The Smart Logistisk Challenge 2018
Mads Frederik Madsen
28th of June 2018

Cobotic systems:
Reducing the amount of repetitive work

Author: Mads Frederik Madsen, the Technological University of Denmark, Industrial Engineering and Management.

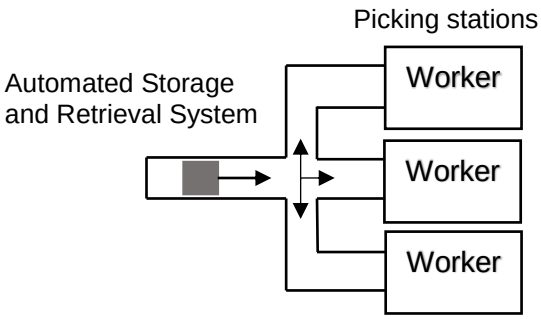
Teaser:

This concept combines cobots, Machine Learning and 3D scanning technologies to reduce worker fatigue from repetitive work at the picking stations from an Automated Storage and Retrieval System.

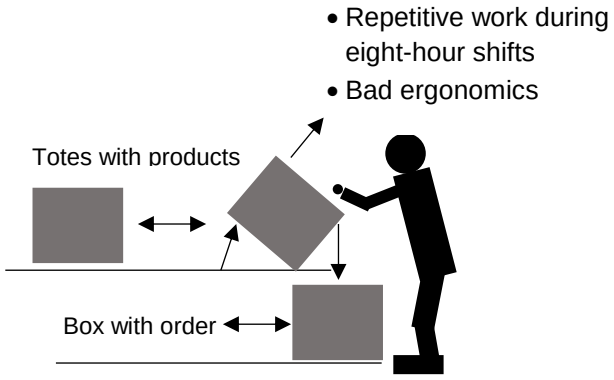
Description of the current challenges

This concept is developed to reduce worker fatigue from repetitive work and increase efficiency at the manual picking stations within an Automated Storage and Retrieval System (ASRS). In the ARSR the products are stored in totes either individually or in lots. The ASRS systems mostly contain a huge assortment and have thousands of picks every day, which put tremendous pressure on the workers. Even though the workers have tools for improving ergonomics such as variable platform height and anti-fatigue mats, the work is without doubt highly repetitive and uncomfortable. See the following sketches of the current set up.

With the huge volumes, the workers most likely work in two eight-hour shifts which include 2x15 min and 1x30 min break which yields a utilization of 87.5% without considered other disruptions. Replacing the workers with cobots will increase utilization close to 100%.



Sketch 1: The concept of an Automated Storage and Retrieval System (Top view)



Sketch 2: At the picking station the work is highly repetitive with bad ergonomics (Side view)

As the storing and transport of products is automated, the next step to reduce cost is to automate the picking. However, as the products are offered in any amounts from a single unit to whole lots and combined with the high variety of products, the picking system must be highly flexible. A fully automated system that handle this complexity in a robust and repeatable manner is not existing today.

Objectives

1. Reduce worker fatigue from repetitive work.
2. Reduce cost.
3. Increase efficiency.
4. Ensure consistent quality.

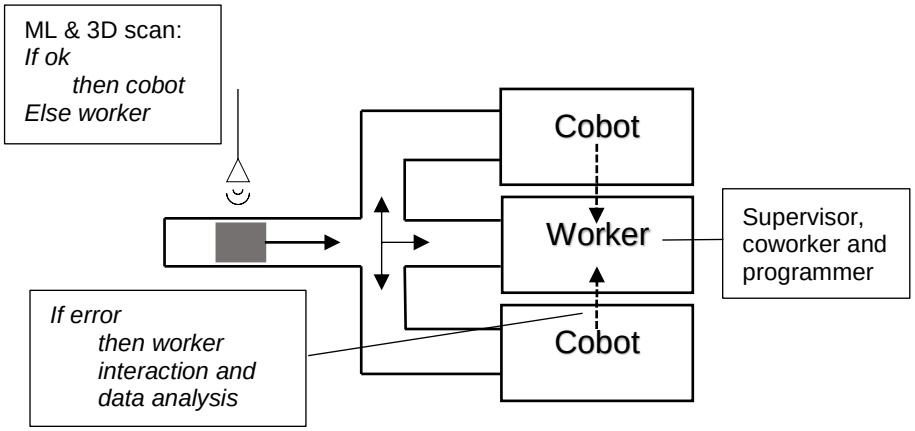
Challenges

1. Product variety is huge
2. Products are offered in any quantity
3. Picking must be flexible
4. Picking must be reliable

The solution

A short term available solution filling the gap between manual and fully automated picking can be a team of a worker, a number of cobots and advanced analytics to automate the picking.

The idea is to have the cobots and worker work side-by-side. Before the totes reaches the picking station the tote is scanned and analyzed to decide whether a cobot or a worker should do the pick. See sketch 3. Making the right decision will be of great importance to ensure high throughput. In this case Machine Learning algorithms (ML) evaluate whether the product should be picked by the cobot or worker by analyzing the probability of the cobot being able to grab the product. The analysis should be based on how the content is placed in the tote compared to historical data.

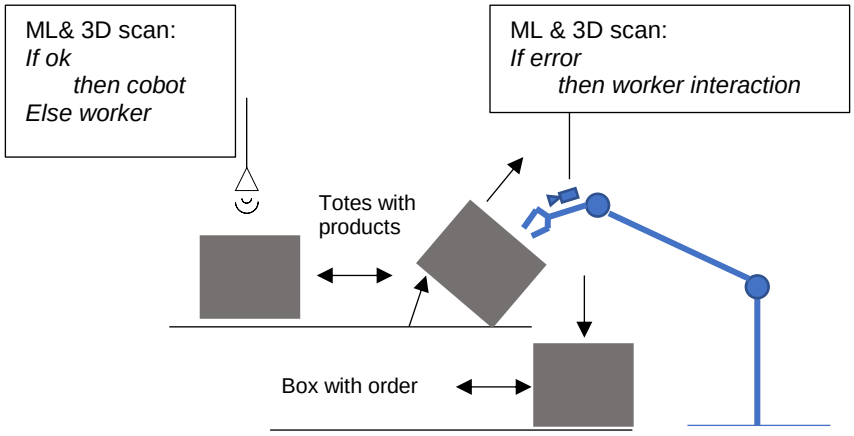


Sketch 3: Machine Learning and 3D scan allow the system to continuously become smarter by evaluating meta-data and actual performance (Top view)

An example is a tote with randomly placed cardboard boxes with dimensions LBH 10x5x5 cm. ML must then decide whether to direct the order to the worker or cobot. In the cases where the cobot should pick the product the cobot is equipped with 3D scanning hard- and software which the cobot can use to location the product. See sketch 4. A typical problem in warehousing is damaged packaging which the software must check as well.

In the case where the cobot cannot grab the products the worker is alerted. The worker can physically show/guide the robot to grab the products as the cobots can ‘learn-by-doing’. This interaction makes the worker both a supervisor, coworker and a programmer. The software further evaluates how much the worker should train the cobot to grab the product and if another gripper should be used. This decision must be based on the actual

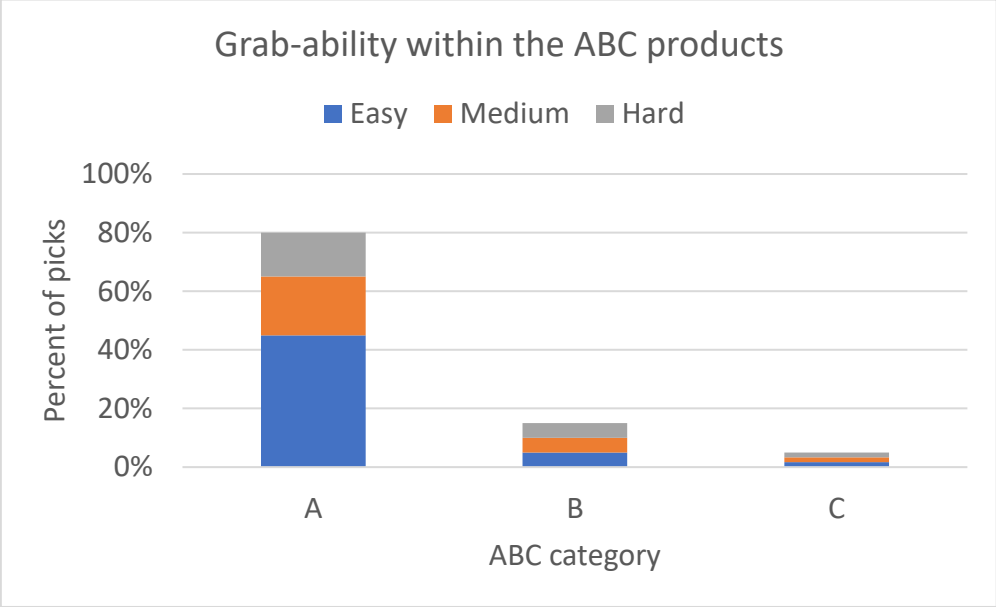
utilization to avoid unnecessary production stops. However, investing in training the cobots and algorithms on the low days will pay off during peak days.



