Inverse kinematics solutions for industrial robot manipulators with offset wrists

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**Abstract**

In this paper, the inverse kinematics solutions for 16 industrial 6-Degrees-of-Freedom (DOF) robot manipulators with offset wrists are solved analytically and numerically based on the existence of the closed form equations. A new numerical algorithm is proposed for the inverse kinematics of the robot manipulators that cannot be solved in closed form. In order to illustrate the performance of the New Inverse Kinematics Algorithm (NIKA), the simulation results attained from NIKA are compared with those obtained from well-known Newton–Raphson Algorithm (NRA). The inverse kinematics solutions of two robot manipulators with offset wrists are given as examples. In order to have a complete idea, the inverse kinematics solution techniques for 16 industrial robot manipulators are also summarized in a table.

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1. Introduction

The solution of the inverse kinematics problem is computationally expensive and generally takes much time for real time control of robot manipulators. It is very important for robot design, trajectory planning and dynamic analysis of robot manipulators. There are mainly two types of inverse kinematics solutions techniques, namely analytical and numerical. Some problems encountered for robot manipulators are singularities (if determinant of the Jacobian matrix is zero, there are singular points and hence there is no solution) and nonlinearities that make the problem more difficult to solve. For a very small class of kinematically simple manipulators such as robot manipulators with Euler wrist (Fig. 1a) have been completely solved analytically [1].

In some industrial applications employed in welding, painting, cutting, material handling, machine tending and surgery etc., robot manipulators are forced to handle high payloads and to get long horizontal reach and appropriate angle. However, robot manipulators with Euler wrist whose three consecutive joint axes intersect a common point (Fig. 1a) may not meet these requirements. In order to meet these requirements, they can be equipped with offset wrists (Fig. 1b) whose three axes do not intersect in a common point. Some robot manipulators with offset wrist such as Panasonic VR-004GII, Kawasaki EE10, ABB IRB 2400, Kuka IR662, and Fanuc P145, etc. are very commonly used in industry. One way of solving inverse kinematics of these robot manipulators in closed form is to transform the kinematics equations into a 16 degree polynomial using the half-angle tangent of joint variables [2]. Unfortunately, obtaining the roots of 16 degree polynomial is very tedious and very time consuming. At the same time, analytical inverse kinematics solutions of some robot manipulators are difficult or impossible due to their complex kinematics structures. In the absence of closed form solution, numerical techniques are potential ways of solving the inverse kinematics problem. There have been developed two types of numerical methods to solve inverse