Industry 4.0:

Evaluation of future applications and business changes

In collaboration with
Allied Vision Technologies GmbH
Contributed by
Fishing for Experience Team
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Abstract

The main purpose of this project is to develop a base for strategy for cameras produced by Allied Vision Technologies in Industry 4.0 framework. The work mainly focuses on the futuristic applications of cameras, which act as sensors and are the focal point on data collection.

The objectives are accomplished by analyzing the cameras specificity in technical, and as well as business aspects. In addition to a fundamental analysis of camera parameters and current applications, research analysis on Industry 4.0, and competitor products were the bases to develop scenarios for cameras. The focused scenarios within smart factories were Augmented Reality and Intra Logistics.

The latter part of the project focuses on the business changes in Allied Vision because of Industry 4.0. Although, a lot of information was collected in terms of business development, concrete information is still unavailable to match with the emerging Industry 4.0 scenario. Despite this, the project made immense contribution in marking the specific areas within the organization, where business changes are to be seen.

The contribution of this project is twofold. On one side, the implication for managerial efficiency with business changes was built through SWOT analysis. The current and future business model and value chain were also created to have a clear distinction on the abilities on Allied Vision in the foreseeable future. On the other hand, the possibility to overcome the identified technical challenges was developed by creating scenarios, which act as a base for establishing their potential in Industry 4.0.

Content

Fishing for Experience

Allied Vision

1. Introduction

The present report summarizes the findings of the project team from Fishing for Experience for Allied Vision Technologies GmbH.

Fishing for Experience is an EU-funded university across program which enables students and graduates of all subject areas to practically apply their expertise to support companies of the metropolitan region of Hamburg.

1.1. Project Team

In the following a short overview of the project team members is given. Throughout the whole project the contact person from Allied Vision was Mrs. Alina Kunkel (Corporate Development Analyst of Allied Vision Technologies GmbH).

	Language	Contact:
Sebastian Krauch Wirtschaftsingenieur	▪ German ▪ English ▪ French ▪ Spanish	Mobile: +49 (0) 176 415 86127 eMail: krauch.sebastian@gmx.net
	**Technical University Hamburg-Harburg**	
	Course of Studies: Internationales Wirtschaftsingenieurwesen (M.Sc)	
	Relevant Experience as: ▪ Central Purchasing (Bosch) ▪ Design for Six Sigma (Continental) ▪ Project and process management in R&D (Continental)	

	Language	Contact:
Max Herrmann Diplom-Physiker	▪ German ▪ English ▪ French	Mobile: +49 (0) 177 652 54 38 eMail: herrmann.max@web.de
	**University of Hamburg**	
	Course of Studies: Physics	
	Relevant Experiences ▪ Diploma thesis: Characterisation of CCD- and CMOS- camerasystems for microtomographie ▪ Field of activity in diploma thesis : Detectorphysics (in spc. digital camerasystems), imaging techniques, physical measurements, softwarebased controlling	

Vishnuu Jothi Prakash Mechanical Engineer	**Language** ▪ English ▪ Tamil ▪ German	**Contact:** Mobile: +49 (0) 176 81265026 eMail: vishnuu.j@gmail.com
	**Technical University Hamburg-Harburg** **Course of Studies:** International Production Management **Relevant Experiences** ▪ Product Development ▪ Production Management	

Pooja Anil Kumar Marketing Fachkauffrau	**Language** ▪ English ▪ German	**Contact:** Mobile: +49 (0) 176 554 33442 eMail: poojapu@gmail.com
	**Technical University Hamburg-Harburg** **Course of Studies:** International Production Management (MSc) **Work Experience as:** ▪ Project Manager Assistant ▪ Research Assistant ▪ Strategic solution implementation	

Ishfaque Waseek Mechanical Engineer	**Language** ▪ English ▪ Bengali ▪ German	**Contact:** Mobile: +49 (0) 15751348516 eMail: waseekishfaque@gmail.com
	**Technical University Hamburg-Harburg** **Course of Studies:** International Production Management **Relevant Experiences:** ▪Production Management ▪Product Development ▪Supply Chain Management	

Elmas Gül Marketing Fachkauffrau	Language	Contact:
	▪ German ▪ Turkish ▪ Greek ▪ English	Mobile: +49 (0) 173 544 39 26 eMail: Elmas.guelmail@gmail.com
	**HAW University of Applied Sciences Hamburg**	
	Course of Studies: Technische BWL/Marketing (B.A.)	
	Work Experience as: ▪Marketing Assistant ▪Marketing & Sales Employee ▪Business Manager	

Junaid Kokan Saleem Kokan Mechanical Engineer	Language	Contact:
	▪ English ▪ German	Mobile: +49 (0) 176 4178 77 06 eMail: junaid.kokan13@gmail.com
	**Technical University Hamburg-Harburg**	
	Course of Studies: International Production Management	
	Relevant Experiences ▪Production Technology ▪SAP, CAD softwares ▪ Basic programming skills	

Thakshith Heragu Rajanna Mechanical Engineer	Language	Contact:
	▪ English ▪ Hindi ▪ German	Mobile: +49 (0) 176 55495528 eMail: thakshith.5@gmail.com
	**Technical University Hamburg-Harburg**	
	Course of Studies: International Production Management	
	Relevant Experiences ▪ Production Management	

1.2. Background

The advancing digitalization alters many areas of everyday's life. Interconnection proceeded strongly especially through the usage of smart phones, tablet computers or other portable devices. It has become an inherent part of our society. The effects reach from digital shopping to integration of sensors in automobiles and digital diagnostics of diseases.

However, digitalization does not only play a part in everyday's life. New technologies show a high potential for changes in the manufacturing industry. The relevance of this topic is especially high in Germany, as there are a high variety of manufacturing industries. Therefore the term "*Industrie 4.0*" was generated. It describes the ongoing digitalization of companies and the associated industrial revolution.

On the factory floor of the future in the context of Industry 4.0 there will be a high demand of various sensors to gather relevant data for production. As a producer of sensors, Allied Vision might face high sales figures in the future due to Industry 4.0. However, the requirements of the camera of the future have to be known, as well as implications that may come from Industry 4.0.

1.3. Project scope

The main goals of this project reads as follows:

"Evaluation of application possibilities and analyzing business changes of image sensors in Industry 4.0 scenarios"

Hereby the focus of the project is constrained to the factory floor. Through identification of the key business changes and technical requirements for camera customizations in defined Industry 4.0 scenarios, the following questions shall be answerable after project completion:

- Is it in the interest of current customers?

- Who could be new customers?

- Do image sensors have to be changed?

1.4. Approach

This report shows the following structure:

Chapter 1	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
Intro-duction	Status Quo of Machine Vision	Industry 4.0	Changes in Machine Vision due to Industry 4.0	Business Develop-ment	Summary

2. Status quo of machine vision

Machine vision is the technology and methods used to provide imaging-based automatic inspection and analysis for process control, automatic inspection and robot guidance in industries. This chapter gives an insight into current applications and external influences of machine vision. It also gives an overview of competitor products as well as different camera and sensor parameters. Analyzing the influences, different application areas and camera parameters, camera requirements for different application areas are discussed using two matrices.

2.1. Insights into current applications

Two major applications of machine vision are automated visual inspection and automated assembly. These two applications have many similarities and can be performed by similar hardware vision systems employing closely related algorithms. The most obvious use of visual inspection is to check products for quality defects, Go / No-Go checks, etc. Another area of application of inspection is to measure a specific parameter for each product and to feed its value back to an earlier stage in the plant in order to "close the loop" of the manufacturing process. These types of camera are used to 'Control' the manufacturing process and also to monitor and store the process parameters for reporting. So, current applications of Machine vision in Manufacturing industries can be categorized under the following three segments:

1. Inspection
2. Control
3. Identification

Inspection

- Geometric measurement of parts made by milling, cutting or bending.
- Surface inspection of die cast components
- Print inspection on food packaging
- Glass inspection for medical tools
- Paint inspection in automotive production
- Robust part inspection
- Operator part placement verification
- 3D robotic guidance

Control

- Controlled adhesive application in car-body manufacturing
- Robot navigation to welding spots
- Sorting and recycling of garbage

Identification

- Identification of parcels in shipping logistics based on bar-codes
- Recognition of the type of a module in production logistics based on 2D codes
- Text recognition on electronic parts

Automotive Applications

Some of the current industrial applications as mentioned in “Machine Vision in automotive applications” by Adil Shafi are summarized below.

Case 1 – Clip Inspection

Application: Checking for the presence or absence of metallic clips in dashboard panels.
Challenge: Being able to detect dirty or corroded clips also.
Hardware and Software: ABB Robot, Cognex In-Sight PatFind vision tool
Parameters: Pattern resolution, Pattern coarseness, Angle range and acceptance threshold.
PC Interface: Shafi’s Reliabot PC software
Data collected: Defects are counted per clip position, per part cavity type, per shift or per day.

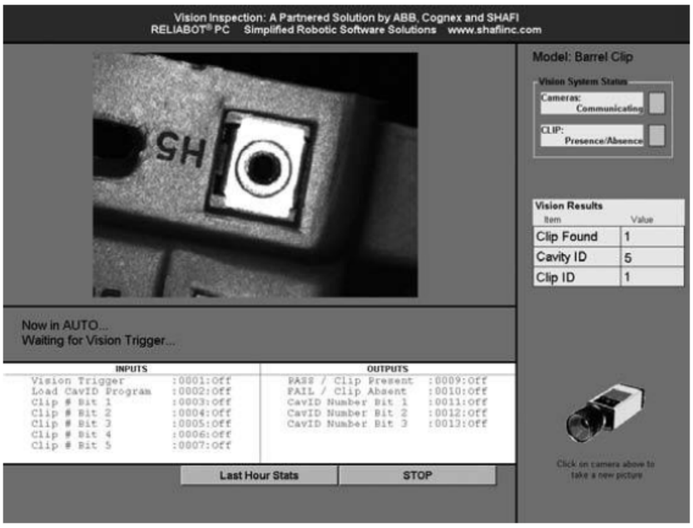


Fig. 2.1 Clip Inspection

Case 2 - Airbag GO/ NOGO Inspection

Application: Inspection of Airbag skin alignment in AGFM scoring machine.
Challenge: Detecting the skin position and providing the information necessary for correct realignment (if needed) will ensure accurate scorings.
Capability: Recognition of embossed logo and star shaped pattern in skin
Developed by: AGFM, Cognex, and Shafi, Inc.
Date Usage: If the alignment is wrong, then the required offset data is provided to the operator in the screen who then makes the change manually.