Sketch 4: Machine Learning and 3D scan allow the system to continuously become smarter by evaluating meta-data and actual performance (Side view)

Continuously improving the data categorization

The combination of the ML, 3D scanning and the cobots will require the data handling system to categorize the products. E.g. as in the following graph.



The above figure illustrates the distribution of the products based on the Pareto Principle – the 80/20 rule. That 80% of the picks comes from 20% of the products. By categorizing the products further into how easy they are to grab (“grab-abilitiy”) the ML can decide whether the cobot or worker should handle the product. Every decision and pick will improve the categorization and ensure that the system continuously will become better.

Two important questions about the concept

What is smart about the ML add-on?

1. **ML can continuously improve the categorization based on meta-data and actual performance.**
2. **Better decisions will increase throughput.**
3. **ML is well developed.**

What is smart about the cobots?

1. **The cobots are flexible in the way that they can do other tasks when needed.**
2. **The cobots can be trained by low-skilled employees and does not need specific programming skills but can be programmed by physically moving the robot.**
3. **There is an established market for cobots.**

The smart way to implement the concept

For implementing this concept, it is suggested to focus on the easy A products first and let the system decide whether there is time for training the cobot on any given day to improve the categorization. This way the categorization will be continuously improved. As the cobots are linked to a central system it is only necessary to train one of the cobots as the system transfer the knowledge to the other cobots. Another option can be to start with a single cobot and test it at the specific system. If this test is offered by the manufacturer as a proof of concept there will be no risk for the customers, which is a good way to test the concept.

There is a great potential for cost reductions at the picking stations

The following customer business case is based on Danish labor cost. A worker cost ~17 EUR/hour(1) and with 1924 hours per year the labor cost per worker is ~33 000 EUR/year, which should make the payback time relatively short. However, from an investors perspective the Net Present Value (NPV) is often of greater interest. See table 1.

For an ASRS it should be fair to assume that ten workers are to be replaced when considering five picking stations and two shifts. This result in a potential saving of 330 000 EUR/year. As the size of the investment is uncertain the interval from 300-700 t EUR is investigated. For the NPV calculation is used a discount rate of 10% and a time horizon of five years. The investment is based on estimations of the prices of five cobots, ML and 3D scan.

Table 1: Five year Net Present Value and Discounted Return on Investment (DRoI) for replacing two shifts with five workers.

	10 workers	
Investment	**NPV**	**DRoI**
[t EUR]	[t EUR]	[%]
300	2,078	693%
400	1,599	400%
500	1,120	224%
600	641	107%
700	162	23%

The investment is truly favorable. Ignoring the time value of money, the investment of 700 t EUR has a pay back time of less than three years. However, critics might say that only companies with big volumes have ASRS. In response to that, the concept can be easily transferred to other types of warehousing when combining the concept with AGVs.

From the manufacturer's perspective, the potential for cost reductions for the customers, will make it possible to charge premium prices whether the revenue stream will be based on leasing or traditional sales. In addition to ownership, value is in the training of the ML which foster discussion about who should own the system. This perspective weighs towards leasing the system to the customers, however the customers do probably not want to give away the valuable data. A further perspective for the manufacturer is that it is a concept that is fast to test in a pilot project at a real customer application.

Further perspectives to the concept

The argument for this concept increases with the amount of 'easy to grab' products as it will be easier to replace workers. This can e.g. be achieved by placing the products in the totes smart. Furthermore, the concept can be used within any type of warehousing and can work together with e.g. AGVs in existing setup. The cobots are flexible and can be customized to the existing physical conditions which almost make it a plug-and-play solution even though it requires complicated software.

This is a great idea because:

1. It reduces worker fatigue while improving throughput and reducing cost.
2. It takes advantage of easy-to-program cobots.
    a. Does not require experts to program robots in the daily operations.
3. The cobots are flexible and can be moved to other tasks.
4. There is no need to hire extra people for operations.
5. There is no need to adapt the setting.
    a. No need for security fence.
    b. The cobots can be mounted on a table with a minimal footprint.
6. It can be implemented fast using a combination of workers and existing cobots and focus on the add-ons, ML and software algorithms, which is what makes this concept innovative.

However, the idea requires:

1. In the development, competences within the technologies.
2. Training of the ML algorithm.
3. Structured and reliable master data.

Conclusion

This concept can be the entry to real use of cobots in the industry as the technologies are well developed and there is a great investment opportunity for both customer and manufacturer. The strength of the concept is the flexibility, daily operations can be performed by low skilled workers, and that the system continuously becomes better while reducing fatigue from repetitive work.

References

(1) https://www.3f.dk/fagforening/fag/lagerarbejder-(industri)/faglaerteoverenskomsten