Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 22 (2018) 468–475

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

11th International Conference Interdisciplinarity in Engineering, INTER-ENG 2017, 5-6 October 2017, Tirgu-Mures, Romania

3-UPU robotic mechanism performance evaluation through kinematic indexes

Badreddine Aboulissane[a,]*, Dikra El Haiek[a], Larbi El Bakkali[a]

[a]*Team Modeling and Simulation of Mechanical Systems, Abdelmalek Essaadi University, Faculty of Sciences, Tetouan, Morocco*

Abstract

This work presents a simple and yet powerful approach for quantitative and qualitative evaluation of the performance of 3-UPU spatial parallel robot. The quaternion approach is used to obtain graphically the workspace of the 3-UPU parallel manipulator. The Jacobian matrix is developed then used to search for conditions that lead to singular configurations where the mobility of the manipulator instantly changes. The condition number of this matrix characterizes the dexterity of a robot manipulator at a given posture in the workplace, which is an important index to measure the performance of the mechanism.
The aim of this work is to evaluate all behaviors of the proposed model of spatial mechanism and analyze the kinematic performances indexes, which allows the evaluation and the comparison of the workspace reached by the spherical parallel manipulator, with the workspace required or prescribed for a desired application.

Peer-review under responsibility of the scientific committee of the 11th International Conference Interdisciplinarity in Engineering.

Keywords: Kinematics; Modeling; Parallel Manipulator; Performance Indexes.

1. Introduction

In recent years, new lower mobility parallel mechanisms that can realize a pure rotational or translational motion, have received a great attention of researchers, due to their potential and advantages. Indeed, these parallel

* Corresponding author. Tel.: +212-699-144-487.
E-mail address: b.aboulissane@gmail.com

2351-9789 © 2018 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the 11th International Conference Interdisciplinarity in Engineering.
10.1016/j.promfg.2018.03.072

manipulators exhibit a high nominal payload/weight ratio, and a high positioning accuracy due to their inherent rigidity and high dynamic performance, but they have a limited workspace and a low dexterous manipulability [1].

In the literature, parallel mechanism with three degrees of freedom is presented by Clavel Delta mechanism [2], 3-RUU [3] and 3-UPU mechanism [4]–[6]. The popular translational parallel manipulator Delta robot and the 3-UPU parallel manipulator with its configurations, such as the 3-PUU [7], were generally used in pick & place tasks. Parallel manipulators with spherical motion are studied in-depth for their distinctive kinematic characteristic, simplicity of control and their high practical value. Gosselin and Angeles presented a 3-RRR [8] spherical parallel manipulator, they analyzed its architecture based on different criteria such as: symmetry, workspace and isotropy, Sadeqi et *al.* designed and studied the same manipulator in the context of hip exoskeleton application [9]. A comparative study of 3-DOF asymmetrical spherical parallel manipulators with respect to motion, force transmission and stiffness is carried out by Wu et *al.*[10]. The kinematic performance of the 3-RPR planar parallel manipulator is investigated based on the local conditioning index and global conditioning index [11]. A 3-RRR planar mechanism, was studied by Hamdoun et *al.* based on its optimal workspace and dexterity [12]. The mechanism presented by Di Gregorio named 3-UPU spherical manipulator [13], has the positioning of the mobile platform with respect to the fixed base controlled by three legs with UPU kinematic chain in which U and P stand for universal joint and actuated prismatic joint. Each universal joint is composed of two revolute pairs with orthogonal axes. For this architecture, the first revolute joint connected to the base and the platform must meet in a fixed point.

The inverse kinematic of parallel manipulators is relatively simple and the direct kinematic is challenging. However, the direct kinematic of serial manipulators is simple while their inverse kinematic is quite complicated. The Jacobian matrix is developed then used to search for conditions that lead to singular configurations where the mobility of the manipulator instantly changes. The condition number of this matrix characterizes the dexterity of a robot manipulator at a given posture in the workplace, which is an important index to measure the performance of the mechanism. An approximate approach and yet powerful is used, to obtain graphically the workspace of the 3-UPU parallel manipulator.

This work is organized as follows, section 2 describes the proposed robot, its characteristics and kinematics illustrations. Section 3 shows a simple method to obtain the reachable workspace of the 3-UPU robot. Section 4 presents the singularities of the mechanism. Section 5 shows the dexterity distribution over the workspace. Some concluding remarks are presented in section 6.

Nomenclature

UPU	Universal joint, Prismatic joint, Universal joint
$\mathbf{w}_{ji}$	Unit vector of the *j*th revolute pair axis
θ_{ij}	Joint coordinate of the *j*th revolute pair
$\mathbf{u}_i$	Unit vector of the leg axis
CI	Condition index
GCI	Global Condition Index

2. Structure of 3-UPU Spherical robot

The 3-UPU parallel robot is composed of three kinematic chains, where each one has three UPU joints, a universal joint that links the fixed base to the chain, which is actuated by a prismatic joint, and another universal joint that links the moving platform with the chain.

Referring to Fig. 1 the 3-UPU spherical robot is described as follows: In the base we have three points A_1, A_2 and A_3, the centers of the universal joints, these points form an equilateral triangle, and connect the legs to the base. In the platform we have the same situation. An equilateral triangle formed by points B_1, B_2 and B_3, centers of the universal joints that connect the legs to the moving platform. The 3-UPU manipulator is configured this way to make the moving platform's point P coincide with the fixed base's point traced by the crossing of the revolute pair in the base.