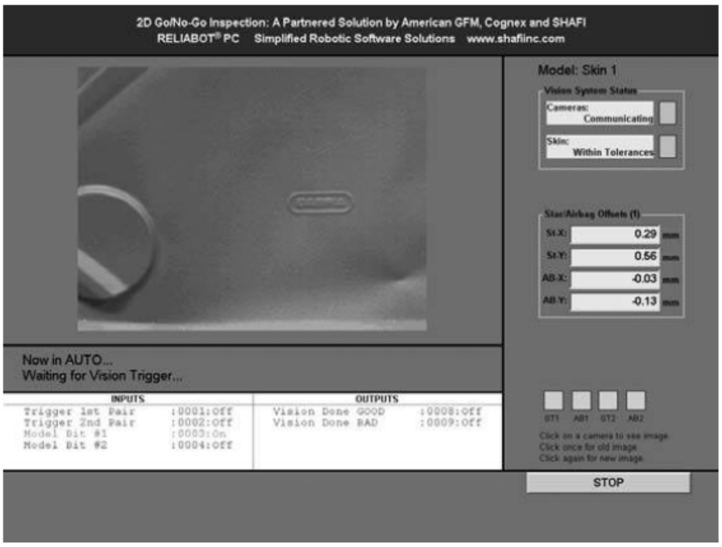


Fig 2.2 Air Bag Inspection

Case 3 - 3D Auto racking

Application: Automatic guiding of Robotic arms for loading of components in the racks.
Challenge: Irregular or false components maybe present in the loading bay and these parts should be rejected rather than wrongly placing them or attempting them to handle by a robot.
System Capability: Cameras mounted in robot's arm will take pictures of the stamped automotive components and recognize the character "S" in "LOADSIDE" and also detects color gradation. Once accepted, the robot moves towards it and takes pictures of top and bottom holes, converts it to find the exact 3D locations. These locations are then transferred to robot's arm which then inserts pins into these holes and lifts them.
Developed by: Nachi, Cognex and Shafi Inc.
Software: All 3D calculations are performed by Shafi's Reliabot PC software using 2D information from 3 cameras from Cognex's MVS-8120VX vision system.

Fig 2.3 3D Auto Racking

Object Identification Systems

With Industry 4.0, customization of products will be increased, which then will bring down the lot size to theoretically 1. Managing and identifying individual order's description will become essential at each and every workstation in a shop floor. Hence, object identification systems will be required with capabilities to read 1D, 2D codes or also to read characters (Optical Character Recognition / Verification). This can be achieved either by line scanners or using image capturing techniques.

Image based Code readers by Sick AG

Sick provides an extensive range of Identification solution systems for reading of 1D and 2D codes. The stationary 2D code scanners from SICK have a multitude of uses. Whether 1D or 2D, or direct marked codes (e.g. laser, dot peening, inkjet) on metallic or plastic surfaces or on paper, they provide a suitable solution for every application. They are multi-compatible in their connectivity: From the machine right up to the control system, they can be integrated in every environment.

Lector 62x – A 2D code scanner from Sick AG

- Decoding of all common 1D, 2D, and stacked codes, as well as optical character recognition (depending on type)
- Flexible interfaces: serial interface, USB, and Ethernet
- Function buttons, aiming laser, focus adjustment, auto-setup, and green feedback LED
- Industrial, compact housing with swivel connector
- Micro-SD memory card for storing images and backup copies of parameters

Fig 2.4 Sick Lector 62x

Technical Specifications of Lector 62x

Focus	Auto focus (during teach-in)
Sensor	CMOS matrix sensor, gray scale values
Sensor resolution	752 px x 480 px (WVGA)
Light source	Lighting LEDs: visible red light (wave length 617 ± 15 nm), visible blue light (wave length 470 ± 15 nm) Feedback spot: visible green light (wave length 525 ± 15 nm) Aiming laser: visible red light (wave length 630 ... 680 nm)
MTBF	75,000 h
LED class	1, radiance L_B < 10 kW/(m^2sr) within 100 s L_R < 28/α kW/(m^2sr) within 10 s at distance > 200 mm (IEC 62471 (2006-07) / EN 62471 (2008-09))
Laser class	1, complies with CFR 1040.10 except for the tolerance according to Laser Notice No. 50 from June 24, 2007 (IEC 60825-1 (2007-3))
Scanning frequency	60 Hz, WVGA resolution
Code resolution	≥ 0.1 mm [1)]
Reading distance (at code resolution)	25 mm ... 500 mm (0.9 mm) [1)]

[1)] Valid for Data Matrix, PDF417 and 1D codes with good printing quality.

2.2. Technical specifications / parameters

In this chapter external influences, camera and sensor parameters, competitor products and camera requirements in different application areas are captured.

2.2.1. External influences

- Ambient operating temperature
- Ambient storing temperature
- Shock load
- Vibration load
- Electrical fluctuations
- Electromagnetic compatibility
- Relative humidity
- Light immunity
- Dust

Environmental conditions

Typical cases of environmental conditions which cause mechanical requirements are

- **Vibrations** which may require mechanical decoupling or other measures, for example to protect sensitive computer equipment or to avoid adverse effects on image quality.

- **Heat** which may also cause damage to equipment; possible remedies are additional cooling means or "spatial decoupling," that is putting computers further away from heat sources.

- **Light shielding** comes in two varieties: shielding the vision system against ambient light and shielding the environment against particular light sources. It is a point which should always be taken into account when discussing the (mechanical) requirements of a vision system.

- **Ambient light** is of course potentially a major disturbance for a machine vision system, which typically depends upon particular and stable illumination conditions. This is especially true if level, direction, or other characteristics of the ambient light vary, as may be the case in a production hall with windows letting in daylight.

2.2.2. Camera and sensor parameters

This chapter starts with a theoretical description of several camera- and sensor-parameter. They are important for the estimation of the suitability of different cameras for the described applications and trends in machine vision.

Here, only a short description is given. The more detailed part can be found in appendix A.

Explanation of the Camera- and Sensor-parameters

1. *Sensor size[number of pixels x number of pixels]:* The *sensor size* is given in two-dimensional coordinates, e.g. 2560 x 2160. This number shows how many pixels can be displayed by a sensor or a screen. The more pixels can be displayed in a picture, the more detailed it is. So the *sensor size* can be seen as a value for the level of details of the sensor and is in general named as resolution.
2. *Pixel size [m]:* The *pixel size* gives the dimension of each pixel. So is sets the minimal size of a structure which can be shown. The combination of sensor Size and Pixel Size can be seen as a value for the image quality.
3. *Shutter modes:* The difference in shutter modes are the way of pixel-exposure. The distinction is between rolling-shutter- (RS) and global-shutter-mode (GS).
4. *Fullwell capacity (FC) [e^-/pixel]:* The *fullwell capacity* is the maximum number of electrons, which can be collected in each pixel. The more electrons a sensor can collect, the longer it takes until he gets overexposed.
5. *Quantum efficiency:* The quantum efficiency specifies, with which probability a photon, which hits a photosensitive pixel, sets free an electron by the inner photoelectric effect. This electron is necessary for detection of the photon. The QE is always between 0 and 1.
6. *Darkcurrent [e^-/s]:* The darkcurrent can be divided into two parts. A constant offset out of mathematical reasons and a variable part for the thermal induced free charge carriers in the semiconductor detector (photodiode). In an ideal scenario with constant cooling e.g. under 0°C, the darkcurrent could be kept constant, in optimum the level of the offset, the variable part of the darkcurrent could be eliminated.

7. *A/D Conversion Gain (CG)[e^-/digital count]:*[1] The CD describes, how many electrons (created in the detector by incoming photons) are necessary to create a digital count in the analog-digital-converter. So the less electrons are necessary, the better is the CG
8. *Noise [e^-/s]:*[2] You get the complete noise of a sensor by adding the noise values of the single parts (incoming photons, electrons after photoeffect, darkcurent, analog-digital-converter, final digital signal)
9. *Signal-Noise-Ratio (SNR):* The SNR is a value for the quality of a digital signal.
10. *Dynamic Range (DR) [dB]:* The DR describes the ratio of minimal to maximal number of photons per pixel.
11. *Frame Rate (FR) [frames/s]:* The FR is the maximum number of frames, which can be pictured per second. It depends of the shutter mode.
12. *Exposure time [s]:* The Exposure time gives the time, the sensor is exposed. The longer it is, the more electrons can be generated in the pixels. So the contrast, the difference between light and dark pixels, increases with longer exposure time.

2.3. Competitor products

In this chapter products of the three big competitors of Allied Vision are described and a basic overview on the companies is given. These are the *Basler AG*, the *Baumer Group* and *Imaging Development Systems GmbH (IDS)*.

More competitors, especially in the field of smart cameras can be found in chapter 4.4.

2.3.1. Basler AG

Locations

Basler AG	Ahrensburg	Germany
Basler, Inc.	Exton	USA
Basler Asia Pte. Ltd.	Singapore	Singapore
Basler Vision Technologies Taiwan Inc.	Jhubei City, Hsinchu County	Taiwan
Basler China Representative Office (Shanghai)	Shanghai	China
Basler China Representative Office (Shenzhen)	Shenzhen	China
Basler Korea Representative Office	Seongnam	Korea
Basler Malaysia Representative Office	Penang	Malaysia
Basler Japan Representative Office	Tokyo	Japan

[1] pco.edge scientific CMOS camera, Datenblatt.
[2] European Machinae Vision Association

Basler is *the largest unit volume producer* of digital cameras for industrial applications in the world.

Employees

417 worldwide

Headquarter in Ahrensburg (357); Sub companies in USA (19), Taiwan (11), Singapore (22)

Representatives in Korea, China and Japan: 8

Volume of sales

79,2 Mio € (2014)

Fields of activity

Industrial	Automotive, Electronics, Food & Beverage, Pharma & Packaging, Photovoltaics, Print, Paper & Postal, Robotics, Semiconductor, Sports & Motion
Biomedical Microscopy	Light Microscopy, Fluorescence Microscopy, Confocal Microscopy, Virtual Microscopy / Automated Slide Scanning, Live Cell Imaging, (Laser-)Microdissection / Micromanipulation, Diagnostic and Surgical Microscopes
Medical and Life Sciences	Medicine, Sports & Motion
Traffic and Transportation	Enforcement , Tolling , Traffic Monitoring
Security / Surveillance	Bank Security, Casino Security, Logistics
Industrial Microscopy	Industrial microscopy users need precise and reliable detection of smallest structures. The high-performance digital cameras are used for the detailed optical inspection of material, surfaces, nano-structures, weld seams etc.

Products

Area Scan Cameras	
Line Scan Cameras	
Network Cameras	

2.3.2. Baumer Group

Locations

Headquarter in Frauenfeld, Switzerland.

37 locations in 19 countries (Switzerland, France, USA, UK, Germany, Italy, Canada, Sweden etc.)

Employees

2300 worldwide

Volume of sales

~400 Mio. CHF (2011) = 380 Mio € (2015 exchange rate)

Fields of activity

Machinery	Handling, installation, robotics, Graphic machinery, Packaging machines, Textile machinery, Machine tools, Medical & laboratory technology, Semiconductor industry
Plant construction	Food & beverage industry, Lift construction, Oil and Gas, Steel industry, Chemical industry, Water & Wastewater
Renewable energies	Wind turbines, Solar industry
Transport and logistics	Cranes and heavy lifting equipment, Railed vehicles, Heavy vehicles

Products

Presence detection	Highly accurate, even for detecting the smallest or fastest objects: our sensors and precision switches.	
Distance measurement	Whether long or more exact than "a hair's breadth": sensors and encoders by Baumer measure all distances highly accurately.	
Angle measurement / rotary encoders	Measured data recording for rotary motion from the market leader for add-on encoders: Decades of competence will pay off for you!	
Process instrumentation	"Reliable and precise" Our measuring technology solutions for temperature, pressure, fill level, force, strain or conductivity are highly accurate.	
Identification and image processing	Solving complex image processing applications in a short amount of time - with industrial cameras and vision sensors from Baumer the first step towards a successful solution has already been made.	

