a division of HDT Global, Inc.
415 Wolfe Street, Fredericksburg, VA 22401 ▪ P: 540.373.1435 ▪ P: 540.373.5069
hdtrobotics.com

Moving Goods

Material Handling and Robotic Manipulators

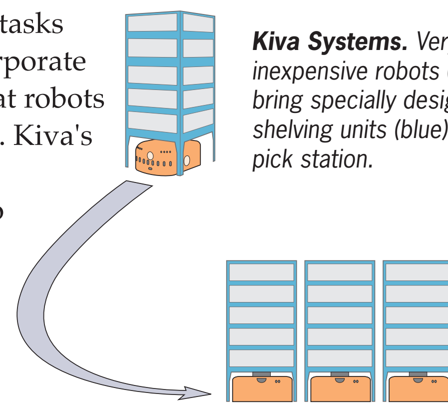
Warehouses, fulfillment operations, and even ordinary stockrooms are all on the cusp of significant breakthroughs in productivity. These changes are being brought about by a new generation of robotic manipulators.

This white paper discusses how robots can greatly improve material handling operations, while working within the current infrastructure.

Robotic Manipulators in Material Handling

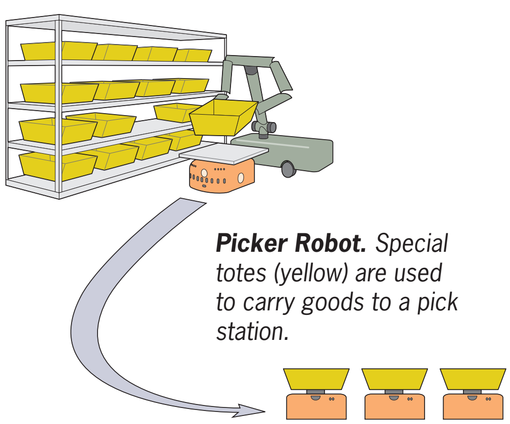
Ideally, a material handling robot would be able to look at a shelf, identify a box, and pick it up. Unfortunately, this ideal is a decade or more away, at least in a robust, generalized form. There are, however, very effective ways to deconstruct and simplify this material handling task, so that robots can perform this action across a broad set of circumstances. The result will be a significant improvement in the productivity of current warehouse operations.

Kiva Systems is an example of how material handling tasks can be deconstructed and simplified to optimally incorporate robots. The goal is to combine robots and people so that robots do what they do best and people do what they do best. Kiva's solution is to have very inexpensive robots bring special shelf units to pick stations. By moving goods to people, the robots eliminate the most labor intensive part of warehouse operations, which is having people walk up and down aisles. Robots are very good at simple, autonomous motion. People are very good at visual perception and dexterous manipulation. Kiva splits the materials handling process into tasks that robots and people can each optimally handle. The primary drawback of Kiva's solution is that installing their system requires starting with a completely empty warehouse, without any shelves or goods.



Kiva Systems. *Very inexpensive robots (orange) bring specially designed shelving units (blue) to a pick station.*

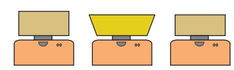
The next generation of robotic manipulators, however, have greater dexterity, which allows a different segmentation of tasks. "Picker" robots can autonomously move totes containing goods to and from existing warehouse shelves. These totes can be easily identified through a combination of RFID tags and bar coding. The totes are specifically designed for easy grasping and handling by robotic manipulators. The picker robot can then carry a tote to a picking station or place a tote on an inexpensive "carrier" robot, similar to Kiva's current robots, which would carry the tote to a picking station.



Picker Robot. *Special totes (yellow) are used to carry goods to a pick station.*

There are several advantages to this revised process. First, a warehouse can be converted to storing goods in totes over time, without a major disruption to operations or any need to change existing shelving. Second, each tote would only contain a single type of product, which would simplify the picking process and reduce errors. Finally, a tote weighs much less than a shelf, so energy costs are reduced compared to moving a shelf weighing up to 800 pounds.

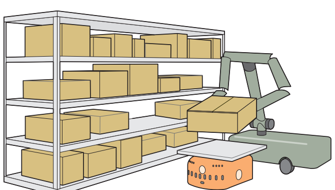
On a smaller scale, such as the prescription medication stock shelves for a retail pharmacy, a robotic picker could retrieve small totes containing stocking bottles and dispensing packs of specific medications. The error rate now associated with manual selection of the correct medication would be greatly reduced. The stock shelves could also be located in an enclosed, locked space, which would reduce losses due to pilferage.

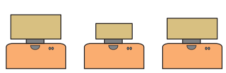


Advances. *As robots become more capable, they will handle a mix of totes and cases.*

As robotic vision, perception, and grasping improves, the picker robots will be able to identify and handle some cases without an enclosing tote. This transition will reduce costs by allowing a greater storage density on shelving, and also reducing the number of totes.

Eventually, almost all of the totes will be eliminated. This manipulator/robot approach, as described above, permits a smooth transition from current capabilities to future levels of autonomy, with minimal disruption to ongoing warehouse operations.





Tele-operation. *Remote human operators can add visual perception and grasp planning skills as needed.*

An alternate approach allows direct case handling right now. This alternative can also play a role in aiding the transition to greater robot autonomy in situations where the picker robot has difficulty recognizing or grasping the correct case. A remote employee can “jump” into the picker robot and tele-operate it. The remote human operator's perception and grasp planning skills are able to take over when the robot is not able to identify and manipulate the correct box.

Using tele-operation for identifying and grasping means that picker robots can work in many current warehouses right now. Most of the picker robot's time is spent moving from one shelf location to another, which is an action that robots can perform without help. Human intervention is only need for the brief time required to identify and grasp the object. A single human operator can control several different picker robots, so there are many fewer people required as tele-operators, compared to the number of human pickers in a all-manual operation.

