Using Anthropomorphism to Improve the Human-Machine Interaction in Industrial Environments (Part II)

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Abstract. The idea of socio-technical systems emphasizes the mutual interrelationship between humans and technical system considering the human operator as an integral part of the system. However, to use the full potential of this idea the technical system has to be perceived and accepted as a team-partner. Anthropomorphism is a promising approach to improve the acceptance of non-human entities as team-partners. In the second part of this joint contribution we present a revised experimental setup of the studies presented in the first part. A virtual environment consisting of a robotized assembly cell was utilized to conduct a prediction experiment with nine subjects comparing anthropomorphic and robotic speed profiles on a gantry robot. As in the first part the task of the participants was to predict the target position during movement. The results show significant effects towards shorter prediction time and less errors when using anthropomorphic speed profiles.

Keywords: Human-robot interaction, anthropomorphism, socio-technical system, prediction, self-optimization.

1 Introduction

Anthropomorphism, which can be derived from the Greek ἄνθρωπος (anthropos) for man and μορφή (morphē) meaning form or appearance, describes "the attribution of human characteristics or behavior to a god, animal, or object" (Oxford Dictionary 2012). Anthropomorphisms can be found throughout the history of man such as historic figurines or in fairy tales e.g. the Aesopian fables which can be dated to about 600 B.C. In everyday life anthropomorphisms are omnipresent and used in advertisements suggesting us something is as intuitive as it is to use natural language.

But how come we are concerning anthropomorphism in industrial environments, especially in the field of industrial robotics? The reason is at hand: Manufacturers like Motoman®, ABB® and KUKA® are introducing robotic systems that are anthropomorphic and might be introduced into future production systems to directly cooperate with humans in pulsed assembly lines.

Therefore, from a human factors point of view it is crucial to consider anthropomorphism as a possible design factor for joint cognitive systems. Especially when regarding production systems with simulated cognitive functions such as self-optimizing assembly systems that can plan autonomously ([2], [3], [4]) and might therefore be even more difficult to monitor and intervene.

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We decided to present our research in two parts. The first part of our research on anthropomorphism in human-robot interaction provides an explorative approach [5]. The second part can be considered as lessons learned resulting in a revised method, focused on one particular aspect research hypothesis.

Our goal was to investigate whether anthropomorphic movement of a gantry robot will have an advantage compared to conventional robotic trajectories such as classic point-to-point. As an experimental setup we chose a self-developed simulation environment which was presented to the subject on a regular screen. In the first part we investigated different influencing factors such as the orientation of the subject to the robot, the type of movement as well as the position.

2 Motion as a Source of Information

The idea to draw information from motion is not new. Detailed analysis on the basis of cyclographic pictures were carried out by Gilbreth as early as 1913 [6] and can be regarded as the foundation to systems of predetermined times such as MTM, Work Factor and many more. In later years Rhomert and Ruthenfranz used a similar approach based on cyclographic analysis to distinguish whether a worker using a hatchet was tired or not ([7], see figure 1). Even though, in the case of cyclographic analysis the motion is decoupled from time we can draw information out of the particular form of the motion patterns.

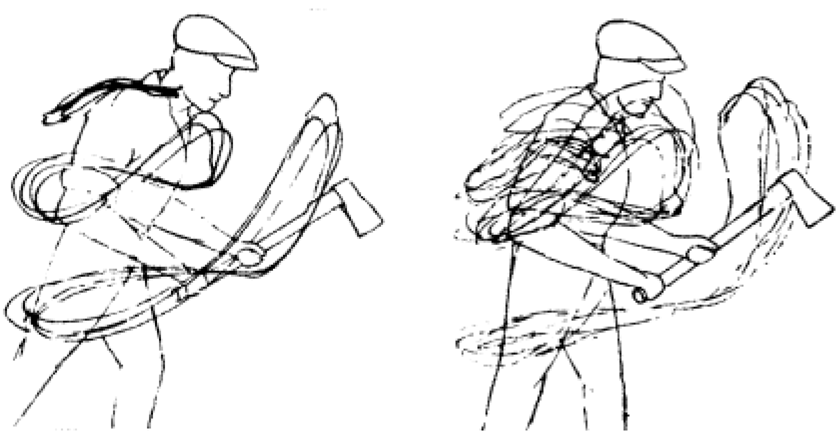

Fig. 1. Cyclographic analysis of a worker using a hatchet (left: not tired; right: tired)