2.3.3. IDS

Locations

Obersulm, Germany (head office)

Paris, Basingstoke (UK), Boston, Tokyo

Employees

More than 190 worldwide

Fields of activity	Machine vision Automation systems Medical technology and Life Sciences Microscopy Science and research Robotics Semiconductor manufacturing Logistics Packaging industry Printing industry Surveillance systems Road charge systems Traffic control/surveillance ITS in general (e.g. speed limit enforcement)
Products	USB 2.0 industrial cameras with CMOS sensors and USB Video Class standard (UVC) USB 2.0 industrial cameras with CCD sensors Gigabit Ethernet industrial cameras with CMOS sensors Gigabit Ethernet industrial cameras with CCD sensors USB 3.0 industrial cameras with CMOS sensors and USB3 Vision standard Ensenso Stereo-3D-Camera Camera accessories (lenses, cables, switches, tripod adapters

2.4. Camera requirements in different application areas

This part will use two matrices to display several technical aspects for the combination of different cameras in different applications.

These two matrices are:

- A rating-matrix which displays the importance of different external and internal factors for different applications.
- A camera-requirement-matrix, which describes the different camera requirements for the same applications.

The focus was set on four general application. These are:

- Automotive
- Electronics
- Packing
- Robotics

The rating-matrix includes different general applications in the first line.

The first column contains the camera- and sensor-parameter, which were described before.

The purpose of this matrix is the easy comparability of different applications and their respective parameter requirements.

	Automotive	Electronics	Packing	Robotics
External factors				
Dust	++	+	+	++
Vibration	+++	+++	+	+++
Ambient operating temperature	+	+	+	+
Ambient storing temperature	++	+	+	++
Electrical fluctuations	+	+	+	++
Electromagnetic compatibility	++	+++	+	++
Relative humidity	+	+	+	*
Light immunity	+	+	++	+++
Internal factors				
Sensor size	+++	+++	+++	+++
Pixel size	+++	+++	+++	+++
Fullwell capacity	++	+	+	+++
A/D conversiongain	*	*	*	*
Noise	++	++	+	+++
Signal-Noise-Ratio	+++	++	++	+++
Framerate	+++	++	++	+++
Exposure time	+++	+++	++	+++

+++	Strong Influence
++	Medium influence
+	Weak influence
*	Not Applicable

Now, the classification of the different cameras is possible with the basis of the information, given by the rating-matrix. For the comparison, these Basler and Allied Vision Cameras were used:

Camera series **(Basler)**	Footprint [mm²]	Resolution [Pixel]	Framerate (USB 3.0) [f/s]	FR (GigE) [f/s] (max FR – min FR)
Ace	29 x 29	640 x 480 - 4608 x 3288	800 - 10	300 f/s – 7 f/s
Aviator	62 x 62	1024 x 1024 - 2330 x 1750	101 - 26	120 - 31
Pilot	44 x 29	646 x 486 – 2456 x 2058	------	210 - 17
Scout	44 x 29	648 x 492 – 1626 x 1236	122 – 14 (FireWire-Interface)	122 - 14

Camera series **(Allied Vision)**	Footprint [mm²]	Resolution [Pixel]	FR (GigE) [f/s] (max FR – min FR)	FR (IEEE 1394b) [f/s]
Mako	60,5 x 29 x 29	644 x 484 - 2592 x 1944	309 - 14	
Guppy PRO	44,8 x 29 x 29	656 x 492 - 2588 x 1940		123 - 13
Manta	86,4 x 44 x 29	656 x 492 - 3384 x 2710	125 - 10	
Stingray	72 x 44 x 29	656 x 492 - 2452 x 2056		84 - 9
Prosilica GT	variable	1280 x 960 - 6576 x 4384	53,7 - 4	
Goldeye	variable	636 x 508 - 640 x 512	301 - 100	
Bonito	44.2 × 80 × 70	2320 × 1726	Up to 386 f/s (camera link)	
Pike	142.8 × 59 × 59	640 × 480 - 4872 × 3248	208 – 3 (FireWire)	

Now, some requirement are the same like in the rating matrix and therefore easy to interpret. However, the requirements *High image quality(HIQ)* and *High speed (HS)* combine more than one parameter.

Application area	Camera Requirements	Allied Vision-Camera	Basler-Camera	Parameter
Automotive	High image quality High speed Small footprint Shock resistance	Stingray, Guppy PRO,	Ace, Aviator, Pilot, Scout	HIQ = High Resolution HS = High FR
Electronics	High quality sensors High frame transmission rates High resolution	Goldeye, Bonito, Pike	Ace, Aviator, Scout	
Pharma, Packaging	High resolution High frame rates A small footprint	Stingray, Guppy PRO, Mako, Manta	Ace, Pilot, Scout	
Robotics	High image quality High frame transmission rates A small footprint Light weight (all Cams are in area of <370 g) Shock resistance	Guppy PRO, Mako	Ace, Aviator, Pilot, Scout	HIQ = High Resolution

For a maximum image quality a high resolution (high sensor size) with maximized small pixels is necessary. When the sensor size should be getting smaller to fit in smaller electronic devices, an increase of image quality is reachable in a decrease of the pixel size.

The requirement *High Speed* is a combination of different parameters. First of all the frame rate and after this it depends on the readout speed of the electronics. The connection of these two terms (just as the terms of sensor size and pixel size) is described in chapter 2.2.2.
To interpret the necessity of new cameras for the implementation in Industry 4.0 scenarios, these two matrixes can be taken as a basis to analyze the already existing cameras in aspects of Industry 4.0.

As it can be seen, the suitable Allied Vision camera for three fourth of the regarded applications is the Guppy PRO, followed by the Mako. Both are manly characterized by their easy handling according to their size and their special resolution and speed in middle section (in view of all Allied Vision Cameras).

The exception is the application of Electronics. Here the speed seems to be much more important, so a version of Goldeye, Bonito or Pike could be the camera of choice.
But therefore all of these applications are just general fields of industry, the right camera for a specific application can differ from the described one in the matrix above. This camera is more suitable for a general overview a comparison of different applications and cameras and should be seen as this.

3. Industry 4.0

The industry is subject to continuous change which regularly brings new challenges to companies. The currently increasing complexity in the market and particularly in the competitive environment endangers the position of conventional production locations, such as Germany and requires fundamental changes in their creation of value. In response, the German government integrated “Industrie 4.0” as a core element in its research and innovation policy. The main focus is on the intelligent networking of production processes in industrial creation of value. In the era of the fourth industrial revolution, products and machines will communicate with each other and enable decentralized controlled operations. Autonomous decisions can be made on the basis of information which is transferred from the product to the machines. Hereby a decentralized intelligence emerges, which ensures a smooth production flow. Further technologies for the generation and processing of big data will reveal new optimization potentials even apart from production. Processes in departments far from production can be analyzed profitably and a new level of transparency within the company can be achieved. Also serious impact on the business relationships between companies are expected. Cross-company processes will be newly defined and construed. This extensive digitization of the value chain will affect the different sectors of industry to a variable extent and in some cases it will lead to a fundamental restructuring of the business concept. Major challenges are

- the increasing competition and price pressure
- shorter product life cycles
- increasing diversity of variants due to individualization and
- increasing complexity in production[3]

New technologies of Industry 4.0 are trying to meet these challenges.

Potential of Industry 4.0

Globally spread production systems will be easily controllable via the connection over the internet. In the future a global network with many production plants will be similarly manageable as a single factory of today with its machines. For the future this gives the possibility to quickly redirect material flows and to boot plants to compensate failures in other production plants (Bauer et al. 2014, S. 24).

Industry 4.0, the cross-link of IT and embedded-systems, will be the future of a modern factory floor.

- This leads to an increase in the demand of various sensors.

[3] Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft, 2013).

- Machines and products will be enabled to do self-configuration, self-diagnosis and self-optimization during the manufacturing process autonomously.

- An increase in efficiency and the flexibility of customization in (mass-)production bare a high potential for the manufacturing industry.

3.1. Industry 4.0 basics

Although *Industry 4.0* is currently a top priority for many companies, research centers, and universities, a generally accepted definition of the term does not exist.

A literature review paper (Hermann et al.) gives a definition of Industry 4.0 and its 4 identified “key components”:

“Industry 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industry 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain.”

The paper defines four key components of Industry 4.0:

Cyber-Physical Systems, *Internet of Things*, *Internet of Services*, and *Smart Factory.*

3.1.1. Cyber-Physical Systems (CPS)

An important component of Industry 4.0 is the fusion of the physical and the virtual world. This fusion is made possible by Cyber Physical Systems (CPS). CPS are “integrations of computation and physical processes.”

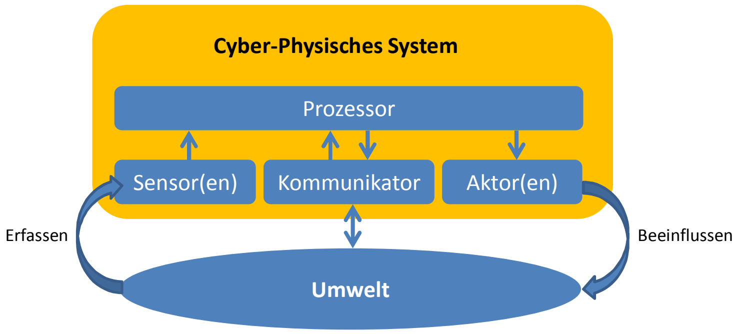


Fig 3.1 Cyber-physical system

Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. The development of CPS is characterized by three phases. The first generation of CPS includes identification technologies like RFID tags, which allow unique identification. Storage and analytics have to be provided as a centralized service. The second generation of CPS are equipped with **sensors** and actuators with a limited range of functions. CPS of the third generation can store and analyze data, are equipped with **multiple sensors** and actuators, and are network compatible. One example of a CPS is the intelligent bin (*iBin*) by Würth. It contains a built-in infrared camera module for C-parts management, which determines the amount of C-parts within the iBin. If the quantity falls below the safety stock, the iBin automatically orders new parts via RFID. This allows consumption based C-parts management in realtime. Chapter 4 will give more information on that application.

3.1.2. Internet of Things

The integration of the Internet of Things (IoT) and the Internet of Services (IoS) in the manufacturing process has initiated the fourth industrial revolution. The IoT allows "things and objects, such as RFID, **sensors**, actuators, mobile phones, which, through unique addressing schemas, interact with each other and cooperate with their neighboring 'smart' components, to reach common goals".

Based on the definition of CPS given above, "things" and "objects" can be understood as CPS. Therefore, the IoT can be defined as a network in which CPS cooperate with each other through unique addressing schemas.

Application examples of the IoT are Smart Factories (see explanation in 3.1.4.).

3.1.3. Internet of Services

The Internet of Services (IoS) enables "service vendors to offer their services via the internet. The IoS consists of participants, an infrastructure for services, business models and the services themselves. Services are offered and combined into value-added services by various suppliers; they are communicated to users as well as consumers and are accessed by them via various channels."

This development allows a new way of dynamic variation of the distribution of individual value chain activities. It is conceivable that this concept will be transferred from single factories to entire value added networks in the future. Factories may go one step further and offer special production technologies instead of just production types. These production technologies will be offered over the IoS and can be used to manufacture products or compensate production capacities. The idea of the IoS has been implemented in a project named *SMART FACE* under the "Autonomics for Industrie 4.0" program initiated by the Federal Ministry for Economic Affairs and Energy. It develops a new distributed production control for the automotive industry. The project is based on a service-oriented architecture. This allows the use of modular assembly stations that can be flexibly modified or expanded. The transportation between the assembly stations is ensured by automated guided vehicles. Both, assembly stations and automated guided vehicles offer their services through the IoS. The vehicle bodies know their customer specific configuration and can decide autonomously which working steps are needed. Therefore, they can individually compose the required processes through the IoS and autonomously navigate through the production.

