The DIY Designer's Sidekick: A Role for Robots in Personal Manufacturing

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Abstract— **Few jobs in traditional manufacturing environments remain beyond the reach of automation [1]. At the same time, the rise of 'maker culture' and DIY (Do-It-Yourself) manufacturing is providing us with a new context for Human-Robot Collaboration (HRC). Manufacturing at this personal scale (as in early design or customization) offers new challenges for HRC in an environment where the human presence is indispensable.**

This paper presents three distinct user stories featuring industrial robots as creative and engaged social agents; the human-robot relationship is re-imagined with the human at the centre.

I. INTRODUCTION

The transformation of manufacturing by Human-Robot Collaboration (HRC) goes beyond the reproduction and extension of many human capabilities; simplifying tasks, increasing productivity and decreasing human worker's ergonomic risk. In Amazon's warehouses, robotic shelves save floor space [3], [4]. On Tesla's assembly lines, robotic arms lift, laser-cut and weld faster than humans can [5]. With robotic sales forecasted to exceed $23 billion by 2019 [6], future automation may quickly displace humans, retaining them primarily as "system managers and maintenance personnel" [7].

Looking beyond large-scale industrial manufacturing, 'maker culture' puts robot-empowered humans at the centre of a new scale of manufacturing. Examples like the Cardboard Machine Kit [11] demonstrate the variety of successful DIY (Do-It-Yourself) machines [1] that can be built with simple materials, pointing the way towards a future where individuals can build their own manufacturing robots. This paper identifies relevant examples of personal-scale use cases for such robots, proposing HRC designs that increase productivity, but also enhance the worker's expressive power and enjoyment.

II. User Stories for Human-Centred HRC

What tasks should be reserved for humans because of their value to the "worker"? Work can be fun, fulfilling, and a source of pride. These use cases suggest collaborations where we increase a human's productivity without losing sight of the sense in which their participation is an end in itself.

[1]Using the same Cardboard Machine Kit developed and supported by the Fab Academy at MIT, fabrication labs around the world demonstrate their unique machines https://vimeo.com/177397311.

A. DIY Manufacturing

Products created by DIY manufacturers or "makers" can arise from unstructured exploratory work where they experiment with tools and materials. Capturing a process discovered in an exploratory way to generate a well-defined series of steps is important for scaling up a lucky accident into a viable product.

Story: Colin is in the early stages of building a custom haptic interface and he is experimenting with a new material. Colin finds himself absorbed by the process, he explores several design directions —some are dead ends and some are put on the back burner in favor of others. Colin's robot helps by documenting his process with video, and suggesting a segmentation into steps. This documentation helps Colin return to directions he would like to explore further. He gets all the creative advantages of unstructured DIY work with the productive advantages of a documented step-by-step process.

Human at the Centre: Creating without a recipe is an experimental process where some ideas are put aside mid-investigation to explore another. Where collaboration is possible, new directions can arise through conversations between co-workers. The resulting design roadmap is nonlinear [8] and it can be costly to lose momentum by documenting the possible design directions across many inventors.

Robot Collaborator: A companion robot to a DIY manufacturer takes on the cognitive load of documenting a process, thereby allowing its human collaborator(s) to devote more energy to the creative and exploratory aspects of the work. Using automatic annotation, the robot creates transcripts of a maker's process, which can be curated for sharing and teaching, as well as helping focus exploration and avoiding duplicate work.

B. Robot-assisted Design

Designing accessories, clothes, or toys is often an iterative process. The production of multiple sample prototypes requires attendant user feedback to close in on the desired design parameters. The process of generating these samples can be repetitive and tedious.

Story: Paula is building a new children's toy to help teach about the systems of the human body. Paula is uncertain how realistic she wants the toy to look —'too realistic' might be frightening but ‘too cartoonish’ defeats the purpose of teaching students to recognize biological components. Paula personally designs two extreme examples: one highly stylized, and the other very realistic. Both designs are passed as inputs to her robot assistant which then generates three more intermediary examples. Now, Paula can better assess where the ‘right’ level of realism lies, and may choose to iterate over these designs with one or more generated prototypes.

Human at the Centre: Designers often have a large space of possibilities to explore, with loosely defined relationships between design parameters and the desired user experience. It is time consuming to generate a set of prototypes that fully explore a design space, however, prototype-based evaluation is often necessary to get the design right.

Robot Collaborator: A prototyping robot acts as a co-designer, helping to explore a design space similar to the way existing animation software generates transitional states [9]. Following methods developed for emotionally expressive design [10], it systematically varies parameters within a designer-defined range to generate a number of samples. This allows a designer to better understand the ideal product without committing excess time to generating many subtly different prototypes.

C. Supporting Maintenance

Consumer products like cars, bicycles, and electronics can require skilled labor for maintenance. Collaborative robots with access to a product knowledge base can act as a diagnostic assistant and smart toolset, allowing non-specialists to service their own equipment.

Story: Lucy recently bought a custom steel bike. Lucy feels her bike becoming sluggish and wants the satisfaction of servicing her own equipment so she decides to fix it with a robot collaborator. Together they narrow down the possible problems, and the robot guides Lucy through a plan for changing her crank-shaft bearings. Using the robot’s sensor-laden on-board tools, Lucy takes the crank-shaft apart, replaces the bearings, and re-tightens the enclosure. The system notifies her once she has applied the right amount of tension and analyzes an image of the final product to verify her work, providing corrections where warranted.

Human at the Centre: People are often faced with break-downs in specialized products (like custom bikes) which are difficult to diagnose. There are several reasons why laypeople would want to repair their own equipment: a sense of mastery and control, and the expense, delay of accessing skilled repair work.

Robot Collaborator: Here, a diagnostic robot uses accesses a product repair database, and provides the tools for and interpretations of diagnostic measurements. It uses a recommender system to provide a human-executable plan for repair or further diagnoses. As the user executes the plan, the robot uses image recognition to determine the state of the repair. It can then offer support by showing animations of the necessary tasks or providing haptic feedback to help the user apply the appropriate amount of torque. In this way an inexpensive robot can provide a hobbyist with the necessary tools and instructions for repairing their personal equipment.

III. Discussion: Developing Human Centred HRC

HRC in manufacturing has largely been about offloading human work to robots that can endure long periods of well-defined and repetitive work. In the examples above, we explored scenarios that move the robot collaborator beyond this *factory worker* role towards new roles such as *talented side-kick*, *co-designer*, *teacher*. These roles are social —a robot’s success in embodying them is measured in terms of the ability to complement humans as opposed to the ability to replace them.

With the maker scene embracing manufacturing and companion robots [11], [12], the first versions of the systems envisioned in this paper are already being created. By drawing on advances in information visualization, intelligent tutoring, and affective computing, among others, HRC researchers can extend maker robots by developing their ability to communicate with humans at a high level. Development along these lines holds a new promise for HRC: robots as engaged and creative social agents that support fulfilling human enterprise.

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