JOINT LIMITS AVOIDANCE STRATEGY IN ROBOTIC SCANNING SYSTEM

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The robotic scanning system (Fig. 1) is used for ultrasonic non-destructive analysis (NDA) of objects with simple and complex geometry.

Fig. 1. The robotic scanning system

This system allows automating process of NDA, as well as accelerating of getting the final picture of defects. Maintenance of it requires advanced knowledge not only in ultrasonic inspection, but also in robotics, math and programming. Moreover, it should be safe and secure for people use and the construction itself. That is why we need to control robot movements on every stage and be sure where manipulator will go and what will get. The existence of singularity in robot manipulators is the main problem here.

Singularity is existence of multiple axis-specific solutions to the same Cartesian position of robot-ambiguous inverse kinematics, even though Status and Turn are specified. Inverse kinematics solve the following equation in terms of Cartesian position of robot end-effector [2] (Eq. 1).

$$Rot(z,\theta_i)Trans(0,0,d_i)Trans(a_i,0,0)Rot(x,\alpha_i) = \begin{bmatrix} l_x & m_x & n_x & p_x \\ l_y & m_y & n_y & p_y \\ l_z & m_z & n_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

Due to non-linear origin of the equation and periodicity of the functions there is exist possibility of multiple solutions for robot position and therefore singularity. Robot behavior in such positions are not predictable and can be very dangerous primary for people that works with it.

In the KUKA KR Agilus robots [3] there are exists three different singularity positions: the overhead singularity, the extended position and the wrist axis singularity [4].

In ultrasonic scanning system due to robot location and geometry of allowed area for scanning the main problem that can occur – wrist axis singularity. Overhead singularity cannot happen because the whole scanning area is always lower robot position, as well as extended position is also not reachable because of geometry limitation of scanning area. Therefore, the main problem left is wrist axis singularity. That is why we will talk more about it.

For checking if A5 singularity is taken place, we would not check the exact equal of A5 to zero, but we will check some angle segment. So, if A5 has value in range [–0.01812°; 0.01812°], we will account it that robot is in wrist axis singularity.

We know that robot moves in S-order for scanning the whole surface with linear (LIN) movement. That is mean the robot moves from one point to the next one directly in a very straight line that is not natural for robot itself unlike point-to-point (PTP) movement. LIN movement requires recalculation of robot position to be sure that robot in that straight line from point to point, PTP – only change axis values from one point to the next one. We can assert that for LIN motion there is not enough to check existence of singularity in the point itself (that is enough for PTP). However, we need to be sure that there will not be any singularity in the between of start and end points.

Finally, singularity avoidance algorithm is shown on Fig. 1.

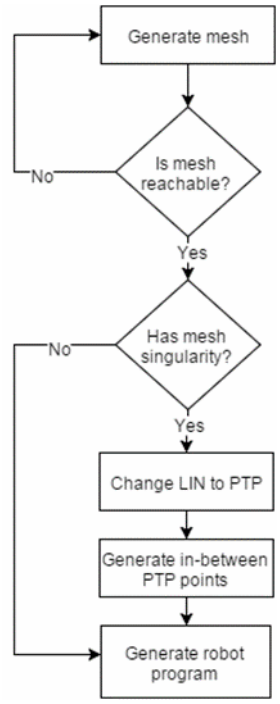

Fig. 1. Singularity avoidance algorithm

The main trick here is when we see in some points that robot may go in singularity, we need to tell him not to do that by exactly specifying the robot position in joints. Because in that case robot does not do any recalculations for inverse kinematics internally and goes exactly to that position (because at the end all robot movements are reduced to recalculations of Cartesian values to robot joints). If we just change LIN to PTP but leave Cartesian values, robot will do inverse kinematics as well, and experiments showed its behavior will not be so smooth and predictable as if we specify position in joints.

Knowledge about singularity is guarantee to have safe and secure ultrasonic system for people as well as have accurate results. The described algorithm has shown its effectiveness and accuracy during different tests and successfully using in production process on the scanning system.

References

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