A Machine Learning Based Optimization Approach for Solving Manipulator Robot's Inverse Kinematics Problem

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The inverse kinematics (IK) problem is fundamental in controlling industrial and autonomous mobile robots (AMRs). Among these robots, spider-like AMRs have gained popularity due to their agility, speed, and stability on uneven terrains. Conventional IK solutions pose challenges for the development of various robot types, including complexity derivation, calculation difficulty, multiple solutions, and lack of immediacy. Once the Degree of Freedom (DOF) (or independent "joints" having motors) is increased, the computational complexity is raised exponentially. Although numerous existing algorithms such as the Jacobian inverse technique, Cyclic Coordinate Descent (CCD) attempt to solve these problems, each encounter at least one of the mentioned issues. Consequently, researchers continue to analyze and optimize numerous methods and algorithms to overcome these limitations. This research proposes an optimization methodology for the Gaussian Damped Least Squares (GDLS) method, incorporating machine learning techniques, more specifically the Gaussian Process Regression to enhance the algorithmic efficiency, reduce complexity, and improve precision and faster solution predictions. The complexity index used to evaluate is the time elapsed to perform the computation for a given scenario (i.e., compute IK for 6 DOF). Approximately, 1.98% gain was reported from the perspective of response time, compared to the Jacobian inverse technique. (It is assumed that the computational overhead is also corelated with time incurred). The GDLS method is employed to analyze the IK problem of robot manipulators, ensuring motion stability. Approximately, an accuracy of 96.6% was obtained for the testing and validation. However, obtaining accurate solutions requires more (training) data points and thousands of iterations, impeding high-speed calculations. By leveraging machine learning techniques, the proposed approach attempts to significantly reduce the computational overhead and the unavoidable complexity associated with IK computations. In conclusion, the approach significantly improves the efficiency of solution prediction, enabling faster and more accurate inverse kinematics computations for manipulator robots.

Keywords: Inverse Kinematics, Manipulator Robots, Optimization Algorithms, Degree of Freedom, Machine Learning