Bachelor thesis

Robot singularity avoidance by means of the virtual redundant axis

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1. Introduction

This thesis presents problems related to robot singularities and ways to solve them. Singularity is a situation when the Jacobian of a manipulator is rank-deficient. In a singular configuration may exist infinite solutions to the inverse kinematics problem. The manipulator could change some of the joint variables and hold constant position and orientation of the end-effector. In the neighborhood of a singularity, small velocities in the operational space may cause large velocities in the joint space.

Singularities can be classified into boundary and internal. In the case of robot type KUKA KR15/2 it can be classified also into arm singularity and wrist singularity.

Main goal of the thesis

This thesis presents problems related to robot singularities and ways to solve them. It discusses the definition of the singular configuration, presents identifiable types of singular configurations and their causes. Its purpose is to perform a detailed analysis of the method allowing to avoid the singularities and thus the singularity-related problems and to verify it by simulation tests.

2. Virtual redundant axis method

To solve a problem with a singular posture we can add one or more virtual redundant axis to the real model of the robot. The new vector of joint variables has more elements than the real vector. To solve the inverse kinematics problem must be added additional condition – minimalization of joint velocities.

The minimalization problem is solved by the Lagrange multipliers method. In consequence, the system of equations must be solved many times in the iterative process.

$$\begin{bmatrix}\Delta\bar{\boldsymbol{q}}\\ \boldsymbol{\mu}^T\end{bmatrix} = \begin{bmatrix}\boldsymbol{W}_{VRA} & \bar{\boldsymbol{J}}^T\\ \bar{\boldsymbol{J}} & \boldsymbol{0}\end{bmatrix}^{-1}\begin{bmatrix}\boldsymbol{0}\\ -\bar{\boldsymbol{\Phi}}\end{bmatrix} \qquad (1)$$

3. Simulation of motion in the neighborhood of a singularity

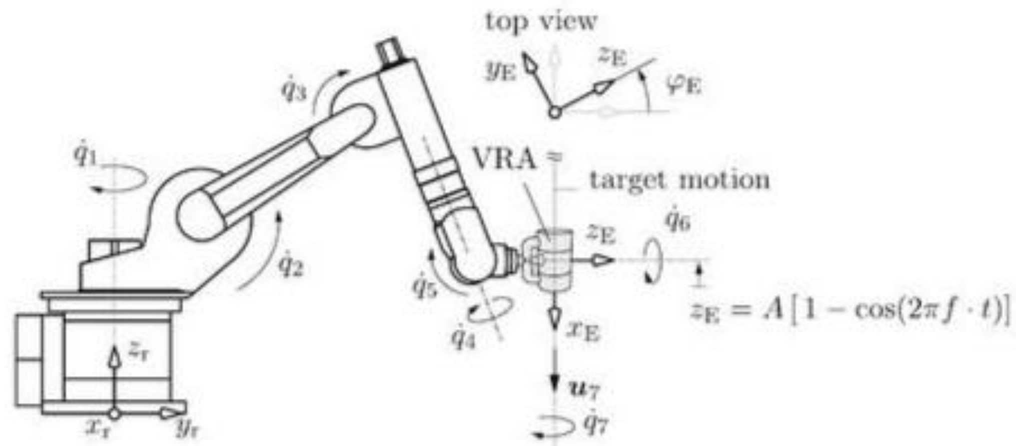

Figure: Vertical motion with constant orientations. F. Geu Flores, S. Rottgermann, B. Weber, A. Kecskemethy: Robust Inverse Kinematics at Position Level by Means of the Virtual Redundant

4. Results of simulations

To realize the motion that is described by the following equation, the manipulator must approach the singularity that is related to wrist extension.

$$\check{\boldsymbol{r}} = \begin{bmatrix}\check{\boldsymbol{r}}_p\\ \check{\boldsymbol{r}}_o\end{bmatrix} = \begin{bmatrix}0 & 1{,}04 & 0{,}155(1-\cos(\frac{\pi}{2}t))+1{,}325 & 0{,}02 & \frac{-\pi}{2} & \frac{\pi}{2}\end{bmatrix}^T \qquad (2)$$

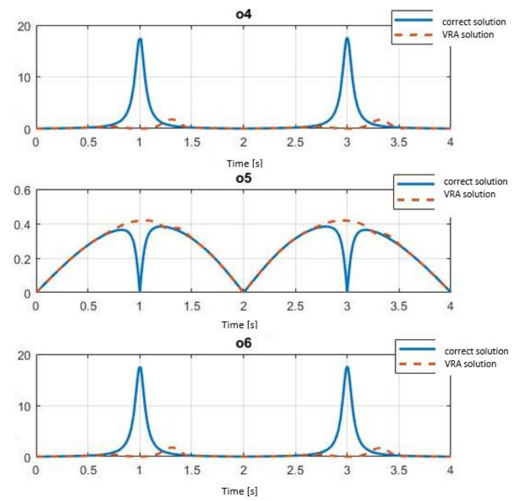

Figure 1 Joint velocities [rad/s] in the wrist

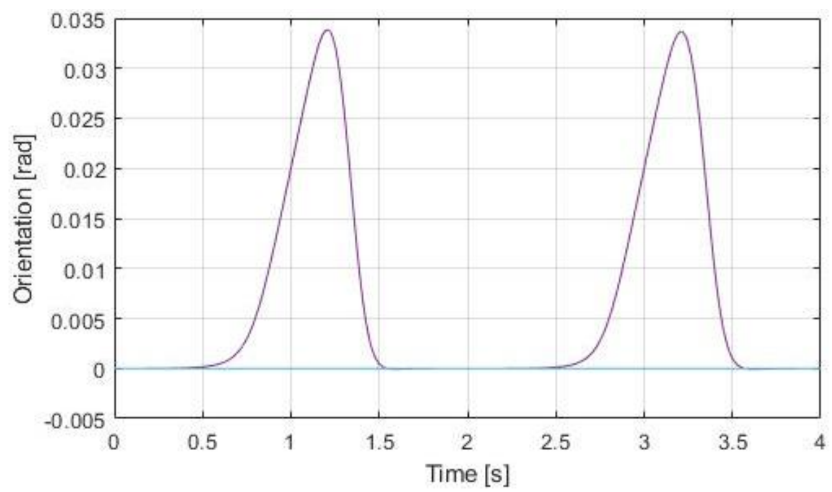

Figure 2 Difference between planned and realized Euler angles

5. Conclusions

- The virtual redundant axis method allows for solving the inverse kinematics problem in a singular configuration.
- The virtual redundant axis method allows to reduced joint velocities in the neighborhood of the singularities, however, in a consequence, the path is distorted. The main advantage is that the required velocities can be achieved by the motors.