When to assist? - A human model for hybrid assembly systems

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Abstract

Over centuries it has been common usage that the cooperation of foreman and assistant increases the working efficiency. This is due to the mutual understanding of each others actions and intentions.

Hence, an important first step for automation in this field is to develop models of this natural and adaptive assistance. An artificial system equipped with such models would enable higher acceptance, passive safety and efficiency.

Towards this goal we investigated the most common physical interaction occurring in human-robot cooperation - the handing over of items. In experiments, the timing and interplay of different modalities during a typical assembly task were analysed. A first model to predict timings and motor programs has been develop [1][2].

Recording multimodal data

Anticipation requires a human model capable to predict the durations of actions. We focus on the timing and prediction of actions, enabling robot systems to react just in time.

We recorded several modalities of subjects performing a typical assembly task (Figure 1). The subjects were asked to build a tower from cubes and bolts. The cubes were provided by a slide at the optimal handing over position in front of the participant [3].

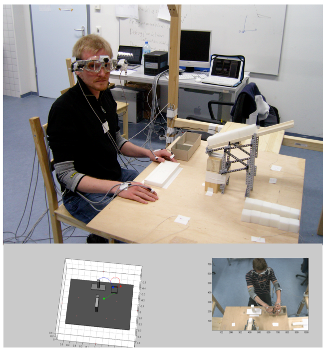

Figure 1: Picture of the experimental set up, consisting of a motion capturing system, an eye-tracker and a camera system. Data is recorded synchronously with up to 240 Hz.

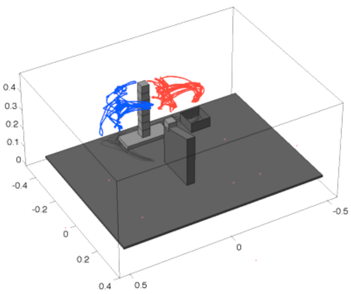

Figure 2: Experimental setup and typical hand-trajectories (blue = right hand, red = left hand) during the experiment. The cube spender is placed in front of the subject, the box containing the bolts at the left. The subject sits behind the table to build the tower.

Predicting the task duration

We developed a model to predict the duration of each assembly step and thus the upcoming handover of a new item (Figure 3):

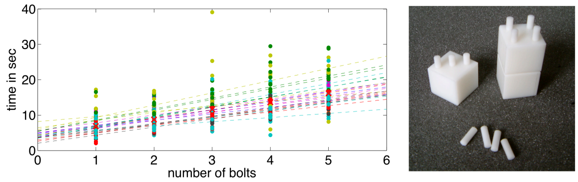

Figure 3: Duration of a working step plotted over complexity (number of bolts) for an assembly task

Analysing the experimental data shows that there is a linear relation between the bolt-numbers of a working step and its duration. However, the distinct parameters differ from subject to subject. Thus, the duration z_k for the k^{th} object for an subject can be described by

$$z_k = x_{1k} + x_{2k} \cdot u_k + v = \begin{bmatrix} 1 & u_k \end{bmatrix} \cdot \underline{x}_k + v$$

with x_k being the state vector of the system (offset and slope) and u_k the complexity (number of bolts). The system assumes that offset and slope are constant for each subject:

$$\underline{x}_k = \underline{x}_{k-1} + \underline{w}$$

The Kalman filter is thus a two-dimensional system with a unity system matrix. The prediction step is:

$$\hat{\underline{x}}_{k|k-1} = \hat{\underline{x}}_{k-1|k-1}$$

$$P_{k|k-1} = P_{k-1|k-1} + Q$$

To make the model more flexible, the bolt-number is replaced by an abstract complexity number. The linear dependency of the duration and the bolt-numbers is used to describe the complexity,

$$u_k = \frac{z_k - x_{1k}}{x_{2k}} + v$$

with u_k is now the complexity, z_k the duration and x_1,x_2 the offset and slope. Now for each different assembly step j a Kalman filter is used for averaging:

$$\hat{z}_{j,k|k-1} = \hat{z}_{j,k-1|k-1}$$

$$p_{k|k-1} = p_{k-1|k-1} + q$$

The standard deviation of the difference of predicted and measure duration over all subjects is less than 2 sec.

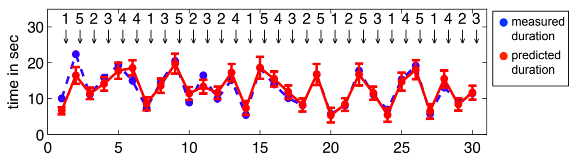

Figure 4: Empirical (blue) and predicted duration (red) over all working steps for a single subject. After initial adaptation, the model predicted the user behaviour well.

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[2] Glasauer, S., Huber, M., Knoll, A., Brandt, T. (2008) Handing over: Anticipation in joint action. International Journal of Psychology 43 (3/4).

[3] Huber, M., Knoll, A., Brandt, T., Glasauer, S. (2008) Handing-over a cube: spatial features of physical joint action. Annals of the New York Academy of Sciences 1431, p. 380-382