VLAIO-TETRA
Machine Vision for Quality Control
Survey Summary & Use Cases

Contents

1 Introduction

The aim of this report is to provide a brief overview of the available knowledge, potential applications, and knowledge need of the companies involved in the TETRA-MV4QC project. The aim of the project is to accelerate the implementation of machine vision for quality control in companies by collecting, structuring, and disseminating the state of the art and innovative technologies on this topic. As a first step towards this aim, insights were gained in (i) the knowledge on machine vision for quality control that is already present in the companies, (ii) the potential applications the companies aim to realize in their infrastructure, (iii) the need for required extra knowledge, based on the knowledge that is already present, to successfully address the potential applications. For this purpose, a survey is held that was sent to all companies that are involved in the project. The summary of this survey is given in this report. In a second step, a kick-off meeting was held with all companies, that are part of the user group of the project, where some specific use cases were defined that will be tackled during the project. To maximize the relevance of the project and the potential to disseminate the project results to a broad target group, both suppliers and integrators of machine vision systems are present in the project beside the potential end users of machine vision applications. All the companies that are involved in the project are listed below and summarized in the next section.

Participating companies		
Suppliers		
Beckhoff Automation	IDS	Isotron
Integrators		
Covicon	Vintecc	CTRL-Engineering
End users		
Actemium	Catael	Marelec
ILVO	KoMotion	LET
Altachem	Decospan	Deprez Handling Solutions
Milcobel	Melexis	MCAM
TVH Parts	Vandemoortele	Ysco

Table 1: Participating companies of the TETRA project Machine Vision for Quality Control

2 Participating companies

At the start of the project, nineteen companies were participating in the project and are eager to actively contribute to the overall aim of the project. The group includes suppliers, integrators and end users of machine vision applications. A summary of each of them is provided below.

2.1 Suppliers

To boost the relevance of the project on an industrial level, some suppliers of machine vision products were invited to participate in the project. These suppliers typically have a vast experience in the possibilities of the hard- and software they provide and can contribute in the collection and structuring of the available technology on the market.

Beckhoff Automation is a company specialized in PC based automation technology. Beckhoff's product range includes Industrial PCs, I/O and fieldbus components, drive technology, automation software and automation without control cabinets. Recently, the company has started to market AI/vision systems for integration in industrial environments. By incorporating image processing and machine vision to the existing universal control platform, Beckhoff simplifies integration in industrial environments. Synchronization with the existing control systems results in a low latency, precise, integrated machine vision solution. They offer their own hardware packages for Machine Vision applications.

IDS is a company specialized in high-performance, easy to handle USB, GigE and 3D cameras with a wide range of sensors and variants. They also designed a compact embedded vision platform for industrial applications with artificial intelligence, called IDS NXT. The goal of NXT is to offer an easy-to-use yet flexible system that can be used to implement all steps of a vision solution, from image acquisition, image analysis and processing, to the control of industrial production machines. The cameras can be used in a wide variety of applications: robotics, medical technology, traffic monitoring, security, etc.

Isotron is a company specialized in automation solutions in industrial environments. Isotron combines their expertise with products from leading companies. The expertise is focused on 4 different automation applications namely:

1. Smart machines: integration of IoT and industry 4.0 in machines
2. Machine vision: integration of cameras and readers in combination with machine vision techniques
3. Parameter control: integration of the right software and hardware to obtain reliable measurements. Here, the data management of validated measurements is key.
4. Machine safety: integration of selected security products selected by Isotron in combination with their expertise

2.2 Integrators

To further boost the relevance of the project on an industrial level, also integrators of machine vision applications were invited to participate in the project. These integrators typically have a vast

experience in the integration of machine vision applications in the industry and have a profound view on the possibilities and challenges of the current available technology. They can definitely add value in the collection and structuring of the available knowledge on the pragmatic implementation of machine vision in an industrial setting. The technology of these companies will serve as a starting point, yet the project partners will perform a broader analysis to arrive at a comprehensive survey of the current machine vision solutions available on the market.

Covicon is a start-up company specialized in the integration of custom made machine vision applications in industrial machines. They mainly offer expertise. Tests, on the most optimal machine vision setup, can be carried out in their lab. They also provide reliable, high-quality software with the required diagnostics.