3.1.4. Smart Factory

Smart factories constitute a key feature of Industry 4.0.

“The Smart Factory is defined as a factory that context-aware assists people and machines in execution of their tasks. This is achieved by systems working in background, so-called Calm-systems and context aware means that the system can take into consideration context information like the position and status of an object. These systems accomplish their tasks based on information coming from physical and virtual world. Information of the physical world is e.g. position or condition of a tool, in contrast to information of the virtual world like electronic documents, drawings and simulation models. Calm systems are referring in this context to the hardware of a Smart Factory. The main difference between calm and other types of systems is the ability to communicate and interact with its environment.” Based on the definitions given for CPS and the IoT, the Smart Factory can be defined as a factory where CPS communicate over the IoT and assist people and machines in the execution of their tasks. An example of a Smart Factory is the WITTENSTEIN bastian’ production facility in Fellbach, Germany, which is organized according to the principles of lean production.

Main characteristics of a smart factory are flexibility and robustness:

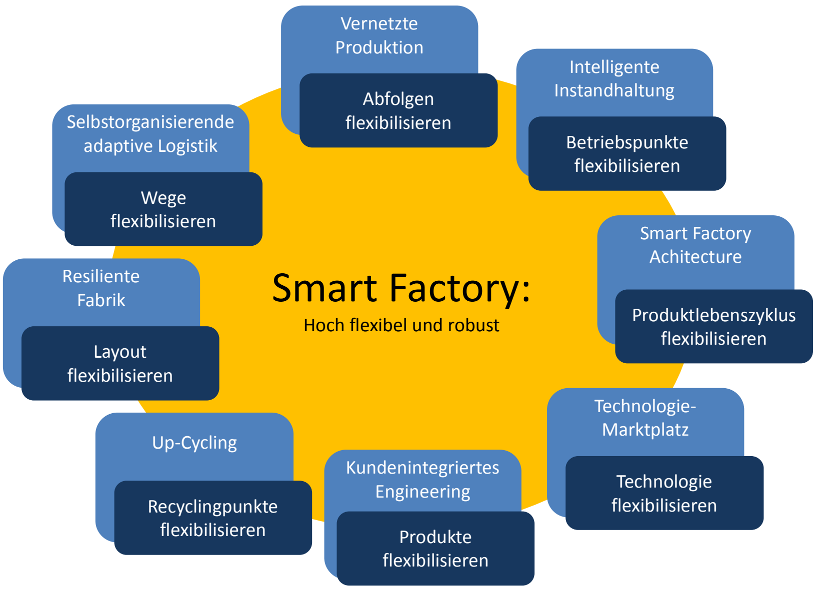


Fig 3.2 Flexibility as a key feature in a Smart Factory

The smart factory is a production environment in which the manufacturing facilities and logistics are automated and self-organized by constant communication between the product and production plant. Smart factory is the result of implementation of Industry 4.0 on the shop floor. It eliminates errors resulting from human manual operations, improving quality consistency, increasing productivity, reducing production costs, and enhancing customer satisfaction.

The following figure gives a graphical representation of applications of vision systems in a smart factory:

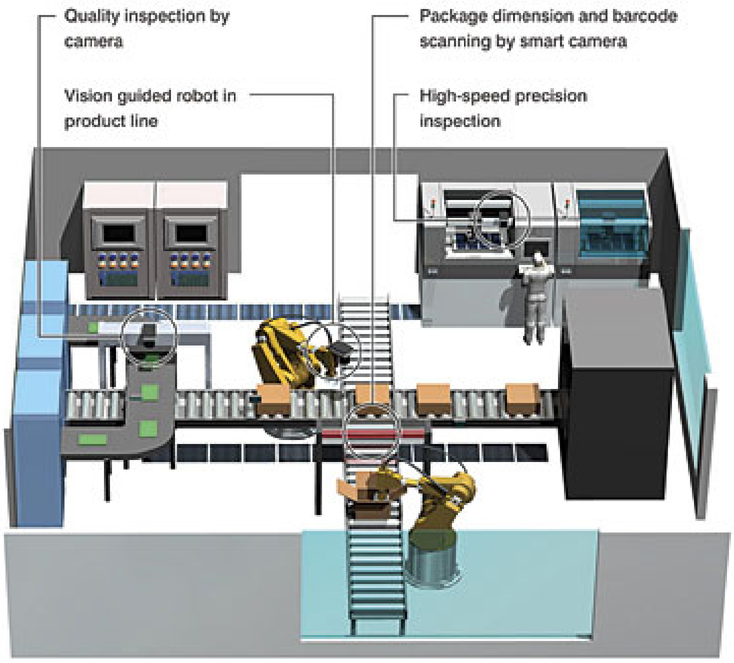


Fig 3.3 Vision Systems in a smart factory

With consideration for limited floor space and budgeting for installation, small, compact, integrated, easily installed vision systems are drawing more interest from operators who are looking for a competitive advantage.

Industrial smart cameras offer a compact size and fan-less operation. They combine the advantages of both embedded vision systems and conventional cameras with integrated processor and memory. They also require low power and at the same time provide high processing capability.

Characteristics of Cameras in smart factory:

- Ruggedness
- Reliability
- High efficiency and throughput time (Balance between resolution and frame rate)
- Third Party Integration
- Compact size and shape
- Multi-utility

Factors of future camera development:

- Increase in robotics
- IT systems integration
- Functionality of camera

- Technological requirements of camera
- RFID systems introduction

Modularity and Connectivity

Modularity according to Merriam-Webster is defined as *having parts that can be connected or combined in different ways*. It is a concept where a product or good is split into small individual modules and developed independently before being assembled into a single product. Connectivity in the context of industrial cameras refers to its capability to be connected to a server or other similar cameras for data collection and analytical purposes. This leads to an interconnected system of cameras in an industry or a particular location, as defined by the requirements.

This concept of modularity is developed with the two most important factors and a matrix was developed containing four different possibilities that could develop in the future. These possibilities are described in Appendix B.

The main outcome is that Cameras follow integration, are industry specific and modular.

According to the analysis and early results from the current industry predict a movement towards modularization and software based development of products. Every product on the market is moving towards connectivity to cloud and software based development and optimization. Even though the concept of modularity exists for quite a few years now, major strides are being made in this field recently and many industries are striving to achieve modularity in their products. Modularity provides multiple advantages, one being suitable for diverse applications. It also aids maintenance ability and simplicity.

Therefore if followed, one camera can potentially be utilized for various purposes in various industries.

3.1.5. Horizontal and vertical integration

To describe the directions of connectedness in Industry 4.0 one refers to **horizontal and vertical integration**.

Due to the connection between digital and physical world, information can be accessed every time and from anywhere. A central feature in the context of Industry 4.0 is the availability of data from the factory in real-time. This data availability makes it possible to create a virtual copy of the real world, which is continuously updated with real-time data (Bauernhansl 2014, p. 15).

Hereby a direct exchange of production and process data can be realized between all players of the value chain (Bauer et al. 2014, S. 24). This exchange can be horizontal, i.e. cross-company along the Supply Chain. This is referred to as the horizontal integration (Schlick et al. 2014, p. 59).

Vertical integration on the other hand describes the connection of physical processes and resources on the shop floor (machines, parts, etc.) with business processes across all company levels, including control- and management systems (Bischoff et al. 2015, p. 7).

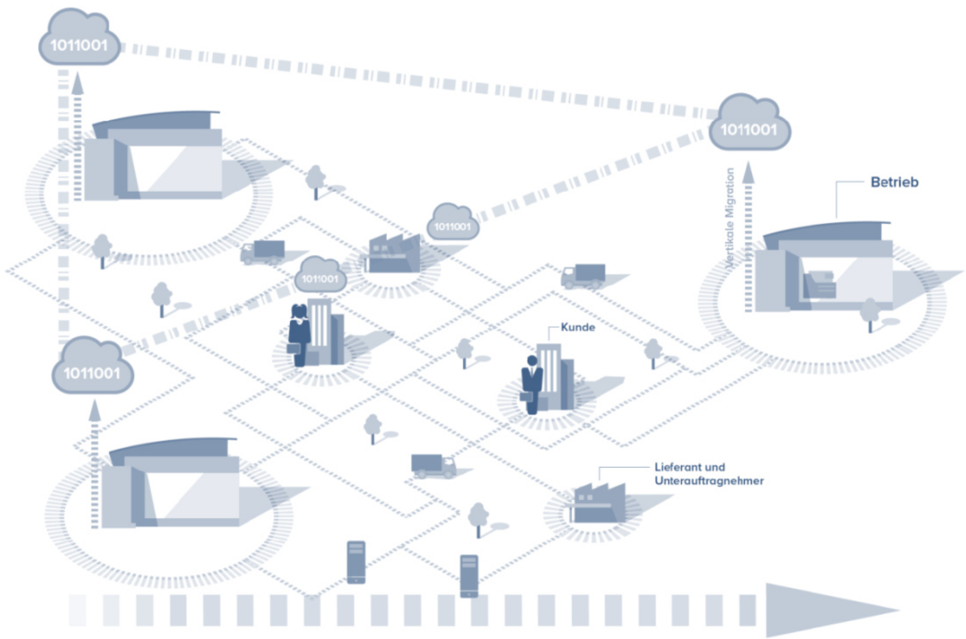


Fig 3.4 Horizontal and vertical Integration (Bischoff et al. 2015)

Machines, production facilities and warehouse systems are capable to communicate with each other, take actions and to even control themselves. With horizontal integration, enhanced supply chain steering and enhanced supply chains can be achieved. The herein contained potential for holistic process improvements is tremendous and does not only affect production, but also development, construction, manufacturing and service (Kleinemeier 2014, S. 571).

3.2. General Industry 4.0 trends

In the following the most influencing trends are captured. These trends will be used among other influences to analyze how Allied Vision's Business Model should adapt to satisfy future customer needs.

The trends are not to be understood independently. Together they form a coherent scenario for the future Value Chain as it might be in the year 2030.

3.2.1. Enhanced interface integration

As already described in chapter 3.1.5., horizontal integration leads to a convergence of all players of the value chain. The interconnectedness between suppliers and manufacturers will continuously increase within the next years and decades.

Gaps in the yet strongly fragmented supply chain will be continuously closed by digital technologies or systems. This trend is represented graphically in the following figure.

Interface Integration hereby means the connection of interfaces in the value chain. Involved companies are enabled to work closer together through stronger links between interfaces. The classical customer-supplier-relationship will belong to the past. The trend is in the direction of partnerships along the supply chain. Herein there are the two trends of cooperation and collaboration. Cooperation means the common orientation towards a goal on different operational levels, whereas collaboration takes place on the same operational level.

In literature a virtual company is described, which works together across company borders. The trend will have special characteristics in the area of product development and supply chain management.

