Collaborative robots are redefining lab automation

The use of robots to automate high-volume repetitive tasks has been common practice going back to the early 1970s, when the German company KUKA developed and deployed the first electromechanical industrial robot. Subsequently, the world began replacing human effort in high-volume repetitive workflows with robots to reduce cost and/or improve productivity. Today robots are both big business and a big focus of discussion. The global robotic systems market (including software peripherals and other related costs) was estimated at $26 billion in 2012, according to IFR and the global industrial robot market is estimated to reach $41 billion by 2020, according to Allied Market Research.

From automotive assembly lines to materials handling to drug discovery, industrial robot penetration has grown steadily over the last few decades, recently showing strong signs of acceleration. It took 50 years to reach the first one million installed industrial robot units but only eight years to reach the second million units.

These traditional industrial robots have specific characteristics and limitations which have heavily influenced both the types of applications in which they have been used and the overall system approach to robot deployment. However, recent advances in robot technology are going to change the breadth of applications suitable for robots and alter how we think about robotic integration. For researchers in the drug discovery and development space, these advancements will open up many new possible ways of thinking through automation, delivering high productivity gains and ultimately reducing drug discovery costs.

Traditional industrial robots

When most people think of robots in industrial settings, they picture something like an automotive assembly line, with numerous large and imposing robots moving quickly and repetitively to perform high-volume tasks. Modern versions, such as the production line shown overleaf, seem futuristic, but are essentially just modestly altered extensions of the industrial robot system model that has been in use for years, and is ultimately governed by the characteristics and limitations of the industrial robots themselves. These robots are typically strong, fast and unintelligent. They excel at simple, repetitive tasks and are highly effective in the right context. However, they have little ability to react to events and, as such, require significant initial set-up and guarding. A human wandering into a line of industrial robots faces real danger, as the industrial robot will not stop moving just because a person is in the way. Couple this with their high payload, and...
rapid movement, and building a robotic line requires quite a bit of forethought about how to make sure the robots and people stay separate.

In addition to substantial guarding requirements, the traditional industrial robot line requires significant upfront programming and configuration in order to be effective. Each robot needs to be taught its positions and movements, with requisite and often complex work holding systems to ensure the workpieces are in the correct location and that the robot does not accidentally crash. A traditional industrial robot requires very high overall design rigidity in order to have repeatability. As a result, installing a traditional industrial robot line is usually very costly and inflexible. The robots themselves are a fraction of the total line cost. Moreover, if after installation the user decides they want to switch the design or configuration of the product being made on the line, the changes to the configuration can be time-consuming and expensive as the systems have a certain monolithic character to it, lacking flexibility and ease of adjustment. As a result of the above limitations and characteristics of traditional industrial robots, the application of robot technology has generally had a shared set of requirements: high volume, repetitive tasks unlikely to change for a long enough period to generate a return on investment. For example, in 2015 almost 70% of all industrial robots were used in the combination of automotive, electronics and metal manufacturing industries, nearly all of which have these characteristics.

While the above comments likely seem obvious when thinking about an automotive assembly line, in truth almost all other robot deployments have effectively been extensions of the basic high-volume assembly line model, including in drug discovery. Automation of scientific research tasks has found its strongest purchase in applications such as high-throughput screening (HTS) and compound management, where like typical industrial assembly lines, repetitive high-volume workflows are common. Traditionally these systems have used scaled-down versions of traditional industrial robots, also requiring significant guarding, increasing the overall footprint and limiting the flexibility and ease of interaction between robots and humans. Because these systems are not able to allow the robot and the human to work together, they must be totally automated – all tasks in the workflow must be done without human intervention even if a human is more effective than the robot at certain steps or processes. While these systems have been effective in increasing research productivity, like the automotive assembly line they have not penetrated broadly into other areas of the drug discovery process such as chemistry and cell culture, due to the nature of the workflows in those areas.

**Collaborative robots**

Today, the limits of traditional industrial robots are being pushed aside by a new generation of robots known as collaborative robots, or ‘cobots’
for short. While similar in appearance to traditional industrial robots, a cobot is designed to work alongside humans in a collaborative but controlled work environment. These cobots can sense the presence of a person, adjust their movement speed accordingly, have specially-designed joints for impact reduction, and an exterior design minimizing sharp corners and pinch points. They have advanced additional sensing for better understanding their environment and are able to be readily-taught through simple interactive steps. They do not require guarding, and can be positioned alongside human workers in a wide range of settings.