Vintecc is a company specialized in model-based software, PLC programming and IoT applications. The goal is to accelerate the automation process by implementing agile software design and state-of-the-art technologies. Vintecc does not only create vision algorithms, they provide the infrastructure to deploy and maintain these algorithms in a production environment.

CTRL-Engineering is an engineering company that tailors a custom fit solution that makes a companie's process efficient, fast and smart. Mechatronics is the core of their business. They leverage years of experience in mechanical and software concepting, development and testing across major industries like automotive and production technology.

2.3 End users

And last but not least, the core group that will eventually adopt the machine vision applications are the end users. They are faced with the problems of manual quality control and have a profound view on what they expect from a machine vision system and what added value this can bring in their business.

Actemium designs, realizes and supports industrial processes for their customers. The company also provides advice on how to improve existing industrial processes. They focus on design and maintenance of complete electrical, mechanical installations; industry-specific solutions for IT-infrastructure and automation of production environments including machine vision.

Altachem is a world leader in the development and production of valves, application tools and accessories for 1K PU foam in pressure canisters

Catael specializes in industrial software applications, in particular PLC based solutions. The services they provide are mainly focused on industrial automation, industrial IT, electrical engineering, robotics and machine construction.

Decospan is the European market leader in the processing of veneer wood. Furniture panels and parquet are some of the products the company offers.

Deprez Handling Solutions is a company that builds machines. They are responsible for the design, its installation and integration throughout the production line. Some of the projects they are involved in are in the food or bulk goods industry.

ILVO is an independent scientific research center funded by the Flemish government. Their goal is to contribute to making the agriculture, fishery and agri-food sector more sustainable. In concrete terms, this means that they conduct research into new and existing methods for optimizing and improving sustainability.

KoMotion is a company that integrates automated production steps in the production process. They mainly focus on designing and building machines, incorporating automation and robotics. They also have software knowledge regarding industrial machines, more in particular the PLC programming and the data logging.

LET is a company that is active both locally and internationally in the field of calibration for both headlights and driver assistance systems. In addition, the company is also specialized in the design, production and calibration of electro-optical measuring devices.

Marelec uses state-of-the-art weighing technology and advanced software to design and build fully accurate and fast graders. They offer grading solutions tailored to customers' specific needs. These can be used for entire birds or cut-up parts, fresh or frozen products. Their graders can sort different sizes into fixed-weight trays or bulk packs. All equipment is built with robustness in mind and meets high standards of hygiene.

Milcobel is an important Belgian dairy cooperative that collects the milk from our dairy farms and processes it into high-quality dairy products such as consumer cheese, ingredient cheese, milk powder, ice cream, butter, cream and whey.

Melexis is a global provider of microelectronic semiconductor solutions. Some of these solutions are semiconductor integrated circuits for various sensor technologies, drivers and transceivers.

MCAM is a leading global manufacturer of high-performance thermoplastics and composites in the form of semi-finished and finished parts. The products are used in a wide range of applications and industries, from aerospace to bioprocessing.

TVH Parts is a global player in parts and accessories for forklifts, industrial vehicles, construction and agricultural machinery.

Vandemoortele is a Belgian company that has 2 business lines. The first is bakery products and the second line is margarine, culinary oils and fats. They are the European market leader in both of their core activities.

Ysco is part of the Belgian dairy cooperative Milcobel. The company mainly focuses on producing ice cream in all shapes and weights.

3 Summary of the survey

In order to have a good overview of the needs and expectations of the participating companies, a survey was conducted that aimed at gaining insights in (i) the knowledge on machine vision for quality control that is already present in the companies, (ii) the potential applications the companies aim to realize in their infrastructure, (iii) the need for required extra knowledge, based on the knowledge that is already present, to successfully address the potential applications. A summary of this survey is provided below.