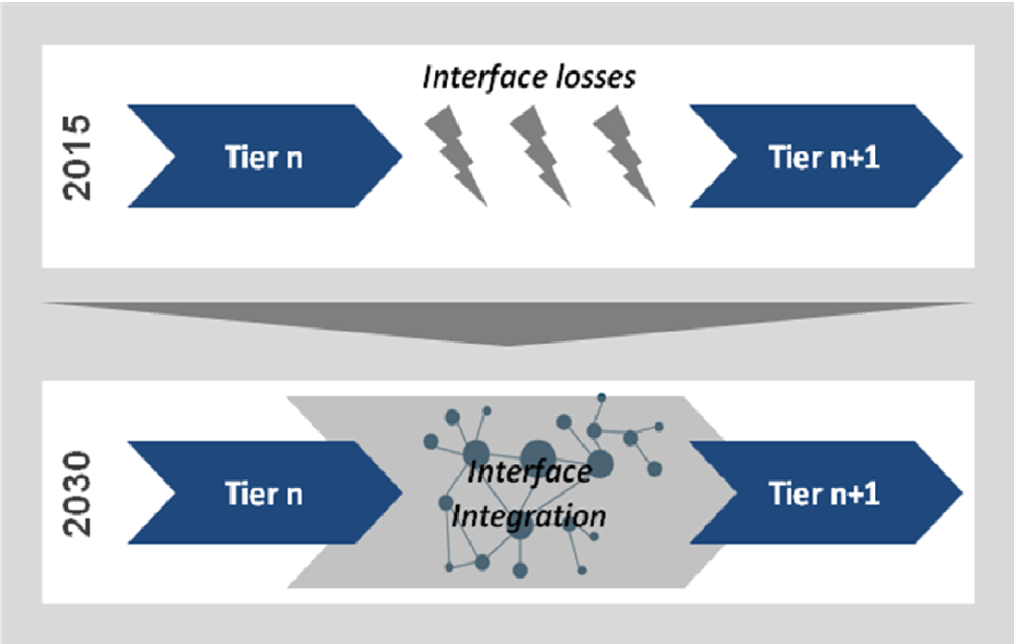


Fig 3.5 Enhanced Interface Integration

In product development there will be a higher focus on core competencies on single tiers of the supply chain. This leads to the fact, that OEMs will have the intensified role as system integrators. The role of developer and innovator on product level passes on to suppliers. This requires strong coordination between OEM and supplier and supporting technologies. The automotive industry is a role model for integration of suppliers into the network of the company. Through Industry 4.0 and digitization there are more drivers for enhanced integration.

On the one hand there are technologies as driving forces such as cloud technologies which create interconnectedness and serve as a basis for successful cooperation across spatial distances.

Other driving forces on the other hand are information technologies for the analysis of big data. Those technologies allow the optimization of processes and products via generation of information from these data. To generate these data and to be able to use them, companies have to move closer together and allow the access to the data.

On business model level mainly customer relationship from customer's view will change. According to the new activities, which the company is assigned to, value proposition and key activities will change in the direction that suppliers will become more integrated into the engineering processes and OEMs generally become system integrators. Effects of stronger integration are cross-company efficiency increases in the interfaces. Here in particular, nowadays there are massive efficiency losses due to insufficient communication and transparency. The newly created transparency in the near future allows an earlier anticipation of delays and supply bottlenecks and thereby leads to an optimized material availability. Furthermore, stronger integration creates an optimization of the whole supply chain. Hence, it is not limited to the achievement of a local optimum in one value-added step.

One risk which comes with the enhanced integration is the strong focus on individual partners. Especially conditioned by the effort for the reconcilement of information systems and platforms for collaboration, the commitment to individual partners is very high. A cutback of the number of companies in the supply chain could be a possible result, as the members have to agree on a mutual system, or platform respectively. Hereby other providers are hindered to enter the market. In total this is a trend which is striven by OEMs, as the coordination effort is decreased analogous to the number of suppliers.

3.2.2. Increasing production flexibility with concurrent efficiency increase

Industry 4.0 will lead to a more flexible production and also to more efficient processes.

In addition to an efficiency increase at the interfaces of the supply chain (chapter 3.2.1.), there will be an efficiency increase within the business of each player of the supply chain, caused by the technologies of Industry 4.0. This trend has an impact on the cost structure and the value proposition in the business model of each player.

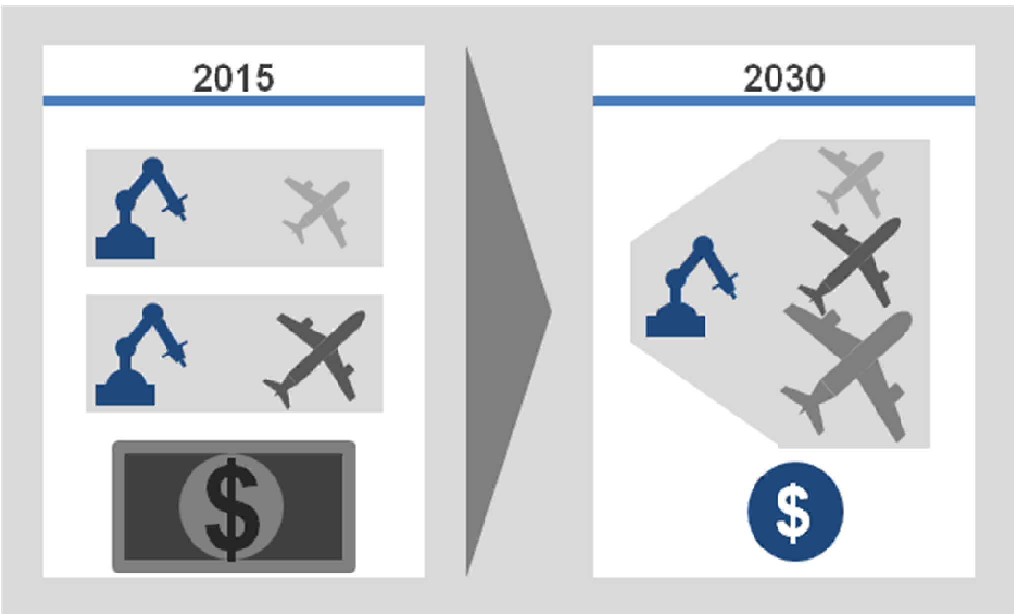


Fig 3.6 Increasing production flexibility with concurrent efficiency increase

Main drivers for this trend are technologies of additive manufacturing (3D printing etc.) and new generations of robotics. Their characteristics like shorter set-up time, lower rate of defective parts, flexible manufacturing and in the case of 3D printing even spatial independence form the basis for this trend. Thus, the customer can be offered more variants which can be produced in a faster and more efficient way. Mass-customization is hereby made economical.

As a consequence a higher value proposition can be given to the customer, as shorter latency times and higher product spectrum are of direct value to the customer.

The implementation of other technologies as IoT, Big Data, Augmented Reality and intelligent machines will make a contribution to a more flexible and efficient supply chain. Huge amounts of data, captured through the internet of things, can be analyzed by new measures of data mining. Hereby better forecasts and better preplanning are made possible. In addition there is a positive impact on quality management.

3.2.3. Data control as competitive advantage

Utilization and especially the possession of data will become a core element of competitive advantages. It will be possible to generate and use relevant information from huge amounts of data. These information will be used for internal optimizations of processes and as a basis for product enhancements and supplementary services. This trend has an impact on the revenue streams of companies. The consequence is that data will become a key resource of many market players what leads to a strong competition for data. The following figure shows this context graphically:

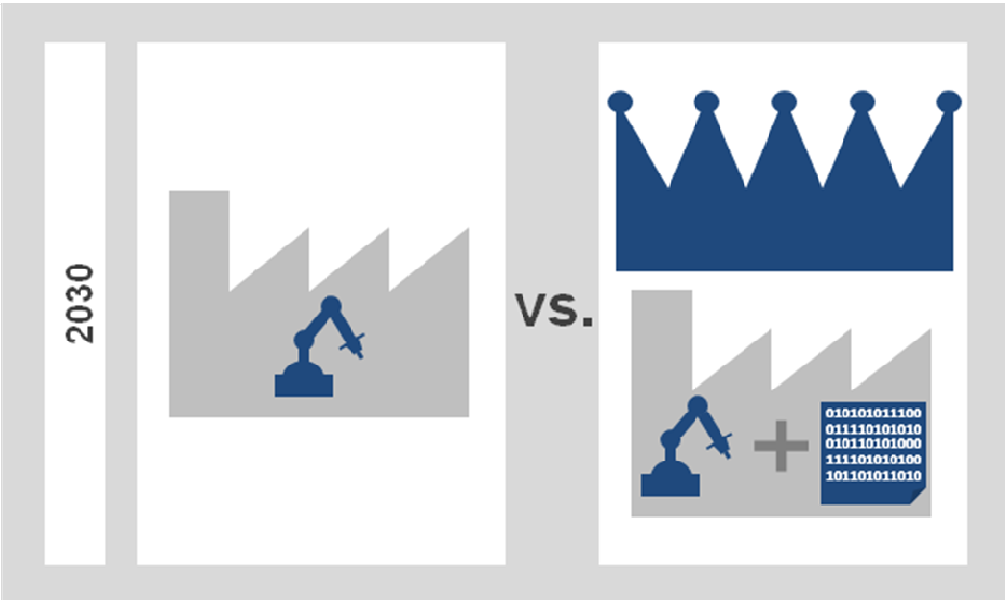


Fig 3.7 Data control as competitive advantage

An important influencing factor for this development is the increasing data generation through the internet of things. Especially the data collection in production and logistics will be intensified due to industry 4.0. Status data on production units and objects are known and can be saved and analyzed.

The need for data is not limited to internal processes, it extends beyond company boundaries. OEMs have a great interest in production data of their suppliers for optimizing their own production flow. High costs for missing material can be prevented by early reactions to a supplier's production problem. Suppliers with an advanced networking of their production thus have a clear competitive advantage and are an attractive business partner for OEMs.

Controlling the data flow makes it possible to improve the products and to upgrade them with appropriate services.

This trend will bring remote services and monitoring to a new level. An example delivers GF Machining Solutions, a producer of machines for tool manufacturing. In January 2016, GF Machining Solutions will connect with the machines at their customer's shop floors via the service solution Symmedia SP/1. Service requests are structured via the SAP ticket system and organized automatically. In addition, the customers can find all relevant service data in the so called customer-cockpit and access it via smartphones. The global interconnection of the service organization with the installed machines leads to a synchronization of processes and increases efficiency on both, customer and provider side[4].

[4] http://www.maschinenmarkt.vogel.de/themenkanaele/betriebstechnik/instandhaltung/articles/500840/?cmp=nl-149

4. Changes in machine vision due to Industry 4.0

As a result of Industry 4.0, there will be many new requirements in the shop floor such as Product identification and Tracking, Quality Inspection along with Control, Customized production process resulting in more complex Intra-logistics system and so on. Hence, these new requirements in shop floor lead to development of additional machine vision functionalities. Some Industry 4.0 scenarios are discussed in this chapter and the corresponding camera requirements and specifications are listed below as well. Further, some of the competitor's products, for example, in Smart camera segment are enumerated.

4.1. Smart Factory

Smart factory is the result of implementation of Industry 4.0 in shop floor. Smart Factory is a production environment in which the manufacturing facilities and logistics are automated and self-organized by constant communication between the product and production plant. For example: auto maintenance, logistics operation, intelligence in value chain, etc. It eliminates errors resulting from human manual operations, improving quality consistency, increasing productivity, reducing production costs, and enhancing customer satisfaction. Fig. 4.1. gives a graphical representation of the various processes carried out in a smart factory. More information about smart factory can be found in Chapter 3.

