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ICHORD: Integrating Cognitions of Human Operators in digital Robot Design

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The project aimed to demonstrate that a cognitive-behavioural rule, which relates human perceptions and behavioural responses to a robot's characteristics and actions, can be usefully integrated into a Computer Aided Design (CAD) tool to model an industrial Human-Robot Collaborative (HRC) system.

Digital human modelling (DHM) for the design of Human-Robot Collaborative (HRC) systems

Human-robot collaboration, where human operators and robots work together on the same task and in the same shared workspace, is becoming a reality in UK manufacturing. Currently this involves small power- and force-limited robots but the ultimate goal is for operators to work with larger traditional high-payload industrial robots in open spaces without physical guarding. Greater proximity and interaction with a robot trigger human cognitive perceptions that affect behavioural responses. In the manufacturing context, this means that HRC systems will bring about human cognitive-behavioural responses that could impact on overall system performance particularly with the high-payload robots that have traditionally been kept behind physical guarding.

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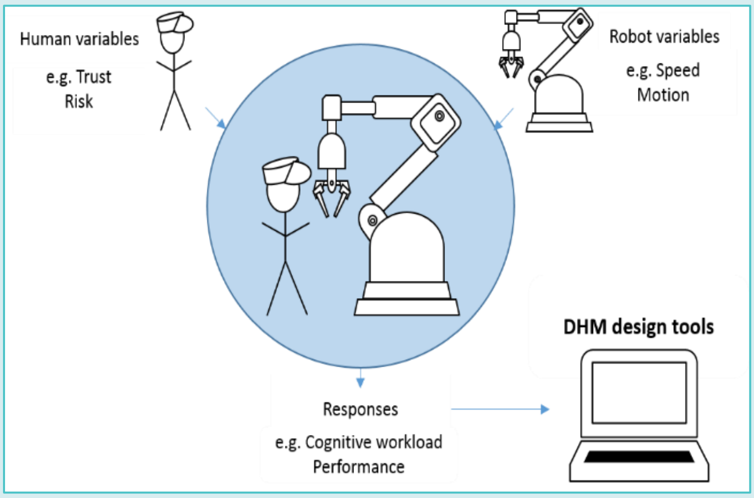
Improving DHM for HRC systems by including human perceptions

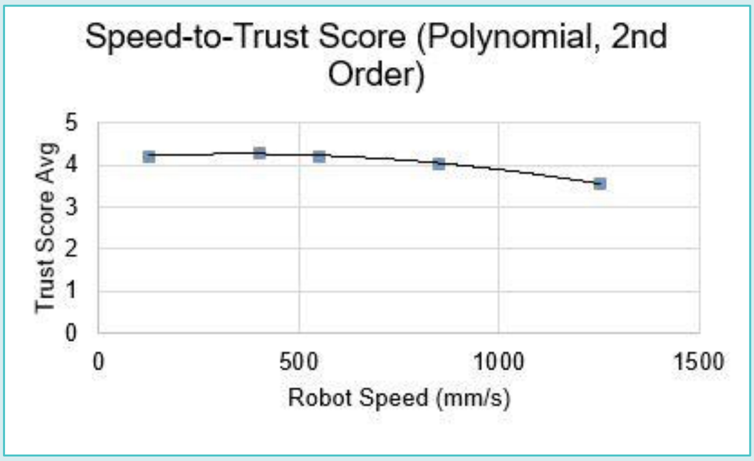
The success of new manufacturing technologies is compromised if there is inadequate consideration of human factors at an early stage in the design process. For this reason, Digital Human Modelling (DHM) is now a common tool in CAD design software packages. These DHM tools offer only physical ergonomic analysis and have no capability for psychological data analysis. Currently, the important cognitive-behavioural rules which will govern the performance of HRC systems cannot be modelled at the design stage.



This project tested whether it is now possible to integrate 'simple' cognitive-behavioural rule into CAD software and, if so, whether this enhancement of DHM capabilities will benefit industrial design modelling. If designers can include, at the outset, the robot specifications that will optimise a worker's trust and performance, this will improve operational performance as well as working conditions.

The project is the first attempt at integrating cognitive-behavioural data in DHM for industrial HRC design.