3.1 Available knowledge

The available knowledge largely depends on the company's relationship with machine vision. Suppliers and integrators typically have a broad knowledge regarding machine vision and have years of experience in development and integration of machine vision systems in industry. Their pragmatic knowledge will definitely benefit the project and the dissemination of the project results to a broad target group. In addition to suppliers and integrators, there are end users of machine vision applications. These can generally be divided into two main groups when it comes to available knowledge: companies that have little or no experience in machine vision and companies that do have experience in machine vision and even have some operating applications in their business. 33% of the end users participating in the project have personnel with machine vision knowledge. In concrete terms, this concerns knowledge about object detection and optical character recognition. 33% of the customers participating in the project have an operating machine vision system. The other 67% do not yet have one or have one under construction. The machine vision systems already present in those 3 companies have various applications. One of those companies has a system that detects broken Cornetto biscuits. Another company has an EyePro system that determines the dimensions and color of donuts. The last of those 3 has a visual inspection system in tape and reel machines. The companies that have some experience with machine vision can be further divided into companies that have basic knowledge of the available hardware and the usage of non data-driven systems, and companies that have a broader knowledge that also touches on data-driven systems using neural networks.

3.2 Potential application

The main reason for the companies to participate in the project is because they have a clear idea of the potential applications of machine vision for quality control that could improve their production and lower costs. The types of application are very diverse, but can generally be summarized in a select number of categories.

1. **Detection of defects:** The detection of damage is a frequently mentioned topic, but can be interpreted very broadly. Some concrete applications are detection of bends in flat steel sheets, detection of poorly painted surfaces, detection of broken pallets or the detection of damaged wooden or plastic crates, detection of damaged or non-readable printing on packaging.

2. **Detection of presence/absence:** The detection of the presence or absence of specific objects is also often mentioned in the survey. Some concrete applications are the detection of empty crates (absence of foreign objects such as screws and bolts), the detection of enough topping on edibles (presence of enough coating on donuts, seeds on buns, nuts and chocolate sauce on Cornetto's) or the detection of tomato presence outside the packaging.

3. **Determination of dimensions:** Dimension determination is very relevant in some production processes. Therefore it is also mentioned a couple of times in the survey. Some use the information to obtain a distribution of a particular product, others use the information to categorize the quality of the product. A concrete application is dimension determination of potatoes, carrots, onions, pastry products and fish.

4. **Determination of composition:** Composition determination is not as frequently mentioned as the other 3 types of applications. A rather concrete application is the fat absorption of donuts after frying.

3.3 Knowledge needs

Looking at the potential applications the companies aim to integrate in their business and the knowledge currently available, a need for extra pragmatic knowledge can be defined to successfully integrate the applications. The knowledge need is twofold, resulting from the fact that customers can be divided in a first group that does not have much experience in machine vision for quality control and a second group that does have experience.

1. The first group has a need for knowledge of the existing hardware devices and software packages available on the market to solve their machine vision problem. The companies are interested to gain insights in the types of lighting, cameras and lenses they can use in different circumstances and for different applications. The companies want to experiment with different types of cameras and lighting techniques in a workshop. They want to see what the influence of this is on the image quality. Visualizing the connection between the hardware part and the software part is also very informative within this group.

2. The second group has a need for knowledge on more advanced and custom machine vision applications. They are especially interested in the possibilities and implementation of data-driven machine vision techniques. They want to gain experience in the offer on plug-and-play solutions for data-driven machine vision on the market and in implementing custom data-driven systems using open-source software. The companies in this group want to gain experience in applying various pre-processing techniques in order to enhance the camera images. When data is captured, it must obviously be stored. An analysis between the different advantages and disadvantages of data platform types can also provide important insights for the companies. The design and training of a deep learning model for machine vision purposes such as classification, object detection, pattern recognition, etc. is something they would like to see developed in a workshop.

In general, beside the interest in gaining technical experience, most of the companies are also interested in networking with other companies that face machine vision problems to learn form each other or that have experience in solving these problems. Having companies in different branches of industry certainly benefits the co-creation within the group.

4 Defined use cases

At the kick-off meeting of the project, the companies were divided into several groups to discuss about the use cases that will be addressed in the project. The aim is to define the use cases so that they cover a broad set of machine vision techniques and can be generalized to most of the aimed applications of the companies in the target group. Looking at the required knowledge of these companies, a good balance is preserved between the usage of both plug-and-play and open source applications, as well as between the usage of non data-driven and data-driven techniques. Some very interesting and specific use cases were defined that comply to these requirements and are described below.

