Effectiveness of AI-Adaptive Robotic Hand in Common Medical and Industrial Tasks

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Mishandling objects in medical and industrial fields is a leading cause of preventable errors. Current robotic grippers rely on static force control, failing to adapt to various distinct objects. This study implements the use of AI-Object detection and tactile sensing to create an AI-adaptive robotic hand that is able to have grip adjustment for varying objects. The robotic arm system uses a Raspberry Pi 4 for processing live feed from a Pi Camera V2 through a custom YOLOv11 Convolutional Neural Network (CNN). An ELEGOO Mega is used for robotic arm control. Force-sensing resistors were used to provide tactile feedback for grip control. The CNN was trained to identify a 9V battery, an earplug, and Chapstick, each simulating heavyweight, delicate, and prone to slip objects common in medical and industrial fields, respectively. The CNN would identify the object and assign the optimal grip threshold. Test trials were split into control and AI-integrated groups, with the objective to transfer various objects while logging data on success rate, deformity, and slippage. For both groups, 20 trials were conducted for each object class. The experiment's results supported the alternate hypothesis, with the robotic arm completing tasks at a 99.2% success rate over 120 trials. A Wilcoxon Rank Sum test indicated that the difference in object deformity between AI and Control modes was not statistically significant (p=0.3557). However, the data showed improvement with the AI-integrated mode, reducing mean deformation from 0.023 mm to 0.015 mm–a 35% decrease. This result demonstrates that the integration of AI object detection with tactile grip control raises a potential solution for minimizing mishandling errors in medical and industrial settings.

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