A Force-Sensorless Controller Approach towards Assisted Human-Robotic Load Co-manipulation

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Introduction

For a human operator, lifting and carrying heavy loads can be a difficult task. Until robotic devices can take over such tasks in a fully autonomous manner, combining the human operator’s intelligence with force support from a robot seems a promising idea. The problem tackled by this work is the design and development of a controller that realizes such assisted human-robotic load co-manipulation. Two challenges must be overcome:

- The force that the human operator applies directly to the load can not be measured, i.e. the designed controller should function in a force-sensorless fashion;
- The mass \( m \) of the load is unknown.

The problem is graphically depicted in Figure 1, where the human operator (H) acts as a human-in-the-loop controller providing guidance based on visual feedback. The human operator’s force \( F_H \) combined with a desired additional force \( \alpha \hat{F}_H \), which is provided by the Power Assistance Controller (PAC), act directly upon the load held by the robotic end-effector \( R_L \).

Controller approach

The proposed PAC tackles the problem in a cyclic fashion, containing two temporal steps:

1. Quantifying the human operator’s intention by means of acceleration estimation; the acceleration estimate has a direct relation with the human operator’s force as no additional control force is present.
2. Estimate the mass of the load by applying an adaptation law, which is based on a difference between the current acceleration and the expected acceleration. Simultaneously, the mass estimate is used to calculate a human operator’s force estimate \( \hat{F}_H \), which is amplified and applied to the system.

Together these steps form one algorithm cycle as shown in Figure 2.

![Figure 2: Cyclic behavior PAC.](image)

Results and Conclusion

Besides simulations, the proposed PAC is implemented on a CFT-transposer robot for experimental validation. Despite satisfactory simulation results and several adjustments, the proposed controller is not able to nicely provide the desired force assistance. The robot exhibiting significant and strongly undesired vibrations is the main drawback. The cause for this is the difficulty in obtaining a proper acceleration estimate from differentiation of the quantized position measurement. Low-pass filtering is required to suppress the noise and obtain smooth acceleration estimates. This introduces time delays after phase transitions. These settling times should be minimal as the time-span of the phases are typically small (<0.005[s]). The cut-off frequency of the low-pass should therefore be set to give a satisfactory trade-off between the contradictory demands of fast but still smooth tracking. Unfortunately, the latter seems impossible and therefore obtaining a proper acceleration estimate remains a significant challenge.

References