# Safe, Cheap, and Smart: Collaborative Robots in Manufacturing

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## Introduction

A recent trend in manufacturing automation is the use of what have become known as ‘Collaborative Robots’. These are robots that are safe to work alongside human workers, as opposed to traditional industrial robots that are generally separated from humans by safety cages. Additionally, these robots are also often easy to program and inexpensive. These properties are in contrast to the traditional industrial robots, which are not safe, expensive, and require an expert to program them.

The properties of collaborative robots enable new classes of applications: those that are too low value, or too variable to be cost effective with traditional robots. These applications are driven by the low cost and easy reprogramming that is possible with a collaborative robot.

This paper will discuss the economics of automating tasks using robots, and discuss what kinds of new tasks are enabled by the use of a collaborative robot. It will provide examples of current collaborative robots on the market, and discuss some of the underlying technologies that enable them to be safe, inexpensive and smart.

## Cost and flexibility

A common thread in all manufacturing businesses is the desire to improve the efficiency and reduce the cost of the manufacturing process in order to increase margins, and thus increase profits. A common way to do this is via automation, for example in the US over the last 70 years, manufacturing productivity has increased steadily while employment in the sector remained roughly constant (see reading list).

Cost is not everything however, as in recent years there has been trend towards smaller batch sizes, and more customized manufacturing. This has been driven by consumer demand. For example, automotive manufacturing is set up to get economies of scale by mass-producing a limited range of models. However, this makes it difficult to respond not only to the demand for customized features per vehicle, but also to respond to different volumes e.g. demand for hot-selling models as opposed to less popular versions. This is forcing manufacturing to be driven both by cost and flexibility.

There are a variety of approaches to automation with different cost/flexibility tradeoffs, and they are driven somewhat by the properties of the automation technology used. Fixed automation, which is using custom machinery for most or all of a process, tends to be expensive to design and create, but very efficient once implemented. It is however inflexible and so relies on a long production runs to justify the expense. Fixed automation is thus common in industries with stable long running production, for example consumer packaged goods such as diapers.

Traditional robotics is more flexible than fixed automation, but still has a high cost. Cells running robots are expensive to design and set up, and require long runs to get a return on investment. The dominant market for industrial robots is the automotive sector, where for example a spot welding robot can be used on a variety of models, yet be tweaked or reprogrammed as necessary as body shapes change.

The most common automation method is to prioritize investment on machinery for high-value parts of the manufacturing process and use human labor to complement the machinery. For example, a CNC milling machine can be used to turn metal slugs into parts (high value operation), while being tended by human operators (where the loading and unloading is lower or no value). This is a very common approach, because it gives cost savings, but with greater flexibility on how a line is constructed and used, but is more expensive in terms of running costs than fixed or robotic automation.

Collaborative robots have a different set of technology properties than fixed or traditional robotic automation (safe, inexpensive, smart), which makes them more appropriate for low-value and variable processes. Ultimately these properties boil down to cost and flexibility. Being safe reduces cost, both directly (safety systems are by their nature extremely reliable high end systems, and thus expensive), and indirectly (the floor area taken by safety systems cannot be used for manufacturing). Safety also increases flexibility – the risk assessments required for each application are the same, but redesign of safety systems adds to the cost and time to redeploy. Having inexpensive hardware obviously reduces overall cost, and being easy to train reduces application cost, ongoing maintenance and redeployment costs.

By offering low cost and flexible automation, collaborative robots are appropriate for use in many of the areas that are not currently automated – low value, variable tasks. These include machine tending, kitting (picking parts into a kit for an assembly operation), line loading and unloading, and packaging, many of which are largely not automated.

Examples of collaborative robots

This section provides a few examples of collaborative robots on the market today (for a fuller review see reading list).

Universal Robotics

Universal Robotics sells two collaborative robot arms, the UR5 (with a 5kg payload) and the UR10 (10kg payload). These are both six-degree of freedom arms, with around 1m reach. Safety for these robots comes from their low payloads and speeds, and they are inexpensive (around $35k for the UR5). The programming interface to the robot is very simple and easy to use, which allow quick training and retraining of the robot by users without programming skills. They also provide out of the box support for communication with machines and other pieces of industrial automation.

## Rethink Robotics

Rethink sells the Baxter robot, which is a humanoid robot with two seven degree of freedom arms. Safety on Baxter is achieved by having arms with a low payload (2kg), and by using an actuator technology called Series Elastic Actuators, which embeds springs in each joint of the arm, so making the arms inherently compliant.

Series elastic actuators were invented at MIT in the 1990s, and consist of a spring in series with the output of an electric motor and gearbox. A sensor is used to measure the twist of the spring, and a control system is used to control the output torque at the joint. The spring and control loop allow good performance to be obtained while using inexpensive components, because the spring naturally cleans up some of the undesirable properties of inexpensive gearboxes. In addition the torque sensing at each joint that this type of actuator affords opens up different strategies for controlling robots, using force control rather than position control.

The use of series elastic actuators allows the cost of Baxter to be low ($30k), and the robot comes pre-integrated with sensors (force sensing, cameras etc) that are intended to make the integration process easier. Baxter’s user interface is very different from traditional robot programming – it is programmed by demonstration, and consists of manipulating higher order primitives (picks and places) as opposed to the normal programming method (which is lower level functionality such as moves). This opens up the use of the robot to non-programmers.

## Precise Automation

Precise Automation produce the PF-400, which is a small SCARA robot with a small reach (0.5m) and payload (1kg). Safety is achieved by its low power, along with force limiting features. The robot cost is also low (not published but expected to be under $20k). The robot programming environment offers a teach-by-demonstration mode for quickly training key points in the robots environment, although it is otherwise trained like an industrial robot.

## Conclusion

Market forces and business realities for manufacturing to continue to invest in ways to reduce cost and increase flexibility in their manufacturing processes. Traditional fixed and robotic automation can offer efficiencies, but tend to be inflexible and require large batch sizes to obtain return on investment. There is an opportunity for automation that can be both efficient but also be inexpensive enough to work on lower-value operations and flexible enough to be repurposed for variable or small-batch sizes.

Collaborative robots are one automation choice that meets these needs. These are a new set of technologies and products that offer robots that are safe to be around humans (which in turn has cost and flexibility benefits), are inexpensive (the robot hardware is inexpensive), and are flexible (they have user interfaces that are designed to make them easy to train and repurpose). These robots are expected to complement existing automation approaches, as well as provide more opportunities for greater productivity in the manufacturing sector.

Reading List


1. Universal Robotics, http://www.universal-robots.dk/

2. Rethink Robotics, http://rethinkrobotics.com

3. Precise Automation, http://www.preciseautomation.com

4. Collaborative Robot Ebook, Robotiq, available from http://blog.robotiq.com/collaborative-robot-ebook

5. Is the US losing its Manufacturing Base? William Strauss, Federal Reserve Bank of Chicago, Rocky Mountain Economic Summit, Afton, WY, July 10, 2014. Available from https://chicagofed.org/digital_assets/others/people/research_resources/strauss_william/07-10-2014-rocky-mountain-economic-symposium.pdf

6. Series Elastic Actuators, G. A. Pratt and M. M. Williamson, Proceeding 1995 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Pittsburg PA. 1995.