Control simulations and design of ISOGLIDE3 medical parallel robot

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Abstract: - The paper presents the design and control simulations of ISOGLIDE3 parallel robot. An innovative user interface for high-level control of a 3 DOF parallel robot is also presented. The robot interface using virtual reality was verified and tested, and results in MATLAB, Simulink, and SimMechanics were presented. The ISOGLIDE3 robot offers the superior characteristics with regards to the other parallel manipulators, such as the light weight construction.

Key-Words: - ISOGLIDE, decoupled motions, parallel robot, design, control.

1 Introduction

The structure of the 3 DOF Isoglide3 parallel robot is shown in Fig. 1, where a mobile platform is coupled with the fixed base by three legs of type PRRR (Prismatic Revolute Revolute Revolute).

![Fig. 1. CAD design of 3 DOF Isoglide3 parallel robot.](image1)

Fig. 1. CAD design of 3 DOF Isoglide3 parallel robot.

The mobile platform can be visualized as a square whose side length 2L is defined by B1, B2, and B3 points. The fixed base is defined by three guide rods that passing through A1, A2, and A3 points, respectively (Fig. 3).

![Fig. 2. 3 DOF Isoglide3 parallel robot realized at Mechatronics Department.](image2)

Fig. 2. 3 DOF Isoglide3 parallel robot realized at Mechatronics Department.

Fixed coordinate frame originates at the point O. In Fig. 4, the reference frame XYZ is attached to the fixed base.

![Fig. 3. The mobile platform of 3 DOF Isoglide3 parallel robot.](image3)

Fig. 3. The mobile platform of 3 DOF Isoglide3 parallel robot.
The three revolute joint axes at each of these links are parallel to the ground connected prismatic joint axis, and are located at points $A_i$, $M_i$, and $B_i$, respectively. Also, the three prismatic joint axes passing through points $A_i$, for $i = 1, 2, 3$, are parallel to the X, Y, and Z axes, respectively.

The first prismatic joint axis lies on the X-axis; the second prismatic joint axis lies on the Y axis; while the third prismatic joint axis is parallel to the Z axis.

Consequently, the location of point $P$ is determined by the intersection of three planes. The forward and inverse kinematic analysis is trivial. A simple kinematic relation can be written as (1).

$$
\begin{bmatrix}
  x \\
  y \\
  z
\end{bmatrix} =
\begin{bmatrix}
  d_1 \\
  d_2 \\
  d_3
\end{bmatrix} \quad (1)
$$

This robot architecture was also implemented and known in the literature under the name of Isoglide3-T3 (Gogu 2004, 2008), Orthogonal Tripteron (Gosselin et al. 2004), or CPM (Kim and Tsai 2002).

## 2 Trajectory planning

Path is defined as sequence of robot configurations in a particular order without regard for timing of these configurations while trajectory is concerned about when each part of the path must be obtained thus specifying timing.

The control of the robot is implemented using a joint-based control scheme. In such a scheme, the end effector is positioned by finding the difference between the desired quantities and the actual ones expressed in the joint space.
The interface is based on a virtual reality approach in order to provide the user with an interactive 3D graphical representation of the parallel robot.

The interface was designed to give a novice user an intuitive tool to control any kind of mechanical structure (serial, parallel or hybrid), requiring no programming skills. Computer based simulation allows mimicking of a real life or potential situations.

SimMechanics models, however, can be interfaced seamlessly with ordinary Simulink block diagrams. For example, this enables user to design the mechanical and the control system in one common environment.

Fig. 8. ISOGLIDE3 virtual reality robot interface.

In addition, Virtual Reality Toolbox for MATLAB makes possible a more realistic rendering of bodies. Arbitrary virtual worlds can be designed with Virtual Reality Modeling Language (VRML), and interfaced to the SimMechanics model.

3 Simulation results

The sample trajectory of the end-effector is chosen to be a circular path with the radius of 0.3 meters and its center is O(0 , 0, 0).

This path is designed to be completed in 7 seconds when the end-effector reaches the starting point P1 (0.3, 0, 0) again with constant angular velocity \( \omega = 0.5\pi \) rad/sec. The end-effector path is shown in figure 7.

The desired force obtained from the actuators to move the end-effector of the Isoglide3 parallel robot along the desired trajectory is shown in figure 8.

Fig. 9. End-effector path for the circular trajectory.

Fig. 10. The desired force obtained from the actuators.

Fig. 11. End-effector path for the circular trajectory.
The desired force obtained from the actuators to move the end-effector of the Isoglide3 parallel robot for the trajectory presented in Fig. 11 is shown in Fig. 12.

![Diagram](image)

Fig. 12. The desired force obtained from the actuators.

4 Conclusion

The paper presents the design and control simulations of Isoglide3 parallel robot. Also is presented a Virtual Reality Interface for the 3 DOF Isoglide3 parallel robot (IG3PR) control. An evaluation model from the Matlab/SimMechanics environment was used for the simulation. An interactive tool for dynamics system modeling and analysis was presented and exemplified on the control in Virtual Reality environment of this Isoglide3 parallel robot. The main advantages of this parallel manipulator are that all of 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. By means of SimMechanics, the authors considered robotic system as a block of functional diagrams. Besides, such software packages allow visualizing the motion of mechanical system in 3D virtual space. Especially non-experts will benefit from the proposed visualization tools, as they facilitate the modeling and the interpretation of results.

References: