Object Recognition for an Automated Production Process for Electrical Panel Cabinets

Kwan Suppaiboonsuk

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Executive Summary

The Big Hairy Audacious Goal (BHAG) for Modderkolk Projects & Maintenance B.V. is to have 90% of electrical panel cabinets produced by a fully autonomous production line by the year 2028. Implementing a robotic production line allows for benefits in production lead time, quality assurance, error reduction, and possibilities for manpower allocation. This can help the company to maintain it's competitive edge and keep up with customer demands with respect to time and resources. This report details the initial proof of concept in applying object recognition technology as a step towards a fully-automated production line.

1 Background Information

1.1 Company

Modderkolk Projects & Maintenance B.V. is an electro-technical installation company established in 1921 in Wijchen. It is a family company of around 250 employees that specializes in electrical engineering and industrial automation in three different markets: water management, industry, and healthcare. The company provides projects and services that include building, maintaining, and improving various types of electrical panel cabinets. Examples of such cabinets are switch boxes, control cabinets, light and power distribution devices, and terminal boxes.

The company strives to become an eternally flourishing business through the ‘art of technique’, which is the optimal use of time, finances, and energy resources. This means that continuous investments are made to help improve people and processes, which eventually benefits customers as well. The business model revolves around strengthening customer relationships, such that they become business partners. These lasting relationships are important in driving the company’s economic engine, with each valuable correspondence being a key driver. A product or service can be sold once to a customer, but if a partnership is formed, there is recurrent revenue.

Modderkolk’s customers vary per market sectors. For the water management sector, customers are municipalities in the Netherlands. For the industrial sector, customers range from food production to energy companies. For the healthcare sector, customers are usually hospitals. Even though Modderkolk serves a wide range of customers, they all value projects and services being completed on time or in a timely manner. Apart from that, it is also important that the projects or services are completed within budgets and within their scopes.

1.2 Production Process

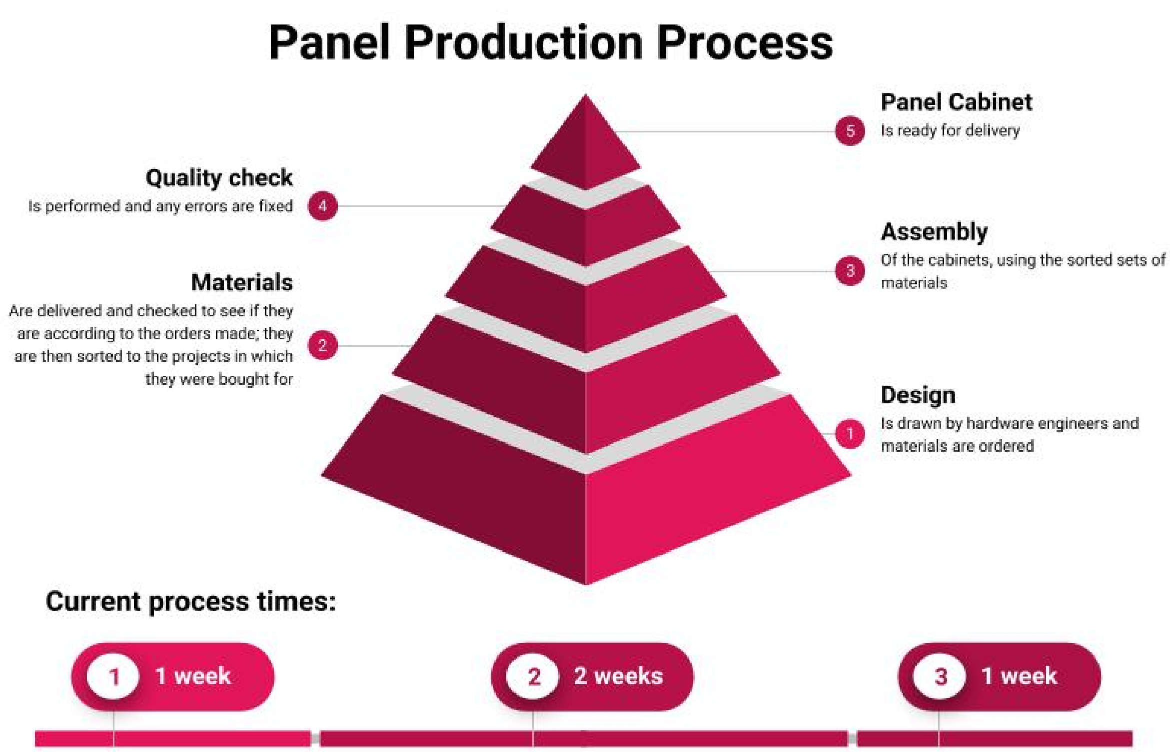

Figure 1: Bottom-up pyramid of production process for a panel cabinet and average times for the three main stages.

