# INTISARI

## PERENCANAAN TRAYEKTORI DAN KENDALI *END-EFFECTOR* ROBOT MANIPULATOR UNTUK MENDUKUNG *PICK AND PLACE*

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Sistem kendali robot manipulator enam derajat kebebasan (6-DOF) untuk mendukung proses pick and place umumnya masih bergantung pada perhitungan inverse kinematics (IK) klasik yang bersifat iterative, sensitif terhadap tebakan awal, dan berpotensi menimbulkan *overshoot* berupa kesalahan posisi *end-effector*. Kondisi ini dapat menurunkan akurasi dan kestabilan gerak, terutama pada tugas berulang yang menuntut presisi tinggi.

Penelitian ini mengusulkan pendekatan *inverse kinematics* berbasis *multilayer perceptron* (MLP) melalui *pipeline* terintegrasi yang meliputi pembuatan dataset, pelatihan, *pra-deployment*, dan pengujian. Dataset dibangun menggunakan model URDF robot dan Pustaka universal inverse kinematics untuk menghasilkan pasangan data posisi *end-effector* dan sudut sendi pada *workspace* dengan resolusi 1 mm, kemudian dibagi menjadi data latih, validasi, dan uji berdasarkan *statistic global*. Pada pelatihan, posisi dinormalisasi, diperkaya dengan fitur fourier, dan dipetakan menggunakan arsitektur ResMLPBound yang membatasi keluaran sudut sendi sesuai batas *joint* pada URDF. Model terlatih selanjutnya diintegrasikan ke lingkungan simulasi PyBullet untuk pengujian titik *end-effector* dan skenario pergerakan *pick and place*, serta divalidasi pada robot fisik

Hasil pengujian menunjukkan bahwa pendekatan *inverse kinematics* berbasis *multilayer perceptron* (MLP) meningkatkan kinerja kendali robot manipulator 6 DOF pada skenario *pick and place* dibandingkan *universal inverse kinematics* (IKPy) yang bersifat iteratif dan sensitif terhadap tebakan awal. Metode MLP menghasilkan prediksi sudut sendi yang lebih konsisten sehingga meningkatkan akurasi *mean error* posisi sebesar 76.7%, meningkatkan akurasi pada fase *pick* sebesar 68.7%, dan pada fase *place* sebesar 52.5 %. Dari sisi efisien komputasi, metode MLP juga mempercepat proses perhitungan IK dengan meningkatkan kinerja *mean periode loop* sebesar 52.6% serta percepatan waktu inferensi rata-rata sebesar 62.7%, sehingga lebih efisien untuk diterapkan baik pada simulasi maupun robot fisik.

**Kata Kunci: robot manipulator 6 DOF, *inverse kinematics, multilayer perceptron, pick and place.***

# ABSTRACT

## *TRAJECTORY PLANNING AND END-EFFECTOR CONTROL OF ROBOT MANIPULATOR TO SUPPORT PICK AND PLACE*

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Control systems for six degree of freedom (6 DOF) robotic manipulators used in pick and place tasks commonly rely on classical inverse kinematics (IK) methods that are iterative, sensitive to initial guesses, and prone to overshoot in the form of end effector position errors. These limitations can reduce motion accuracy and stability, particularly in repetitive tasks requiring high precision.

This research develops multilayer perceptron (MLP) based IK approach implemented through an integrated pipeline comprising dataset generation, model training, pre-deployment, and testing. The dataset is constructed using a robot URDF model and a universal inverse kinematics library to generate paired data of end effector positions and joint angles over the workspace with a 1 mm resolution. The dataset is then partitioned into training, validation, and test sets based on global statistics. During training, positional inputs are normalized, enriched with Fourier features, and mapped using a ResMLPBound architecture that constrains the predicted joint angles within the joint limits defined in the URDF. The trained model is subsequently integrated into the PyBullet simulation environment for end effector point testing and pick and place motion scenarios, and further validated on a physical robot.

Experimental results demonstrate that the proposed multilayer perceptron (MLP) based inverse kinematics approach improves both accuracy and computational efficiency for a 6-DOF robotic manipulator in a pick and place task compared with universal inverse kinematics (IKPy). The proposed method yields more consistent joint-angle predictions, achieving accuracy improvements of 76.7% in mean end effector position error, 68.7% in pick error, and 52.5% in place error. In terms of efficiency, it also provides faster computation, with improvements of 52.6% in the mean loop period and 62.7% in the average inference time. These results indicate that the proposed MLP based method is a practical and efficient alternative to iterative conventional inverse kinematics, and it can be applied effectively in both simulation and real robot implementations.

**Keywords: manipulators robots, 6 DOF, inverse kinematics, multilayer perceptron, pick and place**