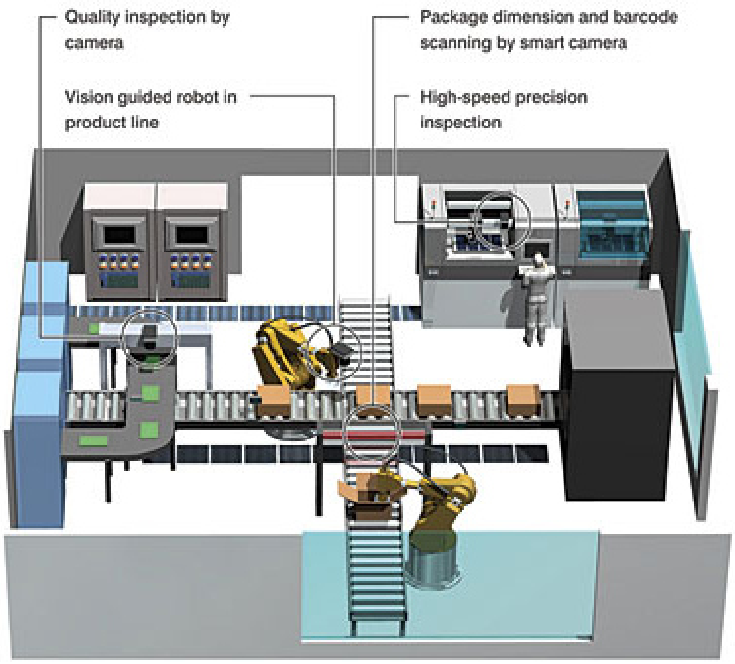


Fig. 4.1. Graphical Representation of a Smart Factory

4.2. Augmented Reality

Augmented Reality is a live direct or indirect view of a physical, real-world environment whose elements are supplemented by computer-generated sensory input such as sound, video or graphics data. Augmented reality finds a significant application in the field of simulation. Simulation process is a step by step process. Initially a model of the product or a function is designed considering all functionalities and working conditions. This design is evaluated with desired working conditions. The design may be subjected to optimization based on the results of evaluation.

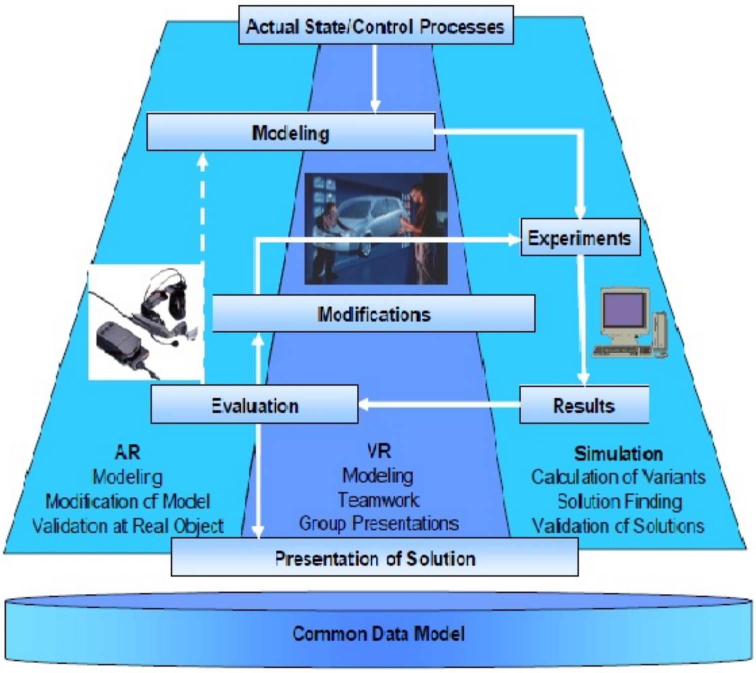


Fig. 4.2. Augmented Reality supported simulation

The cycle is carried out in iterative steps until an optimum solution is achieved. This solution is passed on to manufacturing unit for further processes. The technologies, Augmented Reality (AR) and Virtual Reality (VR), offer high potentials concerning the improved application of simulation techniques. The utilization of AR and VR through the process of simulation in various steps is as shown in Fig. 4.2.

Areas of application in production line:

- Product Design
    - CAD model visualization
    - Realistic visualization of surfaces
- Assembly
    - Collision analyses
    - Visualization of assembly/ disassembly process
    - Interdisciplinary analyses (engine compartment, cable loom etc.)
    - Guided Installation or Assembly of complex machines

- Factory shop floor
    - Layout optimization
    - Warehouse management – Routing to Pick-up points and identification of storage locations
- Enhancing Quality of manufacturing processes
    - Weld line assistant

4.2.1. Scenario Description

Fig 4.3 shows the scenario of an industrial pipeline system with many inlet and outlet pipes connected to the control unit of a machine. As the image show, when a device like iPad with a camera is used, it captures the image and then from the database of images, it maps the respective parts and highlights it in the portable device display (i.e., iPad) some vital information and safety advices.

Fig.4.3. Circuit Safety Instructions In a Portable Display

Another scenario in factory shop floor would be to optimize the layout of machines or whenever a new machine has to be integrated into the existing production line, augmented reality helps in the real time visualization of shop floor in a digital display device. Fig. 4.4. shows the possibility to retrieve some technical information about the machine that is present in the shop floor.

Fig. 4.4. Factory Layout and Machine Information

4.2.2. Image Processing Requirements

Cameras have to fulfill two vital roles in the process of image generation for augmented reality.

1. To support diverse applications the cameras have to provide scalable graphics power with high performance and image quality.
2. For efficient visualization it has to facilitate an automatic and fast data preparation from other applications.

The image generated has to fulfill various purpose requirements such that the image generated functions in various hardware platforms such as, mobile PDA (data capture), desktop PC (simulation), portable notebooks (presentation), or PC-cluster for high-end VR-systems (large-format projection for a number of persons). The system has to facilitate visualization of very large and stereoscopic AR-scenes with any topology (single objects like robots, subassemblies and product lines as well as manufacturing plants and production sites). A special technique is required to develop a virtual scene and display in real-time on a single PC of manufacturing plants due to its immense complexity. The graphics generated by camera has to provide a high-quality, photo-realistic display through new techniques such as real-time shadows, reflections and a high-performance of the display on various platforms like PDA, monitor etc.. A scalable PC-cluster generates the virtual scenes in parallel. The data from virtual scenes and the image generated is then integrated which results in Augmented reality.

4.3. Intra logistics

Intra logistics deals with data acquisition and processing goods (in-house products) through constant communication and automated movements with the help of camera technologies. Conventionally laser systems are used for this process. But camera systems help increase the degree of automation, accelerate processes, increase the efficiency and productivity in personnel placement and reduce the logistics costs per article. This is the result of implementation of industry 4.0, where all the systems within the industry are interconnected. This is a key technology for warehouse automation.

4.3.1. Scenario Description

iBin by Würth Industry

Würth Industry is part of the Adolf Würth GmbH & Co. KG based in Künzelsau (Germany) which is one of the world's largest industrial distributors. Würth Industry in Belgium and Luxemburg is comprised of 2 fastener and assembly component distribution companies. The company specialises in range of more than 1,000,000 items including fastening elements, connectors, rivets, and many other C-Parts. The C-Part refers to ABC classification of inventory system. C-parts contribute to 5% of customers purchasing value only, but the percentage of items (in numbers) could be as high as 85%. The purchasing volume of C-parts is very low but the procuring costs are very high, because of the manual work involved in continuous stock taking and order placement. Würth provides various C-Part Management services like Kanban, Modular logistics and so on.

The flow of materials in Kanban systems is managed via two bins, refer Fig. 4.5, each of which has a bar-coded Kanban label, RFID tag or iBin® module, which specifies the customer, storage location, item, bin, batch and quantity in more detail. Each bin movement is captured and documented, so that it can give information about the status of the company's Kanban system at any time. The data is used to schedule all C-Parts close to the point of use, to optimise stock levels and warehouse technology regularly and to update statistical data.

Fig. 4.5. Kanban Bin System for Inventory Management

With iBin® it is now possible to automatically transfer filling levels, quantities and article information on a bin level to the inventory management system via an integrated camera using RFID technology. This means that not only is consumer-controlled supply of small parts for production requirements possible on a just-in-time basis, but C-Part supply is executed in real time transfer via image format.

The iBin® enables new, individual opportunities as well as a transparent view of the inside of the bin – related to any individual piece. Whereas currently an empty bin triggers an order, in the future the iBin® will monitor the stocks inside the bin itself and triggers a respective order, thus setting new standards as a future-oriented, intelligent system. Refer 4.6 and 4.7 for iBin components.

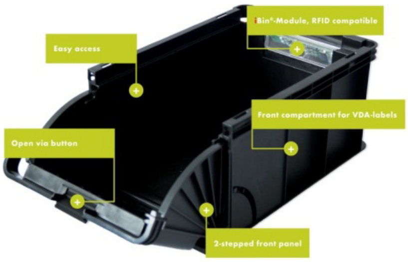


Fig.4.6. Kanban Bin with iBin and RFID compatibility

Fig.4.7. Electronic Module of iBin with Camera

Automated Guided Vehicles

Automated Guided Vehicles (AGV) is one of the most vital systems in Intra-Logistics of an Assembly shop-floor and in Warehouse Management. Some of the various techniques employed for the working of an AGV are: Line Following, Laser Measurement, Barcodes, GPS, RFID and so on.. Line follower can be designed either with Cameras or Lasers.

Fig. 4.8. Automated Guided Vehicle

Mototok is a company that manufactures AGVs especially for aircraft assembly carrier. **Cameras** mounted underneath the Mototok, refer Fig. 4.9, scan the steering control line installed on the production hall floor and independently sends control signals to the controller. Mototok follows the steering control line to within a few millimetres.

Fig 4.9. Automatic Steering through Camera Guidance

Image based code reader

With increased necessity for object tracking and identification in shop-floor, 2D barcodes and QR codes (Quick Response Codes) will be used extensively. One solution that has been discussed already uses laser to scan the codes. Another alternative solution is to use vision-based system to capture image and then interpret the data. There are such image-based code readers available in the market which includes Sick AG's 'Sick Lector Series'. Some of the specifications of it are:

- 2/4 MP, High frame rate - 40 Hz
- Dynamic focus adjustment
- Integrated high-power LED
- Intelligent, rapid decoding algorithm
- MicroSD memory card

4.3.2. Camera Requirements:

Some of the important requirements suitable for intra-Logistics are:

- Applications like iBin and AGVs are stand-alone and portable. Hence, they require less power consumption cameras and vision system.
- Low light in warehouses may raise the need to equip the camera with night vision technologies like IR cameras.
- Dust and contamination protection becomes important in warehouse applications.
- AGV applications require position awareness inside shop-floor, thus require GPS or RFID or such a similar tracking technology working alongside with the vision system. Integrating the machine vision system with such technologies might be required.

For Image based code reading applications, the following are the requirements:

- Obtain more usable information from the image
- Higher read rate
- Immediately display the read result and the image of the object and thus allow an evaluation in real time
- Acquire additional data such as the volume and the weight of the object and to use this data for storage and logistics processes,
- Read more data types such as diverse 2D-codes and plain text (OCR),
- Allow read rates of 100% due to the utilization of video coding (supplementing missing information based on the evaluation of the images by employees),
- Read several different code types at once
- Also register the smallest or damaged codes, codes under foil and on the underside of goods.

4.4. Smart cameras

4.4.1. Definition

Practical definition for Smart Cameras (Belbachir, 2010) developed by the *Automated imaging association* (AIA) defines three essential common features for cameras as being *smart*:

1. *Integration* of some key functions into the device (e.g., optics, illumination, imaging capture, and image processing).

2. *Utilizing a processor and software* in order to achieve computational intelligence at some level.

3. *The ability* to perform multiple applications without requiring manual actions.