4.1 C1: Detection of surface damage on flat sheets

Motivation Surface damage can occur in many forms: dents, scratches, color difference, bad flatness, etc. Also the type of material can differ: steel, plastic, wood, etc. Control of this damage is currently largely done manually which can cause rather subjective observations. As the production of sheets is mostly a continuous process, it is also difficult to have a permanent manual control of the sheets. Automating the quality control process could eliminate subjective and erroneous behavior and could provide a continuous monitoring of the produced sheets.

Objectives The objective of this case is to detect a variety of surface defects (scratches, dents, scuffs, etc.) on a flat sheets (plastic, steel, paint coating, etc.). Correct lighting is very important here, and it should be taken into account that sheets can have a strong gloss. The difficulty lies in the subtle variations in the color of the sheets and defects.

Methodology The first step is to determine a suitable setup to detect surface damage. Here, the emphasis is mainly on the correct lighting technique. After that, data can be collected and labeled. Data augmentation can be used due to the lack of defects. The data can then be used to apply both non data-driven and data-driven techniques. The quality of the material can be classified into different quality categories.

Insights Finding an optimal lighting setup for the detection of surface damage is not obvious. A comparison between the different lighting techniques can therefore provide many useful insights. The labeling of the data will also be a challenge as the differences in color and defects can be very subtle. Hence, insights on data labeling techniques could be obtained in this use case.

4.2 C2: Detection of the optimal cut line for chicory

Motivation After the harvesting of the chicory, the roots need to be removed. This is done automatically by a cutting machine. The laborers, who clean the chicory, then need to determine for each sample if it needs to be further trimmed or not. This determination is time-consuming and subjective. Therefore, implementing machine vision in this case will help the robustness as well as the efficiency of detecting the optimal cut line.

Objectives The goal of this case is two-fold. First, the optimal cut line detection will help in pre-eliminating the chicory who do not need further trimming. This will help the laborers in their efficiency during the job because not all the chicory needs to be controlled. Last, detecting the

optimal cut line by the machine vision system can help the cutting machine to identify where it needs to cut the chicory. This will result in a significant reduction of bad trimmed chicory.

Methodology A camera setup is already established and has already been used to record chicory on a conveyor belt. The optimal cut line is drawn on this data and is therefore already labeled. A data-driven technique is used to first predict if a chicory is well cut or not. Subsequently, another data-driven technique is trained to detect the optimal cut line on a chicory.

Insights Some useful insights that this case can provide is the detection of an optimal cut line, because this task is frequently occurring for all sorts of industrial fruits and vegetables handling.

4.3 C3: Inline determination of the length distribution of fish by category

Motivation The inline determination of the length distribution per fish species mainly has an ecological purpose. Namely, to better map the fish population in the North Sea and gain insights into overfishing of certain species.

Objectives This case aims to determine the length distribution of fish on a conveyor belt per species. The fish must be detected after which the species and length of the fish must be determined. The difficulty lies in the fact that the fish can all be on top of each other, that species can be difficult to distinguish and that the lighting on a boat is not always optimal.

Methodology A camera setup is already established and has already been used to record footage of fish on a conveyor belt per species. As a result, labeled (big) data are already present. There is currently no exposure technique available. First, the entire fish should be detected on the images. Then the detected fish should be labeled by category. Finally, the length of the fish is determined using camera calibration. Therefore, actual fish measurements must be performed to train length measurements. The data already present can be used to apply data-driven techniques. Finally, an economic evaluation can be made.

Insights Insights can be gathered on how a neural network is trained and validated when using big data. In addition, a certain exposure technique, for example using homogeneous light, can be used to determine its influence on the accuracy of the predictions. Also, insights can be obtained in the detection of objects in a chaotic environment as in reality, all fish can overlap on the conveyor belt.

