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DESIGN, SIMULATION AND CONTROL OF ISOGLIDE T3R1 PARALLEL ROBOT

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Aceasta lucrare prezinta un robot paralel cu patru grade de libertate. Robotul paralel T3R1 este un robot cu miscari independente. In lucrare se va prezenta proiectarea, simularea si comanda utilizind Matlab/Simulink and Matlab/Virtual Reality.

This paper presents a parallel robot with four degrees of freedom. The isoglide T3R1 parallel robot is a robot with decoupled motions. In this paper will be presented the design, simulation and the control of this robot using Matlab/Simulink and Matlab/Virtual Reality.

Keywords: Simulation, Design, Control, Isoglide.

1. Introduction

In this paper is presented the design, simulation and control of Isoglide T3R1 parallel robot. The first step was to create the CAD model in SolidWorks. This robot has four degrees of freedom and his movements are decoupled. The first prototype was developed at the French Institute of Advance Mechanics (IFMA). The structure also was realised in Technical University of Cluj-Napoca. After the model was created in SolidWorks, on the CAD model was created a Simulink model, fig.4. That Simulink model contains blocks with all the components that are in the structure of this parallel robot. The control of this robot also was made in Matlab/Simulink. With this product the user can also nonintrusively find operating points and compute exact linearization at Simulink model at various operating conditions.

2. Kinematics and Design of Isoglide T3R1 Parallel Robot

The design and kinematics are presented in figure 1. It can be observed the functionality of the robot. This robot has four arms, four translations, revolute joints and a mobile platform that is the end-effector. The design was made in SolidWorks and the modelling was made in Matlab/Simulink and Virtual Reality.

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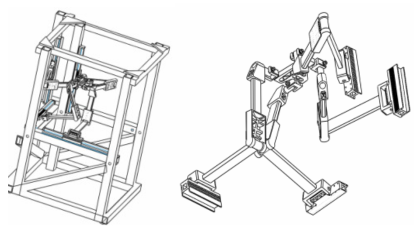

Fig. 1. CAD Model of Isoglide T3R1 Parallel Robot

The main advantage of the Isoglide T3R1 parallel robot, as far as control is concerned, is to have a closed-form expression of the forward kinematic and instantaneous kinematic models [1].

$$\begin{cases} X_e = q_1 - X_0 \\ Y_e = q_2 - Y_0 \\ Z_e = q_3 - Z_0 \\ \sin\theta = \dfrac{q_4 - q_3 + \delta Z}{l} \end{cases} \quad (1)$$

$$D(X) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -\dfrac{1}{L\cos\theta} & \dfrac{1}{L\cos\theta} \end{pmatrix} \quad (2)$$

$X=[X_e\ Y_e\ Z_e\ \theta]^T$ is the end-effector pose, X_0, Y_0, Z_0 and δZ are constant parameters depending on the actuators position in the reference Frame and l is one dimension of the platform. D(x) is the forward kinematics of T3R1 parallel robot [1]. The elements of the robot are presented in figure 2. In this figure are presented: one of the arm, the revolute joints, the translational actuator and the mobile platform.

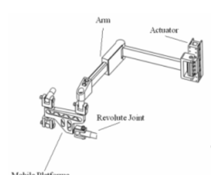

Fig. 2. The Elements of the Parallel Robot

It can see the elements which is made the arm and the connection between arm and mobile platform and the actuator. Between arm and the actuator and mobile platform are only revolute joints who defined the decoupled motions of the parallel robot Isoglide T3R1. This model of robot was developed at the French

Institute of Advanced Mechanics (IFMA).
It was made a new CAD model for make the simulation in Matlab.
In figure 3 is presented the model realised in technical University of Cluj-Napoca.

Fig. 3. The T3R1 parallel robot realized at Technical University of Cluj-Napoca

3. Simulation of T3R1 Parallel Robot

The simulation of T3R1 robot was made in Matlab/Simulink, Matlab/Virtual Reality and GUI (Graphical User Interface). Simulink is an environment for multidomain simulation and Model-Based Design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing.