Smart camera refers to cameras that have the ability to not only take pictures but also more importantly make sense of what is happening in the image and in some cases take some action on behalf of the camera user. Furthermore, the AIA categorizes vision systems, according to the grade of integration, in three product categories:

1. *The smart camera*, as a complete or nearly complete vision system, contained in the camera body itself. Illumination and optics may or may not be integrated, but image processing and software programs must be within this camera body.

2. *The vision sensor*, which is primarily a lower end smart camera that too may approach the same performance of a high-end smart camera category type.

3. *The embedded vision processor*, where a camera is tied to an external computing system.

4.4.2. Applications:

All the above mentioned scenarios can be addressed by a Smart Camera, image sensor with a built-in processor.

- Geometric measurement of parts produced by bending, cutting or milling
- Verification of print results on packages
- Presence / absence detection of certain elements
- Identification of parts via text, bar codes or 2D codes

4.4.3. Product Examples

Vision Components GmbH

VC OEM Smart Cameras - Real time inspection with embedded systems from Vision Components! - Freely programmable Smart Cameras from Vision Components stand for optimum performance. A wide range of sensors as well as several hardware designs, like protective housings, with external sensor housings or with integrated optics and lighting, complete the portfolio. All Digital Signal Processing models are equipped with the especially developed operating system VCRT. VCRT is a multitasking real time operating system, designed for industrial use. It is based on C++ and freely programmable. Thus, the optimal inspection program can be designed for every application.

Some of the products of Vision Components are: VC nano, VC Base, VC Base+, VC Professional, VC Optimum, VC Line, VC Multi Sensor.

Quick info of VC base:

- 1/3" CCD sensor
- resolution: 1024 x 768 Pixel
- frame rate 16 fps
- high-speed shutter: up to 46,7 µs in steps of 76,2 µs
- low-speed shutter: up to 2 s adjustable integration time
- Processor: 3,200 MIPS, 400 MHz.
- Up to 64 MB SDRAM image/data memory.
- Image display via 100 Mbit Ethernet to PC.
- Interfaces: RS232 and 100 Mbit Ethernet.
- Housing dimensions start with 80 x 45 x 20 mm, approx. 90 g.

Adlink

ADLINK is a global company with headquarters in Taiwan and manufacturing in Taiwan and China; R&D and integration in Taiwan, China, the US, and Germany. ADLINK is a Premier Member of the Intel "**Internet of Things Solutions Alliance**". ADLINK Technology is enabling the Internet of Things (IoT) with innovative embedded computing solutions for edge devices, intelligent gateways and cloud services. ADLINK's products are application-ready for industrial automation, communications, medical, defence, transportation, and infotainment industries.

Pharmaceutical inspection, including inspection for visual defects, package labels, pattern matching or scanning barcodes on a high-speed folding machine or product line, demands high resolution captures with powerful processing to manage large image data. Global shutter sensors deployed in a fast moving product line provide clear and stable images for image. To manage the variety of inspection methods used, a flexible and programmable inspection platform is ideally suited to pharmaceutical applications. Fig. 4.10. depicts this scenario with NEON 1040 as the smart solution.

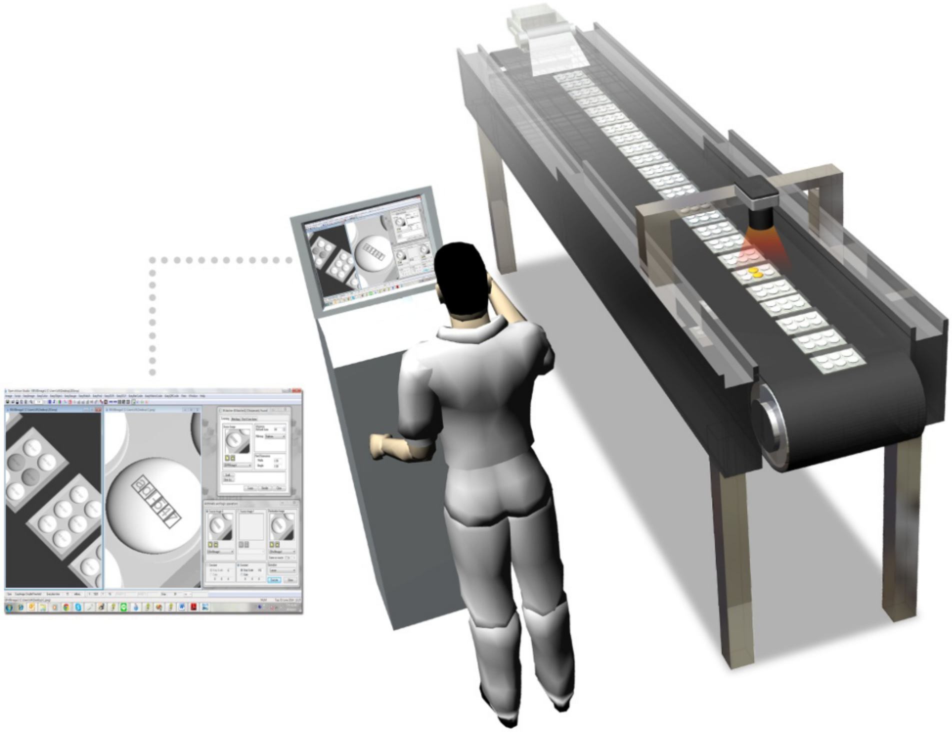


Fig. 4.10. Smart Camera NEON 1040 in Pharma Production

The NEON-1040 features a 4 MP 60 fps, 1-inch global shutter sensor, ideal for precise high-speed moving object inspection, ideal for verification of pill or tablet quality, blister pack contents, and label information and/or bar codes. With IP67-rated housing and M12 connectors, the NEON-1040 resists harsh environments, withstanding damage from moisture and contaminants. With powerful quad core computing and FPGA image pre-processing, the NEON-1040 can process multiple complex inspection tasks simultaneously, and its open architecture x86 based application ready platform simplifies programming of customized inspection applications and use of existing x86 software without requiring new coding language expertise.

NEON-1040

- Intel® Atom™ Quad-Core Processor E3845 1.91GHz
- 4MP, 60fps, monochrome global shutter CMOS sensor
- IP67-rated housing and M12 connectors thoroughly protect against dust & moisture
- Advanced image processing support
- Additional GigE Vision 1 slave camera support reduces TCO
- Built-in PWM lighting control
- Flexible software support with STEMMER Common Vision Blox, MVTec HALCON, and many others
- GeniCam , GenTL, Open CV and Open CL compatible with image acquisition

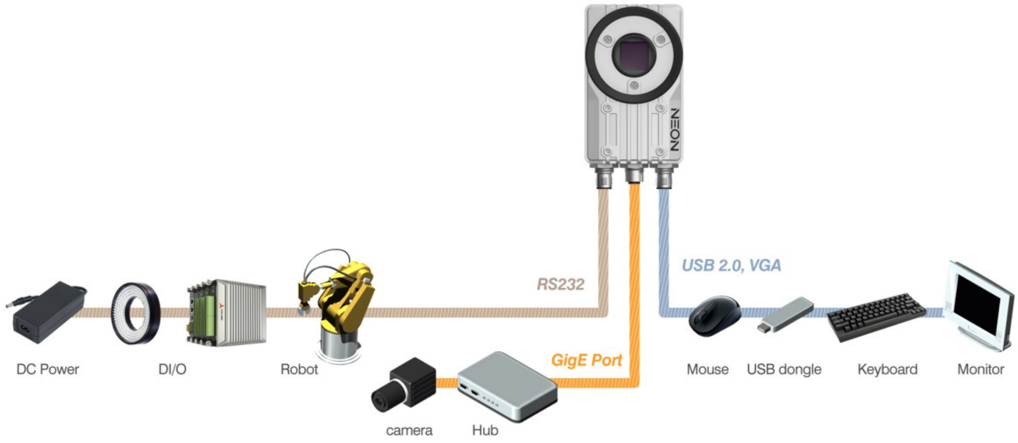


Fig. 4.11. NEON 1040

Sick AG

SICK AG's line of 'Industrial Vision Camera', are smart cameras, self-contained, stand-alone vision systems with an easy-to-use graphical user interface, enabling fast development for 2D and 3D applications. They combine imaging and analysis into one camera. These flexible, high-performance cameras provide tools for inspection, robot guidance, measuring and identification. With only one camera, one can perform any combination of advanced inspections and measurements to optimize production quality. The cameras support customized operator interfaces, and communication via I/O, serial and Ethernet. Two cameras IVC – 2D and IVC – 3D are discussed below.

IVC-2D

- Suitable for advanced inspections and measurements
- Flexible working distance and field of view
- Stand-alone operation, no PC needed
- IP 65 rating
- Easy-to-use interface with more than 110 software tools
- Simple interfacing with PLCs, robots and control systems that support EtherNet/IP or OPC
- Available in 3 different resolutions from fast VGA (0.3MP) to high-resolution UXGA (1.9 MP)

IVC-3D

The smart camera for 3D contour detection ICV-3D is used for automated three-dimensional measurement and inspection of objects. The universal sensor unit can be adjusted by extensive programming software for many applications. Among the possible applications include all tests that determine the geometry of a component, e.g., combined testing of components or assemblies to surface damage and the presence of test and situational awareness in a single pass. The widely contrasting independent method can reliably detect even dark objects against a dark background. Fig.4.12. shows the scenario of automatic quality inspection in food industry.

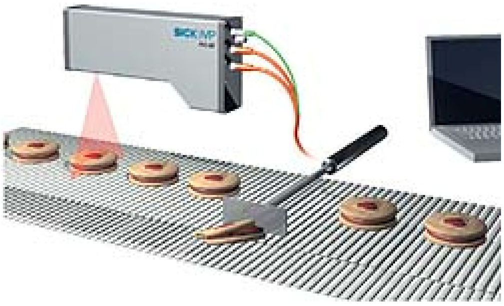


Fig. 4.12. Smart Camera for Quality inspection

- Easy 3D measurement – provides information about object height, shape and volume
- Factory calibrated
- Easy-to-use graphical user interface for fast application development
- Stand-alone operation, no PC needed after configuration
- Simple interfacing with PLCs, robots and control systems that support Ethernet/I
- Scans up to 5,000 profiles per second
- Rated IP 65

4.5. Software and Interfaces

Smart factories require interfaces and software to connect the whole system in a network and to operate conveniently and efficiently. We will discuss on PROFINET, an interface used for emerging Ethernet to industrial automation and MERLIC, machine vision software which facilitates machine vision application without programming.

4.5.1. Profinet

PROFINET is the Standard of PROFIBUS International (PI) to emerge Ethernet to the next generation of industrial automation. PROFINET consists of several topics such as distributed automation (PROFINET CBA), decentralized field devices (PROFINET IO), network management installation guidelines and web integration. All these different topics will help to make standard switched Ethernet easier to use in industrial automation. (Feld, Joachim, 2004)

PROFINET CBA

In the distributed automation concept PROFINET CBA machines and systems are divided into technological modules, each of which is comprised of mechanical and electronic components, electronics and software. The functionality of the technological modules is encapsulated in the form of PROFINET CBA components. From the outside the PROFINET CBA components can be accessed via interfaces with standardized definitions. They can be combined with one another like building blocks as required and easily reused.

The PROFINET CBA Runtime Software or "PROFINET CBA Core" is the software made available by Profibus International to developers. This software is only one of a number of components necessary to implement a PROFINET CBA device. Fig.4.13. graphically represents the components of a PROFINET CBA device. Components in blue indicate off-the-shelf components supplied by the developer. Components in yellow indicate integration tasks for the developer. Components in green indicate parts of the PROFINET CBA core that a developer should not change.