4.4 C4: Determination of the proper functioning of a LED display

Motivation The testing of LED displays is currently done in a test tower by an employee. That employee tests each display individually. Testing consists of plugging the display and checking whether the correct LEDs light up. By implementing machine vision, the employee's task is reduced to placing the display at the test location due to which he has additional time for other tasks. As a result, the quality control for each piece can be guaranteed.

Objectives This case aims to determine if each LED light in a display works and also maintains its function for a certain amount of time. The displays are standard and the contrast of the background with the LED lights is very clear. The difficulty lies in the fact that the LED lights are behind glass, which creates reflection.

Methodology First and foremost, data must be captured. This can be done by placing a camera in a test tower that takes an image of each test. The displays are nicely delineated and can be perfectly distinguished from the background. Testing consists of checking whether certain LEDs light up on the display and what color they have. There is also a more complex display that has more LEDs and a tachometer. Here it would be interesting to link the position of the meter to a certain speed. The labeled data will be used to apply data-driven techniques. Finally, an economic evaluation can be made.

Insights Important insights that can be gained from this case are locating different parts and checking the status of these parts at the same time. Determining the status of moving parts, such as the tachometer, is also interesting.

4.5 C5: Inline determination of the fat absorption of donuts after frying

Motivation Fat absorption is an important characteristic for determining the quality of donuts. However, this cannot be determined visually. Currently it is difficult to determine the fat level inline and correctly. The appearance of glaze on donuts with a too-high fat level leads to complaints. With the help of hyperspectral cameras, it is possible to determine the fat level. Fat reduction, therefore, leads to cost reduction.

Objectives This case aims to determine the fat content of donuts that come out of the deep fryer at 20,000 per hour. Donuts consist primarily of dough and butter. Therefore, the intention is to determine the percentage of fat as well as the decrease in percentage over time. The difficulty lies in the fact that the fat content cannot be determined by the naked eye.

Methodology Dough balls or donuts with varying degrees (0-50%) of fat are used for calibration. Then the determination of the spectrum of fat can be determined with a hyperspectral camera. Subsequently, an exposure technique and camera, set to the specific spectrum, can be determined. The influence of the fat level can then be determined on the camera images. The data can then be used to apply both non data-driven and data-driven techniques. Finally, an economic evaluation can be made of all applied techniques.

Insights Important insights that can be gained from this use case is the use of hyperspectral data to determine the composition. It is also interesting to see this applied inline.

4.6 C6: Detection of a sufficient presence of nuts and sauce on Cornettos

Motivation The control is usually done manually from a sample of the produced Cornettos. For this reason, it is usually too late to notice when defects occur. This leads not only to financial losses but also to loss of image with the customer. Ideally, continuous inline monitoring using Machine Vision would lead to a reduction in financial losses and no image damage.

Objectives The purpose of this case is to determine if there are enough nuts and sauce in the Cornettos just before placing the cardboard lid. The aim is to obtain a degree of coverage of the nuts and an estimate of the thickness of the sauce. The difficulty lies in determining the thickness of the sauce layer.

Methodology The first step is choosing a camera and exposure technique. Experts within the company will then explain which Cornettos fall under defects and which are correctly produced. Subsequently, the data will be collected and labeled. The data can then be used to apply both non-data-driven and data-driven techniques. Finally, an economic evaluation of all applied techniques can be made.

Insights Important insights that can be gained from this use case is the application of different techniques to concrete detection problems. It is also interesting to make a cost-benefit analysis (accuracy gain, Return on Investment, etc.) between the different techniques.

Beside these interesting use cases, also optical character recognition (OCR) and position determination are relevant applications for the participating companies.

5 Conclusion

To conclude this report, we can clearly state that all participating companies are eager to gain knowledge on machine vision for quality control or expand their current knowledge. The aims of the companies about the exact knowledge they want to gain is diverse and can be generally divided into basic knowledge on existing plug-and-play hard and software and more advanced knowledge on the implementation of custom data-driven systems using open source software. To accommodate this need, some specific use cases were defined together with the participating companies that will be addressed in the project. All the knowledge that will be gained from these use cases will be collected, structured, and disseminated in a pragmatic way to the companies of the target group in the form of reports, seminars, and workshops. This is in order to accelerate the implementation of machine vision for quality control in their business.