Looking at motions that are really "in motion" in terms of a spatial-temporally continuous movement of a man, it is possible to retrieve more information. Even in the case of a heavily reduced representation of a human body by just using dots for major joints, it is possible to determine the direction of motion, the gender, basics about the state of mind (happy or sad) just to mention a view. For more information about this work please refer to [8].

The basic principle behind this is rooted in our brain. Areas that normally would be active in case we actually perform a task also fire if we observe such a task. These regions called mirror neurons were discovered by Rizolatti in 1996 in a study with monkeys [9]. There have been discussions about whether mirror neurons can be activated if observing non-living things such as robots [10]. However, in later works it could be shown that mirror neurons are not limited to living beings but can also fire in case of a robot performing tasks [11].

In case we want to transform motion patterns that are normal to a certain entity to another entity we have to regard the study carried out by Saygin et al. [12]. Theis study deals with the combination of movements typical for a robot and a human appearance. To do this kind of investigation three sorts of videos were recorded. The first one was a female person waving. The second was a robot that was designed to be a very precise optical imitation of that particular woman. However, the robot was not designed to reproduce typical human motion patterns and therefore moves like a robot. The third combination was the robot stripped to its bare mechanical components doing the same motion as in the second video. As a result of MRT-studies, the findings of Gazzola et al. [11] could be proven right. In the case of the second combination that "should not be", a significant raise in mirror neuron activity could be observed, which Saygin et al. [12] take as a hint for the uncanny valley that will be described in the next paragraph in more detail.

3 The Uncanny Valley

The uncanny valley as presented by Mori in 1970 [13], describes a paradox in the acceptance of technical, nonverbal behavior of artificial figures like robots. The most common presentation of this paradox is the version as depicted in figure 2 with familiarity on the ordinate and human-likeness on the abscissa. Mori states a higher effect when objects are actually moving compared to standing still.

The effect can be explained by the expectations of the person observing animated characters. Be the expectation that of a human being e.g. due to appearance or other influences, missing human features will diminish familiarity and can change to eeriness. In the case of a technical expectation however, additional human-likeness can lead to more familiarity with the system. Approaching the uncanny valley from the technical side, the drop in familiarity might be caused by a shift in expectations.

Despite the logic behind Mori's uncanny valley, the model lacks an empirical validation base is and is based mainly on Mori's thoughts. According to Gellar [14] *"[Mori] drew it as a graph, and that made it seem more scientific."*

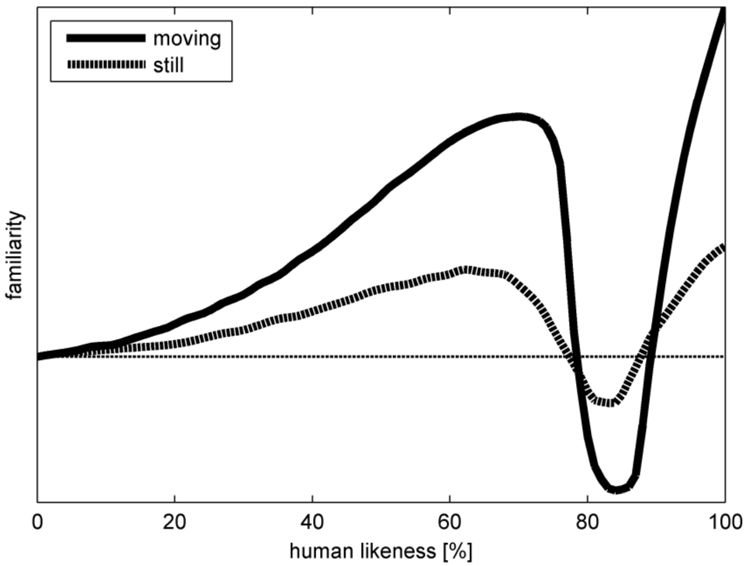

Fig. 2. The relation of human likeness and familiarity known as the uncanny valley

A few studies exist that underpin Mori's model with empirical data such as MacDorman [15]. However, one must say that only the uncanny valley itself was in the focus of this particular study. More generally speaking the main focus of research related to Mori's model tries to explain and thus to avoid or minimize the valley when approaching it from 100% human likeness.