Establishing a rule for HRC – relating robot speed and human trust



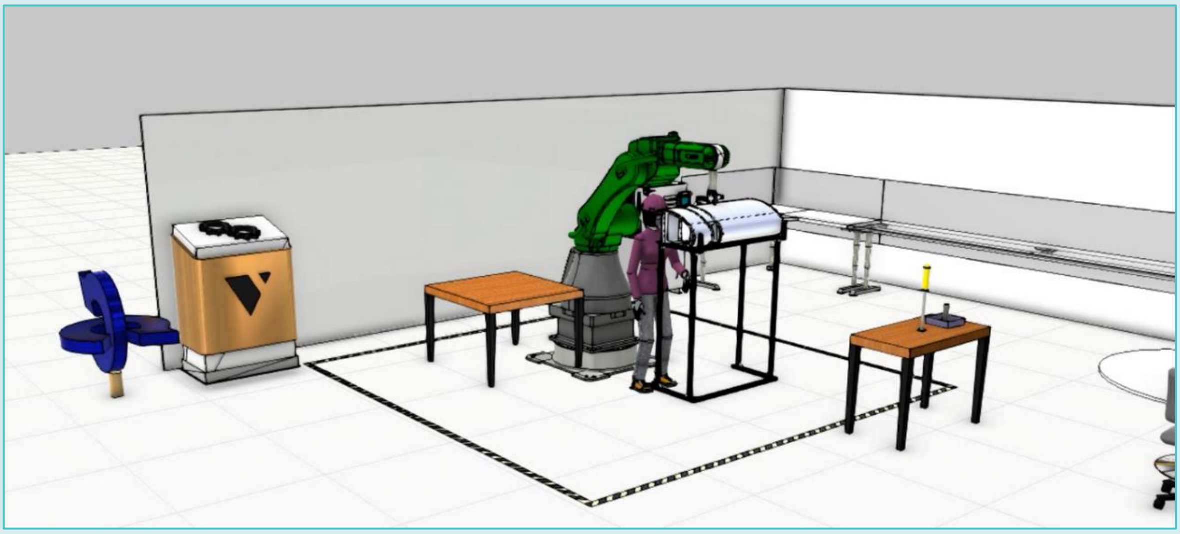
Trial participants' trust in a robot operating at five speeds was measured using the Cranfield Trust Scale, a measure of people's trust in large-scale industrial robots.

The data allowed an equation to be derived which related robot speed to human trust. The middle speed, 550 mm/sec, was chosen as the optimal speed, as it gives the fastest operating speed before human trust begins to decrease.

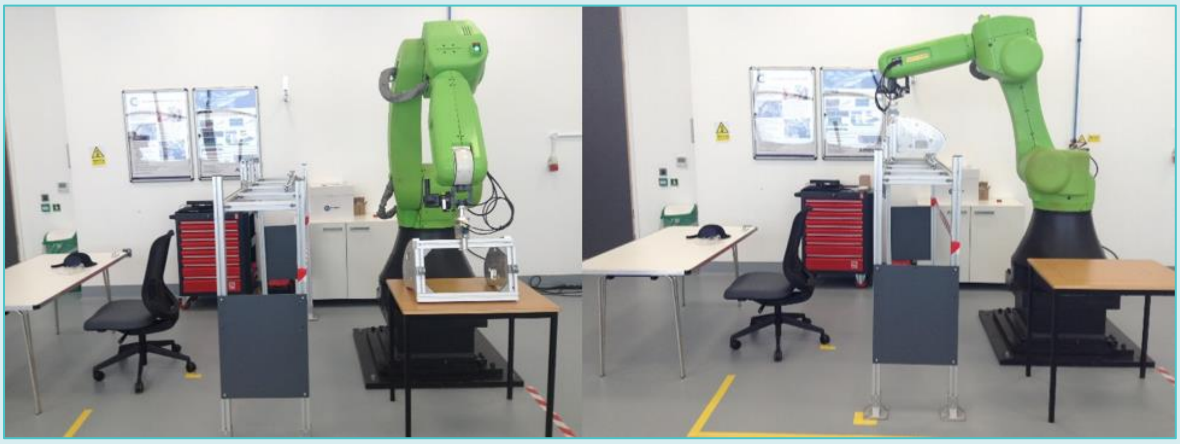
Using the new rule relating robot speed and human trust in DHM

Aircraft slat installation, at Airbus, was selected as an appropriate industrial use case. This currently manual process is ideal as it includes tasks involving large and heavy components, thus re-designing for HRC can be expected to bring productivity and health and safety improvements.

The AMRC designed a robotic cell in which the currently performed manual task is transferred to a new human-robot assembly task. The pick-up and placement of the slat onto the wing was identified as a suitable aspect of the slat installation process for a robot to complete. A digital model of the task incorporating the newly established rule, relating human trust to robot speed, was developed. It is possible to plug in a speed and get an output of predicted trust.



A CAD model redesign of the manual Airbus slat installation process to a HRC process



Participant trials were conducted in a lab-based demonstrator at Cranfield University

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In the final stage of the project, participants' levels of trust were recorded after they collaborated with a robot on the slat-installation task in a newly created lab-based demonstrator at Cranfield University (see image on previous page).

Trust at robot speed of 600 mm/s in Demonstrator:	Mean = 41.45	Range (39.22 to 43.69)
Trust at Middle Speed of 550 mm/s in initial trials:	Mean = 42.14	Range (39.79 to 44.48)
Trust predicted for robot speed 600 mm/s by model:	Mean = 41.57	

Key finding 1

A high level of agreement was found between the measured and predicted levels of trust in robots operating at speeds of 550mm/s or 600 mm/s.

Key finding 2

Human cognitive data can be integrated in DHM and has the potential to improve design for HRC

Wider applications

This successful demonstration of modelling a human cognitive-behavioural response will pave the way for more sophisticated digital modelling in the design of industrial systems. There is the possibility to gather data from more variables of humans (for example, heart-rate) and robots (for example, distance, gripper state) and these could be mapped over time. This potentially allows a simulation of human-robot interactions in real-time in a factory.

Human-robot systems in other contexts such as surgical, health care, domestic care and consumer contexts will be of interest.

What next?

We propose to test other rules to explore whether such an approach is useful generally or only suited to particular types of robots, systems and contexts.

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