starting from 2002. Recent research based on the same principle of operation are developed in U.K. [5] France [6] and Romania [7, 8]. In these researches the airflow is generated by an electrical fan located in the upper section from the center of fuselage. Flight control is accomplished with mobile and fixed wings, positioned on nozzle and fuselage.