Several technology advances have enabled cobots to progress in their development. Notably, torque and force sensing has advanced to the point where a cobot ‘feels’ the impact with an object or person, and is able to shut its motion down and absorb the force of impact while only delivering a very modest amount of force to the object or person. In addition, ranged motion sensors allow cobots to know if someone is moving into their vicinity and adjust their speeds accordingly. As sensors and electronics generally have become more sophisticated and far less expensive, robots have been developed with numerous safety and sensing redundancies, turning the traditional unintelligent, non-sensing industrial robot into a somewhat intelligent mechanism capable of operating in the same workspace as people without posing a danger. These technologies have allowed the cobots some key performance attributes, such as power and force limiting and speed and separation monitoring.4

The development of cobots is, in many ways, driving the overall societal discussion about robots and jobs which, while having a legitimate basis in fact, is also at the peak of its hype cycle. From our vantage point, we do not see robots replacing anything close to 50% of jobs in any timeframe worth discussing.5 Books such as Rise of the Robots by Martin Ford and The Second Machine Age by Brynjolfsson and McAfee offer directionally correct views on how robots will accelerate their penetration into labour markets, but likely overstate the pace and extent to which it will happen. In addition, robots will not design, programme or maintain themselves for a long time, allowing job creation alongside job elimination. Still, penetration of automation will accelerate and cobots are one of the most important drivers. Why? The advent of a robot capable of operating in a workspace alongside humans greatly widens the number of jobs that can be automated. Inherently safe robotic arms combined with advances in sensing (is a person present, am I hitting something or can I use the arm to measure something, am I picking up a cat or a gear?) and machine learning are creating an explosion of applicability. By allowing robots and humans to share tasks, the robot technology bar is ironically lowered significantly, allowing a much more frequent case of incremental advancement and deployment. Most estimates suggest that less than 10% of jobs are fully automatable.6 Cobots answer this problem by allowing less than 100% robotic solutions.

Warehouse automation is a good example of human and robot collaboration lowering the robot technology bar. In a typical warehouse operation, humans spend roughly 50% of their time walking from one location to another. They receive instructions about an item to pick from stock, walk to its location, put it on a cart and walk it back over to a packing/shipping station. Rinse, repeat. Using existing sensing technology, indoor navigation and mapping methods and a small robotic mobile base, a fairly inexpensive robot can be designed to replace the walking portion of the overall warehouse picking task. Numerous examples of such robots are currently being developed by companies such as Locus Robotics, Gray Orange, 6 River Systems, Fetch Robotics and others. On the other hand, asking a robot to reach into a bin and retrieve a wide range of objects is very complicated. As the work at the University of California Berkeley on teaching a robot to fold laundry has shown, a robotic system with sufficient machine vision and gripping technology to pull a single object out of a location accurately is a challenge (Amazon has an annual contest on this problem). Even if possible, a vision-based robot picker is much more expensive than a robot only designed to replace the walking in the picking task. Human eyes and hands will be the best picking technology for a long time to come. Thus, by having humans pick items and pass them to robots, the vast majority of the labour cost can be reduced without taking humans completely out of the equation. This is how collaborative robots are opening up new applications and making stepwise advancement possible. As only about...
5% of existing warehouses are automated\(^\text{10}\), there is a lot of penetration to come.

The effects of collaborative robot technology can already be seen across many industries. Where in 2005, automotive OEM and component manufacturing applications represented 69% of all industrial robot orders, by 2013 it had dropped to 56%, being replaced by a broader array of industry needs including medical robots, warehouse applications, etc\(^\text{11}\). These developments are not lost on investors – since 2014, disclosed private investment in robotics-related companies has soared from just over $500 million to more than $2.5 billion\(^\text{12}\). A recent Barclays study suggests that the collaborative robot market will grow from around $1 billion in annual revenue in 2017 to a staggering $12 billion by 2025\(^\text{13}\). Much of this will be driven by service robot expansion, which are almost 100% collaborative.

**Collaborative robots in lab applications**

The impact of robots being able to work alongside humans in the lab as opposed to in monolithic and isolated dedicated lines is significant. To begin with, the overall footprint required for a system is now much smaller as guarding has been eliminated. As lab space is often a high-demand and low-availability resource, a cobot’s ability to reduce the overall space required to execute workflows is critical. Further, this space reduction is not incremental. Where 10 years ago a typical compound management system with a central industrial robot might occupy 150-300 square feet of lab space, today it is possible to have a single 3’x4’ cart with a robot and all requisite devices that can do the same functions. This would simply not be possible in a circumstance where the robot required guarding or was unable to work in close proximity to people.