With Simulink, it can be quickly create, model, and maintain a detailed block diagram of parallel robot T3R1 using a comprehensive set of predefined blocks. In figure 4 is presented the Simulink model of the robot also in figure 5 is presented the dynamic model of the parallel robot.

The simulation in GUI is made on the direct kinematics and inverse kinematics of the Isoglide T3R1 parallel robot.

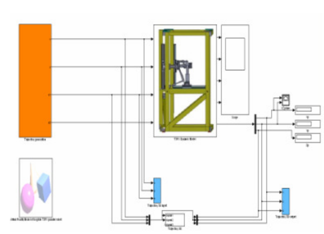

Fig. 4. Simulink model of the robot

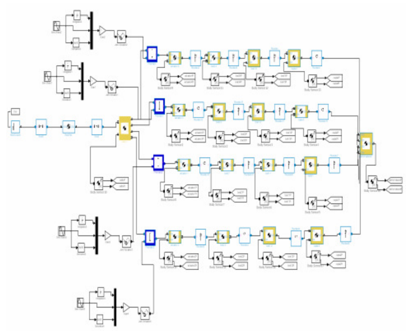

Fig. 5. The dynamic model of the T3R1 parallel robot

Virtual Reality Toolbox for MATLAB makes possible a more realistic rendering of bodies. Arbitrary virtual worlds can be designed with Virtual Reality Modelling Language (VRML), and interfaced to the SimMechanics model. The procedure of modelling in Virtual Realty in details is described in Fig. 6.

The user simply describes geometrical properties of the robot first. Then, in order to move any part of the robot through 3D input devices, the problems are automatically solved in real time.

The interface was also designed to provide the user decision capabilities when the problems such as singularities are encountered.

VR interface enables users to interact with the robot in an intuitive way. This means that the operator can pick and choose any part of the robot and move it using translation and rotation using 3D sensors, as easily as a “drag and drop” operation is.

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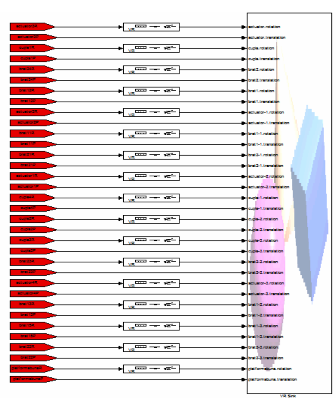

Fig. 6. Virtual blocks

The use of a VR interface to simulate robots drastically improves the “feeling” for the robot. In particular, the interface allows user to understand behaviour of an existing robot, and to investigate performance of a newly designed structures without the need of hardware implementation. In figure 7 is the CAD model of the robot visualised in Virtual Reality [2].

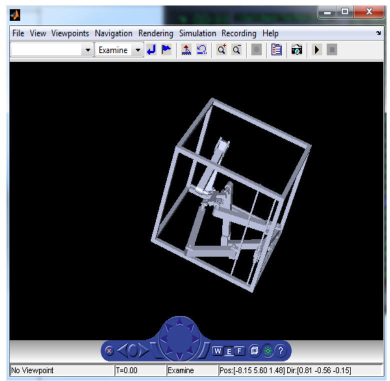

Fig. 7. The model in Virtual/Reality

4. Control of the T3R1 Parallel Robot

For modelling the DC motor who acting the joints was used the equation (3):

$$M = K_i \frac{V_{cc} - n \cdot K_v}{R} \tag{3}$$

Where: M - torque, V_{cc} – the voltage, n – speed of motor, R – motor resistance

In addition was added a voltage limiter top prevent the motor damages. Finally the DC motor used for this structure is presented in figure 8:

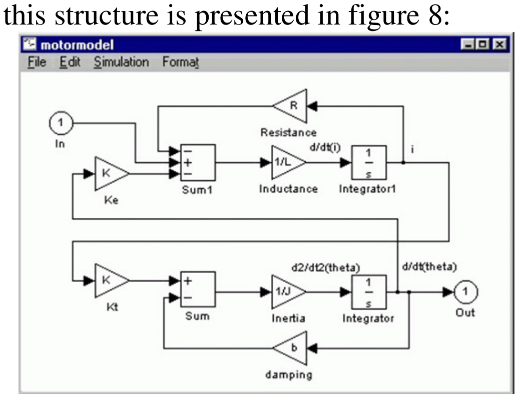

Fig.8. The DC motor [http://www.library.cmu.edu/ctms/ctms/simulink/examples/motor/motorsim.htm]

A PID algorithm was used for simulation of T3R1 parallel robot. It was applied the model of DC motor of one of the actuators, the others three motors are fixed. The subsystem that generates the control signals for the virtual model is presented in the next figure.
For obtain a answer it was introduced a PID block control in the model of the Isoglide T3R1 parallel robot. For determinate the control parameters Kp, Ki, Kd it can be used different methods. One of this method consist in to determinate the values manually.

The algorithm optimisation process consist in to a first phase who must to find values that satisfy the criteria required by the user than is done an optimisation of the output signal for reach the reference value in a short time and minim errors. In the next figure are presented the results who appears due process of finding the three parameters Kp, Ki, Kd. In figure are presented the tries that are made to fit within the limits imposed. In figure 9 is shown the subsystem that generates the control signals

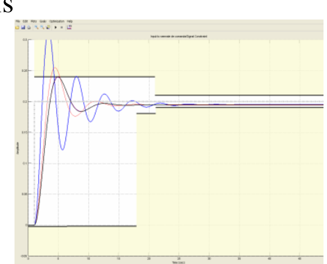

Fig. 9. The subsystem that generates the control signals

5. Simulation Results

There are several reasons for realizing a model of the platform. Firstly, it is possible to check the functionality of the construction and to determine the working area by simulation. Furthermore, control program can be developed and tested before the real platform is available.

The mechanical construction is performed with the CAD program SolidWorks and the data is exported to Sim-Mechanics , a simulation tool for mechanical systems.

Using SimMechanics the dynamic behaviour of the platform can be tested with a real or simulated control before it is set up.
The model of the manipulator respects geometrical constraints, joints and mass distribution. Friction is neglected in this model. In order to simulate behaviour of the robot, a dynamic model of the robot has to be built.

This is a complex subject and different methods were developed in order to solve it [3].

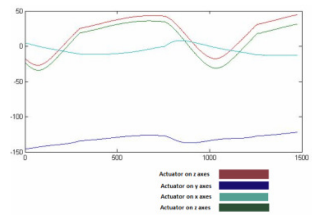

Fig. 10. Desired forces on actuators

In figure 10 is presented the desired force, using inverse kinematics and an imposition of a movement on the end-effector results a necessary force to actuated the joints for obtain the speed of end-efector.

The next step in the simulation of the robot is motion control. For doing that multiples types of trajectory were generated using user made blocks that generate them. Two of these subsystems are illustrated in the figures 11 [3].

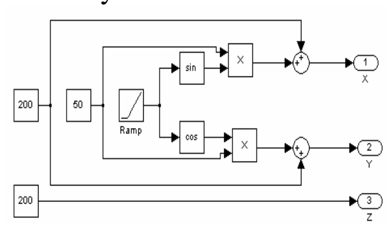

Fig. 11. Circle generating subsystem

6. Conclusions

In this paper was presented the design, simulation and control of T3R1 parallel robot. The CAD design was made in SolidWorks than was imported with SimMechanics translator in Matlab/Simulink. Also was presented the Matlab/Virtual Reality simulation. For this simulation was used the new CAD model.

The control was also made in Matlab/Simulink. The advantages of this parallel robot are that the movements are decoupled.

It was presented the model of the parallel robot realized at the Technical University of Cluj-Napoca.

Acknowledgment

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