From a scientific point of view the more interesting approach is to focus on what we call the canny hill. It is the area left of the uncanny valley where the expectation of the human observer is of mainly technical nature. The introduction of human like features is little compared to the amount of human likeness that would make expectations shift to human. Hence, with the experiments introduced in the first part of this two part publication as well as the experiment presented in the following, we introduce human motion patterns as an additional feature of an industrial gantry robot to improve safety, efficiency and job satisfaction in a manufacturing environment.

4 Revising the Method

The results presented in the first part of our contribution did not show main effects that can be interpreted right away. We did not see a significant difference in prediction time comparing robotic movement to human movement. Regarding the trajectories for human motion and robotic point-to-point movement, we see a large difference in the trajectories which might have lead to the observed results, for the classic point-to-point trajectories tend to converge faster with the target position and from the very start, whereas for human trajectories convergence occurs later and slower. Additionally, we see a difference for target positions that are closer to the robot (left side (x ca. 600), figure 3) compared to positions further away (right side (x ca. 1050), figure 3). In case we look at the relative length of the trajectory that was performed until the prediction, we find tendencies in the data, that for target positions that are close to the robot and therefore have similar trajectories, the results for prediction time and relative length of human and robotic movement is comparable, despite the later and slower convergence of human motion with the target position.

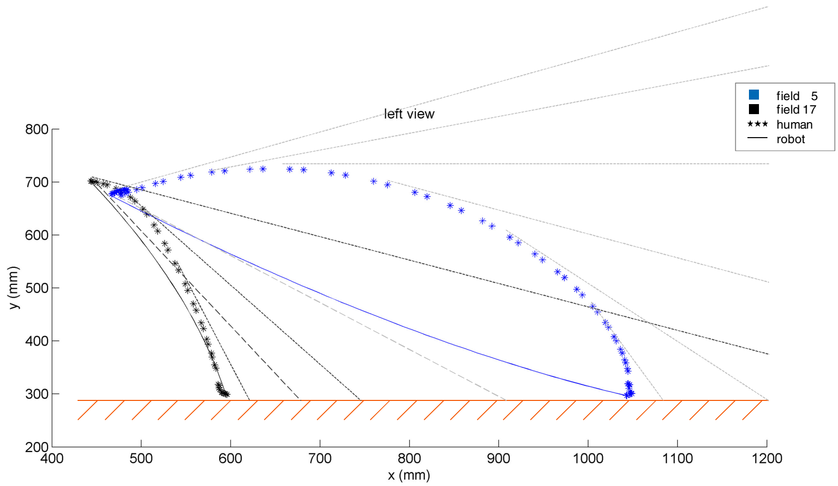

Fig. 3. Comparison of human trajectories (dotted lines) to point-to-point robotic movements (solid lines) regarding convergence (depicted as tangents) with near to the robot target positions (left) and positions further away (right)

Since a detailed description of the method and the experimental setup can be found in the first part of the contribution (see Kuz et al. [5]) we want to focus more on the changes made to the experiment. The task of the participants of the study, to predict the target position of a robot performing a pick-and-place operation, was adjusted in three points. 1) Compared to the first study, the motion now covers full pick-and-place trajectories starting on the same height as the target position. 2) We chose the lateral view for the second study, since regarding the subjective ratings of the subjects the lateral view was perceived better compared to the frontal view [5]. 3) There is only one trajectory per target position based on a human movement but with different speed profiles as shown in figure 4. The level for the constant speed profile equals the mean speed of the anthropomorphic profile to assure identical times for the approaching of each field.

