Measures of Reliance in Physical Human Machine Coordination

pHMC

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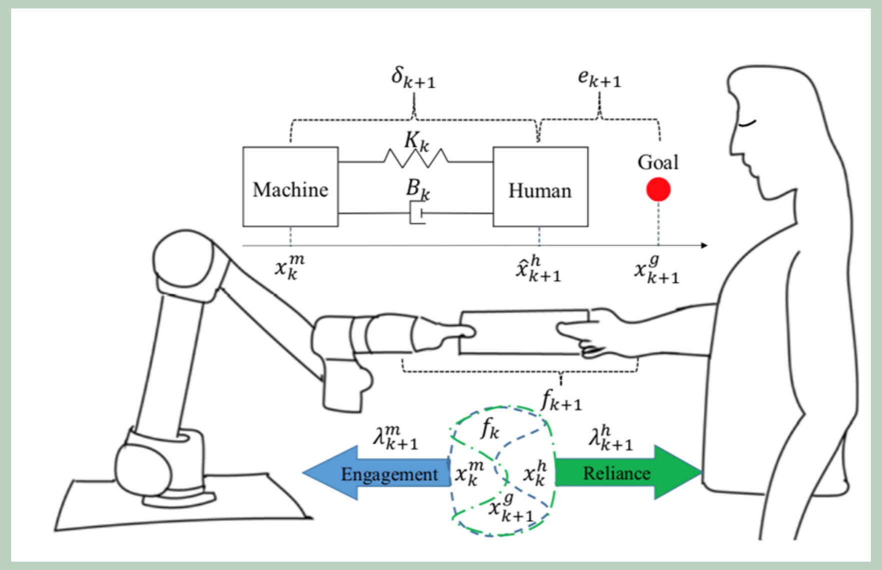
Abstract

Physical human-machine coordination (pHMC) in joint tasks is a highly interdisciplinary problem that involves machine design, planning and control, human factors, and human motor control. To achieve smooth pHMC, a human decision-making model should consider how a person generates their motor control signal during joint coordination task with a robot. A weighing factor, defined as reliance, is incorporated in the cost function of the motor control model to describe the human factors involved in a joint physical coordination task. Reliance is suggestively measured through a trust questionnaire after participants completed a coordinating task with a robotic arm. Preliminary results suggest that the motor control model proposed can explain differences of physical behavior between different participants, and potentially the relationship between trust and reliance in human-machine physical coordination.

Motor Control Model

The cognitive process by which people activate and coordinate the muscles involved in the performance of a motor skill.



A weighing factor estimated by the machine is λ^_k incorporated in the cost function to describe the human factors, with a small λ^_k indicating an aggressive leader and vice versa.

e_k -- Distance to the goal

δ_k -- Distance between robot and human hand

x_k^m -- Robot arm location

$\hat{x}_k^h$ -- Human arm location

The optimal motor control mechanism is based on the following equations.

$$\begin{aligned} \min_{\hat{x}_{k+1}^h} \quad & e_{k+1}^2 + \hat{\lambda}_{k+1}^h f_{k+1}^2 \\ \text{s.t.} \quad & e_{k+1} = x_{k+1}^g - \hat{x}_{k+1}^h \\ & \delta_{k+1} = \hat{x}_{k+1}^h - x_k^m \\ & f_{k+1} = K_k \cdot \delta_{k+1} + B_k \cdot \dot{\delta}_{k+1} \end{aligned}$$

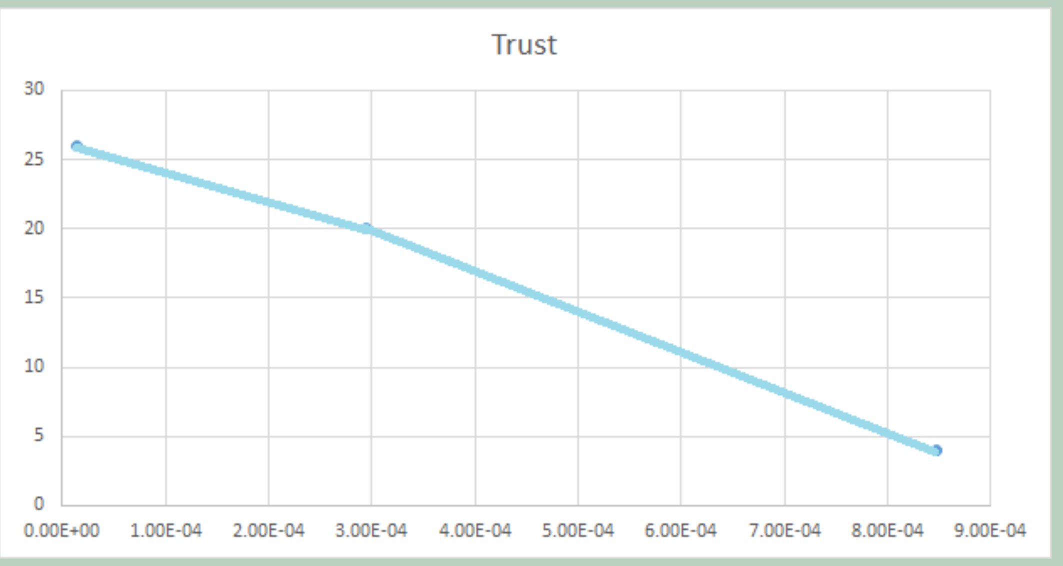
f_k -- Interaction force

Trust and Reliance

Reliance is an important consideration in pHMC. Reliance can indicate a person's trust in technology, which is the willingness to be vulnerable from the actions of others, or in the face of uncertainty. Trust is important in physical human-machine coordination because if a machine is not trusted, then its action or non-action will be monitored or accounted for, which increases the cognitive and physical demands of the task, respectively. At the same time, over trust may lead to over reliance, automation bias, and complacency. An appropriate level of trust is needed to ensure future successful collaborations. Establishing a way to measure trust and reliance online can thus serve as a valuable performance metric in human-machine physical coordination, and as input for future intelligent robot manipulators in physical task environments, such as in rehabilitation or assistive devices.