In addition to shrinking the requisite footprint for any given automation workflow, collaborative robots have also enabled movable solutions for researchers. The CoLab Flex cart is a good example of such a development. Today, we are able to place a dispenser, storage devices, readers, washers and other ancillary devices on a single moveable cart which can be docked to a larger automation system, or used as a stand-alone unit. Because the robot is collaborative and requires no guarding to separate it from human workers, the entire system can be wheeled to any location in a research facility where it might be useful, making it a ‘mini lab-on-the-go’. This increases its overall potential utilisation as now it can be a resource shared across groups rather than a fixed resource in just one lab.

Collaborative robots are also much more flexible and easy to teach. Because the robot is designed to interact with people, teaching it something new is orders of magnitude simpler than it would be with a traditional industrial robot. A human can simply put the robot into ‘teach mode’, reach out and grab the arm, move it to a new position, press a button or a couple of key clicks and the robot has learned its new position. With a collaborative robotic system, a scientist can walk up to any step of the process for observation and adjustment without process impact. During longer workflows and routines it is common for a scientist to need to make small manual interventions, such as the addition of reagents. In a collaborative system, nothing needs to stop while this happens and the access points for such manual steps are much simpler.
Moreover, stopping in process experiments to make manual adjustments has an impact on consistency and accuracy. By letting the scientists interact with the system in real time, experiments are also more consistent. All of this creates more intuitive process flow, simpler system design and greater uptime due to fewer stoppages for safety reasons.

Collaborative robots also allow the fulfilment of full system modularity. While the concept of designing and building laboratory automation systems organised into moveable and configurable modules has been around for some time, the use of industrial robots as the primary workflow element has impeded full modularity. Why? Because typically each module acts as the guarding element between human and robot. By converting to a collaborative robot, modules can be taken off a system while it is running without endangering scientists. Thus, the use of collaborative robots greatly improves the fulfilment of fully modular designs, not possible with industrial robots.

Beyond the current benefits of collaborative robots mentioned above, potentially the most significant impact on the drug discovery process will be the proliferation of automation into non-traditional process areas. Robots that can be quickly tasked to new shorter-run workflows, and are able to be moved around without any guarding, will pave the way for bringing automation to areas of drug discovery not seen before. Over the next 10 years, labs will have opportunities to fully and partially automate a wide range of workflows previously off the table due to design constraints. As noted previously, traditional industrial robots are best-suited for high-volume low-variability workflows. Collaborative robots enable automation of smaller lot sizes with higher degrees of variability as a human actor in concert with a robot can deliver substantial flexibility and real-time adjustments as shown in the chart above.

The potential gains and new applications for drug discovery automation will also be greatly helped by continued technological advancement and price reductions. BCG estimates that robot costs will drop by 22% between now and 2025, while robot performance is increasing at an estimated 5% per year. As the technology cost of incremental lab automation drops, and its performance increases, the return on investment case for any given workflow being automated gets easier. Smaller and less repetitive workflows become candidates for automation. As robots become more collaborative and human-robot workflows more common, just as in warehouse automation we will find ways to let the robots do what they do best, and let the humans do the same.
The coming business impact of collaborative robots in the drug discovery space is clear. Cobots will reduce the unit capital costs required to bring automation to processes (less guarding, sharing of automation through mobility and higher uptime during workflows), expand the reach of automation into scientific areas previously not possible, and overall reduce drug discovery costs.

We believe the penetration of automation, led by collaborative robots, into both clinical and research lab areas will be very significant over the next 10 years. Beyond the general trends across all industries, labs are prime candidates for automation penetration through robot collaboration. They are highly structured environments. They benefit from precision and repeatability. They require data capture and, at times, traceability. They are expensive environments with a high level of repetitive work. All of these are key criterion for driving suitability for collaborative robots.

Drug discovery costs are substantial, and automation can help. As the next generation of robotics continues to develop, we believe human-robot collaboration can play a major role in reducing the overall discovery cost through increasing productivity, quality and yields in labs. Ultimately, collaborative robots can help scientists be scientists by both eliminating their need to manage or control automation and by removing the tedious and repetitive aspects of lab work and letting them drive research forward as only a human can.

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