At this point, we can only present results of nine subjects which participated in the study so far. As in the first experiment, all subjects are male and either taking part in an engineering bachelor/master program or have finished their studies. The age is comparable to the first group of subjects (mean 26.11 years, SD 4.43).

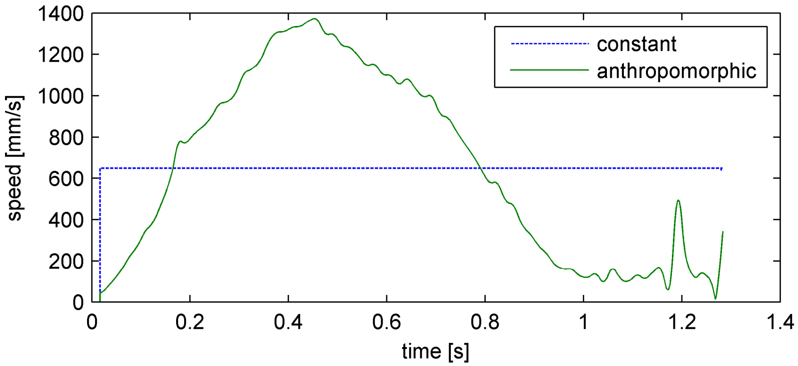

Fig. 4. Comparison of the speed profiles used in the second experiment (exemplary for one particular field)

The independent variables are the field position as in the first part and the speed profile that distinguishes between human and constant profile as in classic point-to-point robotic movement. As dependent variable the elapsed time between the start of the animation and the prediction of the target position was chosen. For statistical analysis a version of the Scheirer Ray Hare Test adjusted to repeated measures was carried out. A detailed description of the test can be found in Mayer [16].

5 Results and Discussion

The statistical results show a significant effect for the field ($p<0.001$) as well as for the speed profile ($p=0.006$). For the significant interaction ($p=0.001$) is ordinal, the main effects can be interpreted individually.

Table 1. Results of the adjusted Scheirer Ray Hare Test

	Sum.Sq	*d.f.*	*H*	*p*
field	1.87E+06	19	135.52	<0.001
error	4.90E+05	152		
speed profile	6.38E+05	1	7.61	0.006
error	1.16E+05	8		
interaction	1.59E+05	19	43.09	0.001
error	4.73E+05	152		

Regarding the fields, the experiments show longer prediction times for fields that are further away from the robot than compared to close fields. Since the trajectories used in the experiment all started and ended at the same height and had comparable shapes, the effect mainly can be explained by the specific time for reaching a particular field.

Comparing human speed profile to constant speed profile, we see shorter prediction times under the human condition. The only difference is the speed profile on an identical trajectory for each field. Hence, the effect clearly shows a timely advantage in predicting a target position when using anthropomorphic speed profiles compared to constant speed. Additionally, we see less false predictions under that condition. Hence, a speed accuracy trade-off does not occur.

6 Summary

Using anthropomorphism in industrial robotics is not an uncommon approach, since manufacturers are offering industrial robots with at least slight anthropomorphic features. Despite this development, little research has been carried out focusing on industrial applications yet, the majority of research work aims at humanoid robotics. From an ergonomic point of view, we see the necessity to address the topic of how to improve human-machine interaction especially in industrial robotics using anthropomorphism as a “natural” way of interaction.

In the two parts of this joint publication we introduced an experimental setup to investigate the influence of anthropomorphism in human-machine interaction for the special application of industrial robots. The task for the subjects in the experiment was to predict the final position of an animated robot during the performance of a pick-and-place task by indicating the expected target field. The results clearly show that anthropomorphic characteristics embedded into the motion of industrial robots can have positive effects on the prediction time of the subjects involved as well as the accuracy of the prediction.

Since the experiments have been carried out on the basis of a simulation, the next step will be to validate the experiment in a realistic scenario. Therefore, the assembly cell as presented by Brecher et al. [3] will be used as the next experimental setup.

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