In Figure 1 the process of producing an electrical panel cabinet can be seen in details. The production process consists of three main stages: design, material-handling, and assembly. For an average cabinet, the design process takes approximately a week. The material-handling process, which involves ordering and checking the incoming materials, can require up to two weeks. The assembly process requires approximately a week. Altogether, the average cabinet has a production time of around a month. Upon completion, quality check is performed prior to packaging. There is an average of 3 errors per cabinet, which leads to approximately an hour of recovery time.

2 Project

2.1 Vision

As the production process is currently done manually, Modderkolk aims to develop an automated production line for electrical panel cabinets. The Big Hairy Audacious Goal (BHAG) is to have 90% of the production process automated by 2028. Having a fully automated production line reduces product lead time and ensures customers' needs for fast product development and delivery times (such that projects can be completed on time and within budgets). Imagine a machine that can work 24/7 as opposed to a human working an 8-hour work day. In addition to this, the machine is also able to perform at a faster rate than humans. This could possibly reduce the product lead time of 4 weeks to only 3 days - 1 day for each of the main stage of production!

Automation will also allow the company to reap other benefits, such as, quality assurance, error reduction, and possibilities for manpower allocation. As the amount of errors created by a robot is expected to be much less than that of humans, quality can be assured. From the removal of human errors, turnover times can expect a reduction. By having a machine automating the repetitive tasks, manpower can be better allocated. As more cabinets are built at a faster rate, more maintenance mechanics will be needed. Overall, this will give Modderkolk a competitive advantage over competitors and help support the company in becoming an eternally flourishing company.

2.2 Approach

To get to a fully automated production process, the three main stages of the production process needs to be innovated. For the design stage, there is already an ongoing initiative within the company known as Typical Manager. This initiative is developing a system to reduce the time of the engineering process through standardization of designs. For the other two stages of materials handling and cabinet assembly, robotics technology can be applied.

To implement robotics such that actions can be performed, the robot first has to be able to recognize the object, as well as it's location. Prior to actualizing movements, the robot needs to learn the motions, then in combination with programmed logic and control, actions can be realized.

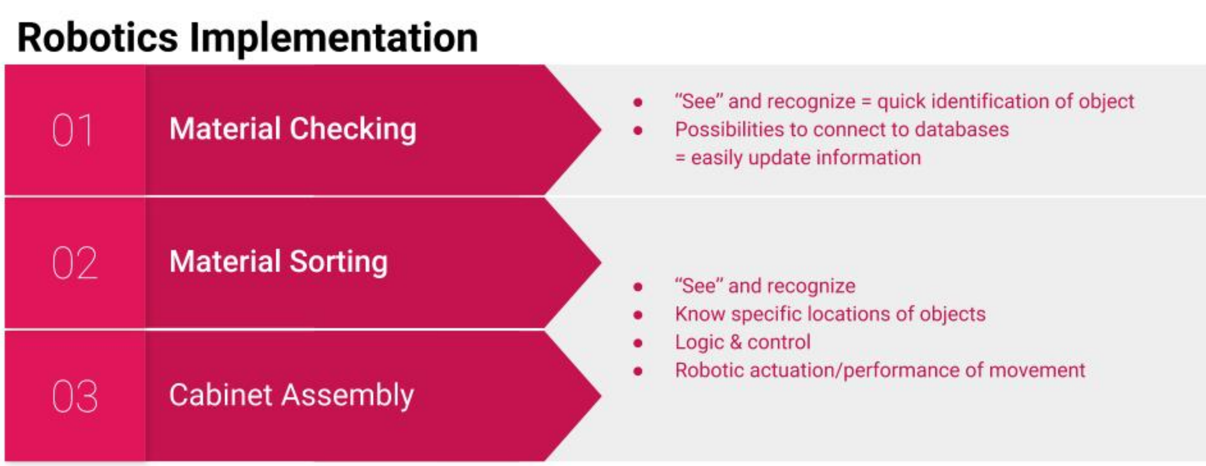

Figure 2: How robotics implementation can help perform to perform actions within the production process. This is a progression of object recognition system to robotic assembly.

In Figure 2 the actions performed in material handling and cabinet assembly are listed, with material handling consisting of two actions: checking and sorting. The material-checking process confirms that the received materials match with what was ordered, while the sorting process separates the materials into the correct bin, according to their respective project numbers.

2.3 Proof of Concept

The development will begin with the object recognition system, with the scope set to 9 main objects that are in a standard cabinet. These objects are electrical components such as relays and circuit breakers. The proof of concept will be a prototype tested on the material-handling process, as there are less financial risks involved for deployment within this phase. As object recognition is only part of the software for robotics, actually developing a robot that performs sorting action is currently out of the scope for this proof of concept. The prototype should assist logistics employees by automating the material-checking process and telling them where the delivered materials should be sorted to.

In order to be able to build an object recognition system, the technologies of Computer Vision and Deep Learning will be utilized. More specifically, edge detection algorithms will be used and Convolutional Neural Networks will be trained. To successfully apply these technology, image data of the components will need to be collected.

Deliverables will consist of the object recognition Application Programming Interface (API), user guide and documentation, and a technology roadmap. The technology roadmap should help to strategize the implementation and guide the company towards the BHAG. These are to be delivered by the end of July 2019, which is the end of the New Engineers academic calendar.

2.3.1 Material Handling Process

As the proof of concept will be applied to a part of the material-handling process, it is useful to have an understanding of what exactly happens for the material checking and sorting procedures. The process done by logistical employees follows the steps below:

1. Receive delivered package(s) of material(s) from suppliers.
2. Unpack material(s) from boxes.
3. Check that delivered material(s) and amount matches content on the receipt.
4. Fill in the receipt number in computer system to get an internal number that is linked to the project the material(s) were bought for.
5. Mark that materials are received and input date. Information is updated and project managers can see which objects have been processed.
6. From the internal number, print an internal receipt to find out which project the delivered material(s) should be sorted to and who the contact person is (eg. project manager, hardware engineer).
7. Sort material(s) and place it in the correct designated project cart.

2.3.2 Object Recognition System

The object recognition system will automate and remove steps 3 to 6, reducing the amount of time needed for this process by almost half.

For the technical specifications of the object recognition system, the object bar code and the object “face” - unique “look” of object- are used as input to drive the logic for the recognition. This is because they are two of the most distinct features for quick identification of a component. In Figure 3, a decision tree model shows the logic. As this is a proof of concept, it is necessary to involve human inputs, such that machine errors can be caught and data can be gathered for further machine learning.

This decision system is implemented within the API. A data flow diagram can be found in Figure 4, showing how the API interacts with other interfaces in order get from an object to controlling the material check and displaying to the user where the object should be sorted to.

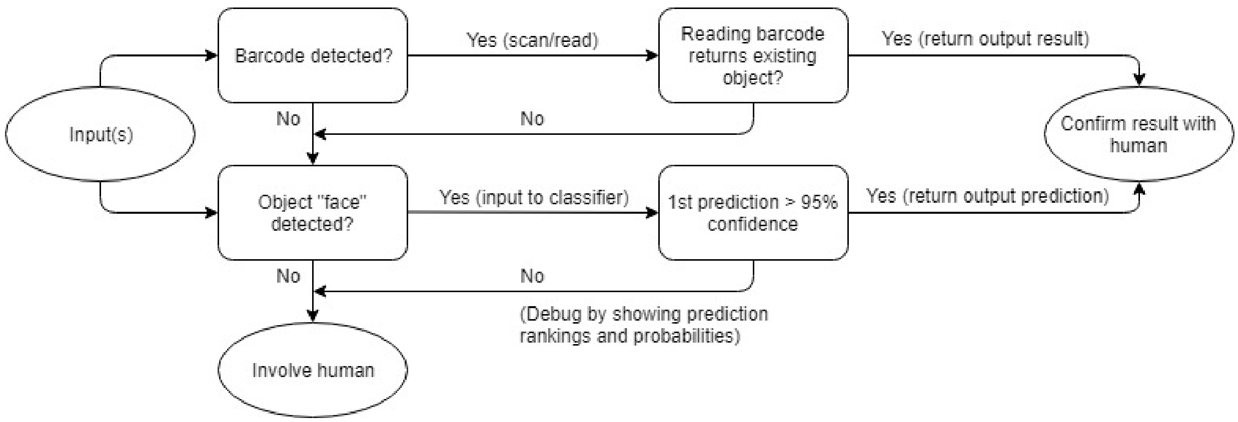

Figure 3: Decision tree model of object recognition system. The ellipses signify actions taken/to take, while boxes signify the deciding factors.

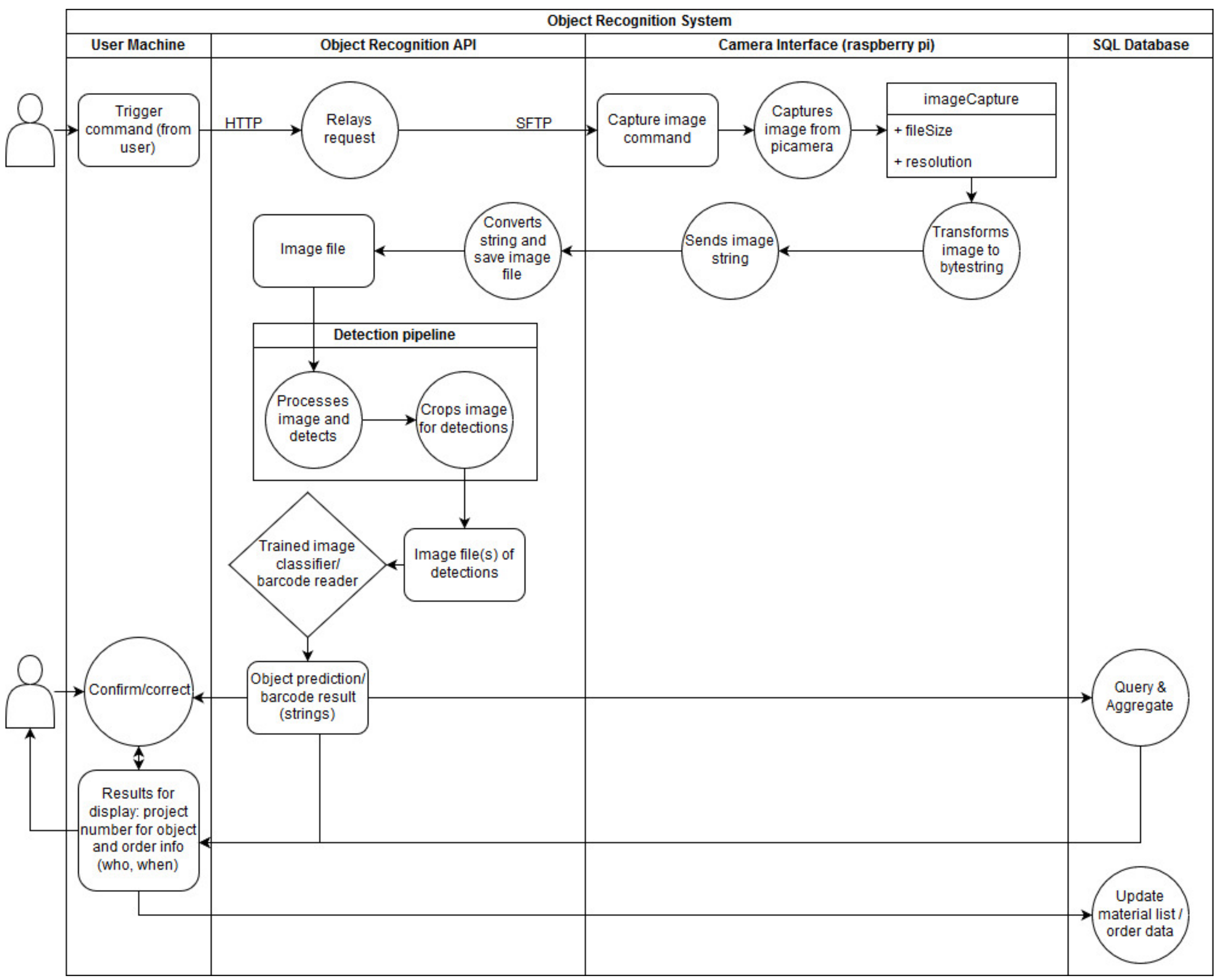

Figure 4: Data flow diagram, showing how data is to be sent between the different interfaces.

With the system of this proof of concept, the steps that the logistical employees have to take now are:

1. Receive delivered package(s) of material(s) from suppliers.
2. Unpack material(s) from boxes.
3. Put object under camera and send command for system to attempt to recognize, then wait a maximum of 10

seconds.

4. Receive the object prediction and list of projects in which object was ordered for (sorted by first order date).
5. Put object in cart for project.

Beyond this process and apart from this proof of concept being a basis for a robotics production line, it can also be a basis for other big data and machine learning projects within Modderkolk. Innovation builds on innovation. This could lead to integration with predictive maintenance systems or it could also lead to the use of an electrical component recognition system to aid maintenance employees in identifying broken components. With a spirit of innovation and discovery, this proof of concept is an exploration of how object recognition can be used to improve processes.

3 Individual Ambitions & Developments

3.1 Aspirations

I aspire to grow into the role of an innovation manager - to work towards finding value in ideas/concepts and bringing it into the environment in such a way that impact can be made. Meanwhile, I would like to continue to improve my skills as a developer/engineer. This project is a great opportunity for me to do both, as I get to start development from the beginning, as well as create strategies for the future.

3.2 Skills Development

Based on discussion with New Engineers (Vincent) and company mentors, a list of skills in which I need to develop has been made.

As an engineer, the skills that I need to further develop are abstract thinking and creating. The knowledge that I need for my project (and for further career development) are in the following areas: computer vision, electrical signals processing, deep learning, and process design. The first three topics are needed in order to be able to successfully build the object recognition system, while process design is needed for integrating all the system functionalities and implementing it.

Building on those skills, to become an innovation manager, I need to further develop my leadership skills and continue to build an attitude of curiosity. The knowledge that I need are in innovation and change management and Scaling Up.

Apart from the skills mentioned above, the plan is to also build effective communication skills.

A detailed plan for when and how I planned to develop these skills can be found in Appendix A, as well as the challenges expected.

Appendix A

From the session on learning style in week 1, I am a person who learns best through discovery and knowledge acquisition. This has been taken into account when making this plan. In the table below, the weeks signify the duration in which I will be continuously learning the topics; although not all topics are equally divided throughout each "weeks", which include preparation and post-week work as well.

Table 1: Skills & Knowledge to Acquire

What?	When? (New Engineers week)	How?
Skills & Attitudes		
- Abstract thinking		"What does success look like in...?"
- Creating	1-8	Developing system for project
- Leadership	1-8	Being more proactive and confident in leadership; Use New Engineers week to develop and get feedback
- Curiosity	2-8	Reading, asking questions; to be more determined
- Communication	2-8	Visual Thinking (materials from Lejla); communication workshops
Knowledge		
- Computer Vision	1-8	Online tutorials; improving through trial and error; reading different algorithms/methods online
- Electrical signals processing	1-8	Same as above.
- Deep learning		Same as above + Coursera and expert help in NE weeks
- Process design	2-7	Application in company project and Value@Travel project
- Innovation and change management	2-8	Design Thinking Communicating to users, in order to apply project; communication of vision
- Scaling Up	1-5	Expert knowledge from New Engineers; giving presentation about it at company

Some challenges for me as I grow into the role of innovation manager is in having confidence - confidence to lead and confidence in my technical skills. It will also be a challenge for me to also be aware of when I need to take a step back and look at things on a more abstract level, as I tend to sometimes get too caught up in the details. Communicating through language barriers is also a challenge for me to overcome. Even though I am starting to feel more comfortable with the Dutch language now, it is still a challenge for me to overcome the shyness and to reach the same level of rapport as in English. Within communication, a challenge is also to be able to switch to the right level of communication depending on who I am speaking to, such that I can effectively deliver my message. These are challenges I will have to overcome by the end of the New Engineers year.