Human-robot interaction: Assessing the ergonomics of tool handover

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SUMMARY

This work focuses on human-robot collaboration for assembly tasks, examining the position of robot-to-human handover of objects. A simulation environment is implemented to ergonomically evaluate the expected posture of the human arm in hypothetical delivery positions in the 3D space.

KEYWORDS

Human-Robot Interaction, Tool Handover, Arm Posture

Introduction

Collaborative robots (cobots) are becoming popular in automotive assembly industry because they can help improve productivity of assembly workers (Ajoudani et al, 2018) [1]. Employees performing physically demanding or repetitive tasks, can be assisted by cobots to improve their working conditions and reduce the risk of musculoskeletal disorders.

A common task that cobots may undertake in collaborative assembly applications is bringing tools from locations away from the assembly location and handover them to the workers. Particularly in assembly environments, tool-passing can happen hundreds of times during the day, and the relevant workload may strain arm muscles. Accordingly, the choice of tool handover position is an important decision made by the robot because, if done with ergonomic criteria, it can reduce the negative impact on the worker's muscles and in the long run it may significantly reduce the occurrence of musculoskeletal problems.

The current work focuses particularly on the study of tool handover, proposing a method that enables the robot to proactively examine the expected posture of the human arm and choose handover positions that “drive” the human arm to ergonomically suitable postures (Vianello et al, 2021). To this end, a simulation environment is implemented where several candidate delivery positions can be evaluated against known ergonomic criteria, considering the expected human arm movements. The robot then selects handover points that enforce ergonomics for the human arm.

Data Collection and Research Design

Demographical data, including age, gender, height, weight, and dominant hand, was collected from a sample of assembly workers. These data were used to adjust the human model in the simulation environment to match the somatometric characteristics of each participant. The study was designed as a simulation-based evaluation of human arm postures during tool handover.

Simulation Environment

The simulation of human actions is implemented in the PyBullet environment (Coumans). We use a human model with 25 degrees of freedom, which can be adjusted to match the somatometric characteristics of any given worker. Moreover, by using the profile of the worker the robot knows whether he is left- or right-handed and examines tool-handover at the appropriate arm. The simulation environment facilitates the use of constraints on arm motion, to simulate realistic hypothetical movements of the human arm, which are then evaluated against ergonomic criteria.

Ergonomic Assessment

The ergonomic criteria provided by the German Institute for Occupational Safety and Health (DGUV) are used to assess and categorize arm postures in three levels: (i) ergonomically appropriate, (ii) conditionally acceptable, and (iii) ergonomically unacceptable, as summarized in Table 1. We examine the angles of four degrees of freedom for the expected human upper limb posture, three at the shoulder and one at the elbow. Then overall ergonomic score of the given arm posture, equals to the score of the angle assessed with the lowest ergonomic score.

When the robot interacts with a human we randomly generate candidate positions/points and examine the hand poses (Figure 1). After finding 10 positions that meet all ergonomic criteria, we select the one that is closer to the robot, and this is used to implement the handover of the object.

Table 1: Ergonomic criteria for the arm

	Ergonomically appropriate	Conditionally accepted	Unacceptable
Shoulder abduction/adduction (ang0)	-20° <ang0< 0°	-60°<ang0<-20°	ang0<-60° or 0°<ang0
Shoulder flexion/extension (ang1)	0° <ang1< 20°	20° <ang1< 60°	ang1<0° or 60°<ang1
Shoulder rotation (ang2)	-15° <ang2 <30°	-30°<ang2<-15° or 30° <ang2 <60°	ang2 <-30° or 60° <ang2
Elbow flexion/extension (ang3)	60° <ang3 <100°	-	ang3 <60° or 100° <ang3

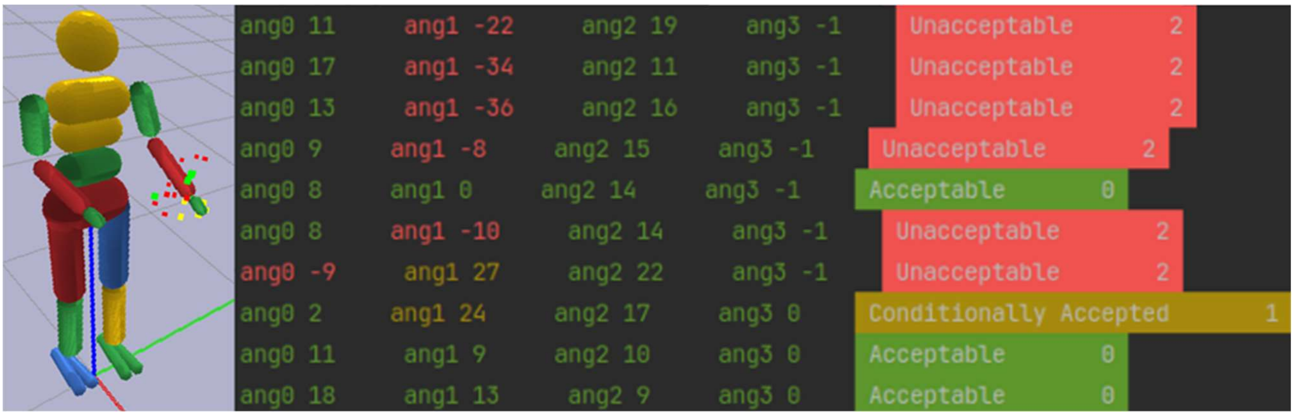

Figure 1: The ergonomic assessment of randomly generated candidate handover positions.

Discussion and Implications of Results

The simulation results show that the proposed method can effectively evaluate the expected posture of the human arm during tool handover and choose a delivery position that meets ergonomic criteria. This can reduce the negative impact of daily work activities on the worker's muscles and reduce the occurrence of musculoskeletal problems in the long run. Future work in this area could incorporate safety measures and evaluate the proposed framework in the real world.

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