Results and Discussion

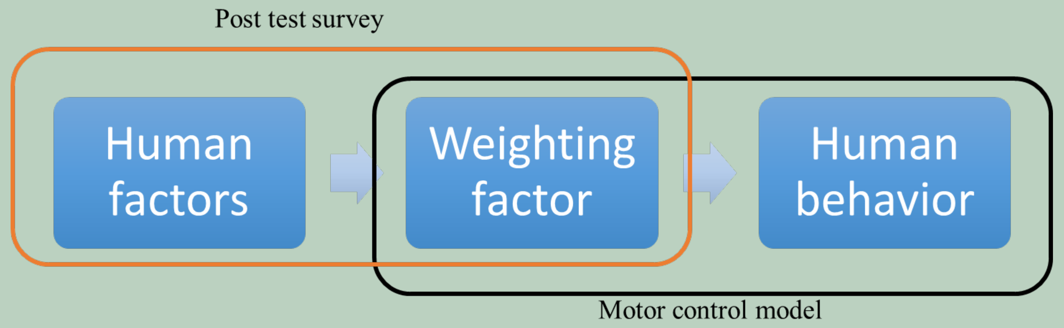
Through observations, trust questionnaire, and the mean weighing factor (mean of Lambda), there appears to be a relationship between Lambda and the general behavior of the participants, both observed and tested in the trust questionnaire. Participant 1 had the lowest Lambda value, and the highest trust value, and researchers noted that the participant appeared more concerned about the interaction force with the robot, and more concerned with accomplishing the task/goal. Participant 2 had the highest Lambda value, and lowest trust value. General behavior observations of Participant 2 were described as careful, slow, and more focused on the interaction with the robot rather than the task/goal. This relationship suggests that trust in the robot arm can affect participants' reliance (or lack there of) on the robot arm, as well as the physical coordination task.



Name	Participant 1	Participant 2	Participant 3
Mean of Lambda	1.3484e-05	8.4691e-04	2.9400e-04
Trust	26	4	20
Researcher Observation	This maximum variation and case sampling of participants suggests a relationship between the optimization parameter (Lambda) and the general behavior of participants. The participant with the lowest alpha value appeared to care less about the interaction force. While the participant with the highest alpha value behaved more cautiously during the experiment.		

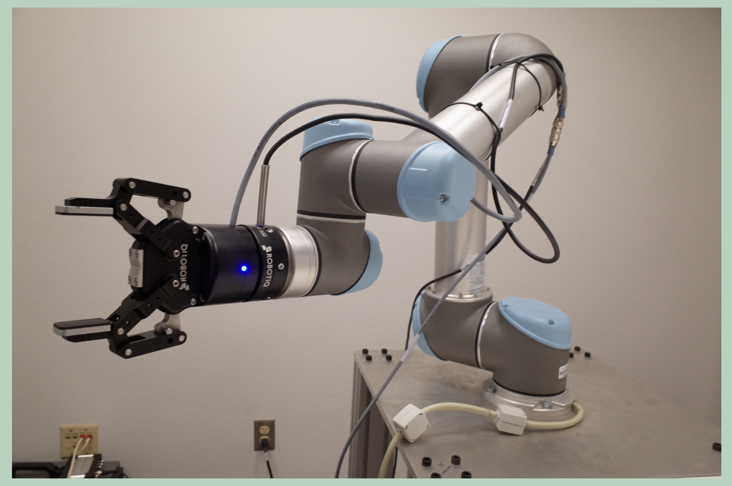
Human Decision-Making Model

The human decision-model is measuring a weighing factor between human factor and human behavior, which can be understood as reliance. This model can potentially predict the general human motion and help create more seamless human machine coordination. While human factors such as trust can affect the results of the HRI/coordinating task, human behaviors such as motor control can also affect the performance of the task as well as be affected by human factors.



Study Procedure

Participants were asked to complete four coordination tasks with a robotic arm. Each task required the participant to remain standing in a designated spot, while gripping a piece of wood attached to the robot arm. Motion sensors were placed on the participant's wrist, elbow, and shoulder to measure movement in time and range. Participants were asked to "help" the robot move from a starting point to four different labeled destinations on a table in front of them, with the last task involving an obstacle along the path. After these tasks, the participants were brought to a separate room where they completed a trust questionnaire.



Trust Questionnaire

The questionnaire used was an adapted version of "Empirically Determined Scale of Trust in Automated systems" (cite), and consisted of 12 questions related to trust or distrust in the robot, which participants were asked to rank on a scale of 1 to 7, with 1 representing "not at all", and 7 representing "extremely". Questions that were reversed scaled were corrected prior to data analysis. The data collected were then summed to create a theoretical trust range from -49 to 49 per participant; with the higher number indicating the more trusting the participant was of the robot.

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