Generally, human tele-operators would be paid a higher hourly rate than manual laborers, which would tend to reduce the advantage of using robots in anything other than high-volume operations. In a 24/7 case picking operation, the case picking robot price would need to be less than $150,000 in order to achieve an 18 month pay-back. If the operation was only two shifts a day and five days a week, however, the maximum picker robot price drops more than half, to $70,000.

Because the robots are controlled remotely, there is no practical limitation on the location of the tele-operators. These remote operators could be in a country with high education, but much lower labor costs. In that case, the picker robot price could be 50% greater than when using local (US) labor for tele-operators.[1]

When robots are picking totes, without any need for tele-operation support, the cost advantage of using robots is even more dramatic.

Regardless of labor outsourcing issues, there is a continuum of functionality, where robots with manipulators can greatly increase the productivity of material handling operations, right now. As Moore's Law continues to increase the capability of machine perception and grasp / task planning, the productivity benefits of robotic material handling will only expand further.

Background

Reports from the Bureau of Labor Statistics[2] show that the primary job function for more than six million workers in the United States is materials handling in warehouses or similar settings. More than three million of these workers spend nearly full time moving boxes on and off of shelves. There are tens of thousands large warehouses in the United States, and hundreds of thousands of smaller facilities with similar materials handling needs, totalling billions of square feet.

There is over 10 billion square feet of built-out warehouse space in the United States.[3] If all that space were in single building, it would be six times larger than Washington DC.

Employee turn-over in warehouse operations is greater than 75% per year.[4] In addition to absenteeism and substance abuse issues, breakage and pilferage are frequent problems reducing productivity and increasing costs.

The vast majority of warehouses have very little automation. Workers in non-automated warehouses and distribution centers spend the majority of their day

---

1. Financial modeling performed by HDT Robotics, Inc., 2013

2. U.S. Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections, Washington, DC:
http://bls.gov/ooh/transportation-and-material-moving/hand-laborers-and-material-movers.htm
http://www.bls.gov/oes/2010/may/oes537051.htm
http://bls.gov/ooh/Office-and-Administrative-Support/Material-recording-clerks.htm

3. U.S. Energy Information Administration, "2003 Commercial Buildings Energy Consumption Buildings (CBECS) Detailed Tables"; Table B1

4. Hokey Min , "Examining Sources of Warehouse Employee Turnover," International Journal of Physical Distribution & Logistics Management 37 no. 5 (2007): 375-388.

walking or driving up and down aisles. The amount of time that workers spend actually placing or removing objects from shelves accounts for only a small portion of the labor hours expended during the worker's typical day.

In typical material flow, a pallet will leave a manufacturer with a 'unit load' of cases, all of which are identical. Each case generally contains multiple cartons, or other containers, of items that are packaged for individual sale. A case typically contains 12 cartons, but that number can vary widely. A 'case' can be a sealed, rectangular cardboard box, or a plastic-wrapped flat of beverages, or other self-contained grouping of items. Unit load pallets can also be made up of sealed bags of loose material.

At the simplest level of warehouse operations, a unit load pallet is placed into storage until it is retrieved and sent out.

The next level of complexity for warehouse operations is breaking open the unit load pallets and reassembling a variety of cases from different pallets, containing different products, together on a single pallet, which is called a 'mixed case pallet'. Distribution warehouses that supply large retail stores often assemble mixed case pallet loads for shipment to individual stores.

The highest level of complexity is when the cases themselves are opened up and individual cartons from one or more cases are assembled together for shipment to an individual customer. An example of this type of 'open case' operation is an internet-based fulfillment center. Open case picking is sometimes called split case picking, broken case picking, piece picking, or each picking.

There are a variety of strategies for labor optimization in picking operations, including batch picking, zone picking, and wave picking. All of these solutions work best in large, high-volume operations and generally require some capital-intensive materials-handling equipment. To implement these strategies, the warehouse or distribution center generally needs to be completely redesigned and reorganized.

More highly automated solutions for open case operations usually involve an automated mechanism that brings cartons in a movable storage unit to a human operator, who removes the desired item (individual carton). These items are packed in boxes for shipment to fulfill the order.

As new unit load pallets and whole cases come in, other operators place cartons from newly opened cases in movable storage units. An automated system keeps track of the content of all of the storage units, the location of all the storage units, and then moves each storage unit to where it needs to be.

These highly automated solutions are very expensive. They also require the interior of the building to be stripped back to a bare concrete floor. Completely unique storage systems and autonomous material transport systems must then be installed. Finally, all of the inventory must be loaded into the system.

Because this level of rework is extremely disruptive to any existing operations, highly automated systems are generally only installed in new facilities.

There are four major categories of tasks performed in open case picking operations:

1) Mobility - moving from location to location
2) Information Processing - deciding what needs to be picked, based on customer orders
3) Visual Processing - scanning the environment to locate the carton that needs to be picked
4) Manipulation - picking up the carton and placing it in a package for shipment to the customer

Automation efforts have primarily focused on improving efficiency in the performance of the first two tasks: mobility and information processing. For the third task of visual processing, some work has been done using light-based cueing to assist workers, generally called "pick to light".

For the fourth task of manipulation, almost no products are available, primarily because it has been very difficult for any robotic device to match the speed and dexterity of people. Only with the issue of lifting heavy objects has some limited work been done in developing manipulation assist devices.

Recent advances in robotic manipulators, however, have come much closer to matching the dexterity, speed, and strength of humans. These advances have enabled the new operating modes described in this white paper that enable significant increases in material handling productivity.