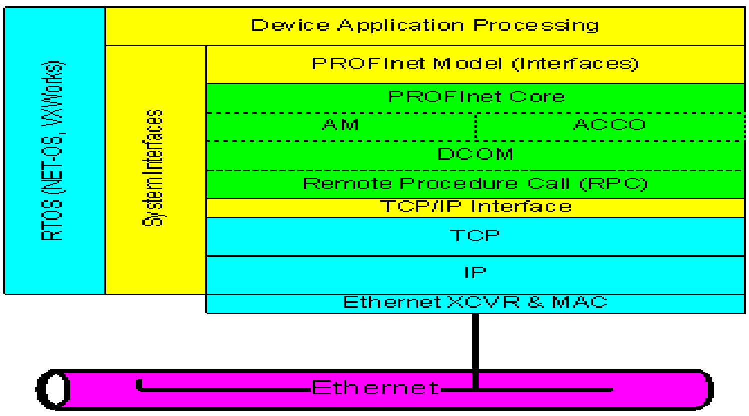


Fig.4.13. PROFInet Runtime Software Components

PROFINET CBA Engineering Model

PROFINET CBA terms the process of building a PROFINET CBA device, creating interconnections between the PROFINET CBA devices of a system and sending the resulting runtime configuration to the system, the "PROFINET CBA Engineering Model."

PROFINET CBA devices are built by decomposing the functionality of the device into components. Each component is modelled as a set of properties, events and methods. Once these external "interfaces" are designed an Extensible Meta Language (XML) file is created. The XML file captures the functionality of the device in a text-based, transportable image that can be processed by the PROFINET CBA Connection Editor.

The PROFINET CBA Connection Editor is a device used to do the System Engineering of a network. The Connection Editor provides a graphical tool for choosing the inter-relationships between devices on a PROFINET CBA network. Connections are made between devices at the component layer. An event in one device can trigger a method in another interface. It makes no difference if the method is part of the same interface or a method of a remote device located miles or countries away.

Once the inter-relationships are chosen the Connection Editor automatically downloads the connections to each PROFINET CBA device. These connections are stored in non-volatile memory and become the basis of the PROFINET CBA Runtime operation. The connections describe to each device what TCP/IP connections must be made, what Remote Procedure Calls are required and what DCOM interfaces are triggered and when they are triggered.

PROFINET IO

PROFINET IO enables the use of decentralized field devices with Ethernet. With decentralized field devices all automation devices including IO-devices, valve islands, frequency converter etc. can easily be used in a homogenous network infrastructure. The combination of distributed automation and decentralized field devices is the base for complete solutions for factory automation. Thus the advantages of a uniform and consistent network infrastructure (one connector, one cable, standardized network management and diagnosis) become available. But there is not only a consistent network infrastructure; also data transfer between devices is standardized and homogenous. Both for communication between intelligent devices and data transfer between PROFINET IO Controller and PROFINET IO-Device the same protocol, communication mechanisms and network scheduling are in charge.

PROFINET IO Benefits

PROFINET IO is a unique industrial Ethernet application layer. It offers many benefits over competing application layers including:

- High Speed Operation – The real time communication channel provides high speed message exchange by bypassing the time required to process the TCP/IP stack.
- Seamless and nearly identical Siemens S7 PLC integration to Profibus
- Support for time critical motion control applications
- Short Startup
- Distributed Intelligence
- Ease of installation
- Minimum commissioning time and engineering support

PROFINET IO Configuration Structure

PROFINET IO devices are typically configured by Siemens Step 7 software. Using Step 7, devices descriptions are loaded from the GSDML files. I/O configurations are mapped into the I/O tables of the Siemens IO Controller and IP addresses are assigned to each PROFINET IO device. Fig.4. 14 graphically represents the structure of this system.

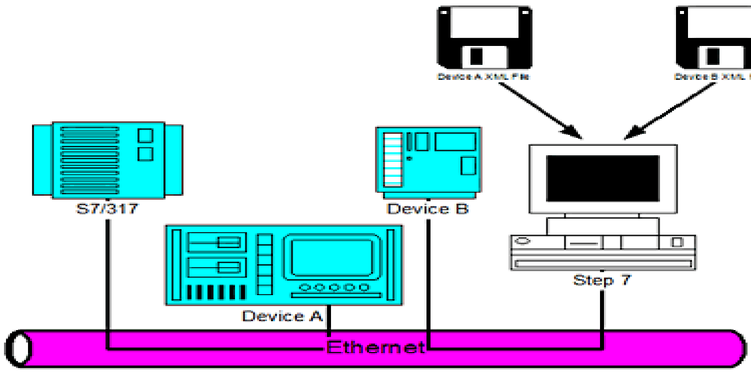


Fig.4.14. PROFInet IO Engineering Model

4.5.2. Merlic

MERLIC is an all-in-one software product for quickly building machine vision applications without programming. It is based on MVTec's extensive machine vision expertise and combines reliable, fast performance with ease of use.

Tools and Features

Machine vision application without programming: While most common machine vision programs require extensive programming knowledge, MERLIC was created to build a machine vision application without programming a single line of code. So instead of coding line by line, one can simply step through the application and rely on the many standard machine vision tools. The vision tools in the MERLIC "MVApp" are connected automatically. Alternatively, one can simply reconnect them by drag & drop.

Image-centered user interface: The clear and reduced interface presents a large view on the processed image in the center of the program. The tool library on the left side provides many standard vision tools such as **acquisition, calibration, alignment, measuring, counting, checking, reading, position determination, and defect detection**. It can also be extended with customized tools. Each tool has its own graphical representation in the workspace, which allows to see and review every step of vision application when scrolling the workspace. The image-centered design allows to configure the application directly via the image without the need to write source code or to adjust lots of parameters.

“easyTouch”: It helps to guide the user interactively towards the solution. For example, simply hovering the mouse pointer over an image and “easyTouch” recognizes and marks objects to be identified.

Integrated tool library: MERLIC’s integrated tool library contains a wide range of tools for the most common vision processing tasks. It can also be expanded by adding customized tools. To facilitate the ease of use, all included tools are named after the task they are meant to execute. Several ‘Evaluation’ tools support with a variety of evaluation processes. Also, the tool library can be extended flexibly with customized, user-defined tools to suit any additional needs.

Multiple languages: MERLIC is available in the following languages: simplified and traditional Chinese, English, French, German, Japanese, and Thai. Not only the graphical user interface (GUI) is translated, but also the entire documentation is available in these languages.

PLC Communication: MERLIC facilitates as a seamless PLC connection. The software supports the entire process of developing an application, from acquiring and processing images to the programmable control (PLC) of the machine.

As a stand-alone software package, MERLIC therefore offers full integration, including digital I/O and the OPC UA standard.

System Requirements for MERLIC:

- x86 processor with SSE2 extension or x64 processor
- Windows 7 or higher
- works best with at least OpenGL 3.0

MERLIC actively makes use of multi-core platforms and AVX for highest performance.

4.6. Technical Recommendations

Industry 4.0 scenarios will bring in the need for Product identification and tracking, hence, developing cameras for image based code-readers with built-in image processing and other technical requirements discussed above is recommended. In addition to it, the scenario will give rise to precise part – handling, i.e., intra logistics with devices like iBin, Automated Guided Vehicles which has to be equipped with image sensors for either guidance and control or information retrieval. A trend towards Smart camera is developing, requiring cameras to be flexible in application. One hardware, which could be used for various applications should be developed. This kind of flexibility can be achieved through software. Preferably, a user- friendly, GUI based software interface could be implemented. Usually, smart cameras tend to be small, compact and efficient. Since data is becoming more important these days, options like SD-card slot or Cloud connectivity could be additional features to a Smart camera. Already established firms in Smart camera division were discussed above. Intel's "Internet of Things Solutions Alliance" or European Commission's "The Alliance for Internet of Things Innovation" could serve as a platform for joint developments and thereby expanding market under the tag "Industry 4.0". These alliances could also be perceived as an opportunity for vertical integration with potential lower and upper stream of companies in the business value chain.

Recommendation for Software and Interfaces

PROFINET is the interface used for emerging Ethernet to industrial automation. The combination of distributed automation (PROFINET CBA) and decentralized field devices (PROFINET IO) is the base for complete solutions for factory automation. For camera devices, which is to be used in this type of interface, it is recommended to consider the interconnection and functionality of camera devices in an interface like PROFINET. MERLIC is the software product for quickly building machine vision applications without programming. Functionality of camera devices in a system operated by software without programming has to be considered and respective software development should be taken into consideration. Considering the current value chain of AVT, it is recommended to involve third party software development firms for development of software which is to be applied on Camera devices for functioning efficiently and effectively in an interface like PROFINET and with software like MERLIC.

5. Business Development

The networking within an 'Internet of things, services, data and people' will transform the future of manufacturing. It is not just the manufacturing, but all the associated business units with manufacturing. For example, Allied Vision sensor cameras. In this chapter, we learn more about the transformation, a raw analysis on the business model and value chain in the present and the future.

In this project we have made a clear distinction between the following concepts-

- Business model
- Value chain
- Strengths and weakness analysis

The term business model is defined herein as "the chosen system of inputs, business activities, outputs and outcomes that aims to create value over the short, medium and long term."

Consideration of inputs, outputs and outcomes of Allied Vision business structure will help to clarify the organization's positive and negative impacts on financial, manufactured, human, intellectual, natural and social and relationship capital. Such considerations will also encourage the organization to take a broader view of the concept of value creation (explained later).

5.1. Current Business model

The Business model canvas gives an overview of the plan implemented by a company to generate revenue and make a profit from operations. It includes the components and functions of the business, as well as the revenues it generates and the expenses it incurs.

Designed for: Allied Vision Technologies GmbH | **Designed by:** FfE-Team | **On:** July.2015

Key Activities:

- Design and development of hard-, soft-, firmware, sensor integr.
- Manufacturing of the MV component camera
- Customization
- Customer support
- Repair
- Content Management (Techn. Documentation)

Key Partners:

- Suppliers (e.g. Sony)
- SW-Partners
- Key Customers

Key Resources:

- Know-how about sensor, FPGA compontents

Values Propositions:

- MV cameras for applications on and off the factory floor
- Help the customer to solve his vision problem by being a trusted partner
- Offer the most effective accessorize to the compontent camera: cables, objects, software

Customer Relationships:

- Trusted partner to the customer
- Fast & efficient repair
- Excellent customer supp

Channels:

- Sales representatives and offices
- Sales through distributers
- Exhibitions

Customer Segments:

- Sales regions: Asia, NAFTA, EMEA
- Market segments: Industrial, Medical..
- OEM customers
- System integrator (SW companies)
- Distributers, also offering lighting, cables, etc.
- Direct customers industrial, medical,

Cost Structure:

- Material purchasing costs: electronics, sensors

Revenue Streams:

- Sales per shipped cameras
- Service models

Fig. 5.1. Current Business Model of Allied Vision

5.2. Current value chain

A value chain is the full range of activities — including design, production, marketing and distribution that businesses go through to bring a product or service from conception to delivery. For companies that produce goods, the value chain starts with the raw materials used to make their products, and consists of everything that is added to it before it is sold to consumers.

Profits for an organization stem from different activities that are performed at different parts of the firm. Therefore by analyzing the activities individually, we can improve the value of the product and modify it to suit to the requirements of Industry 4.0 in the future.

Current activities in the organization are shown below:

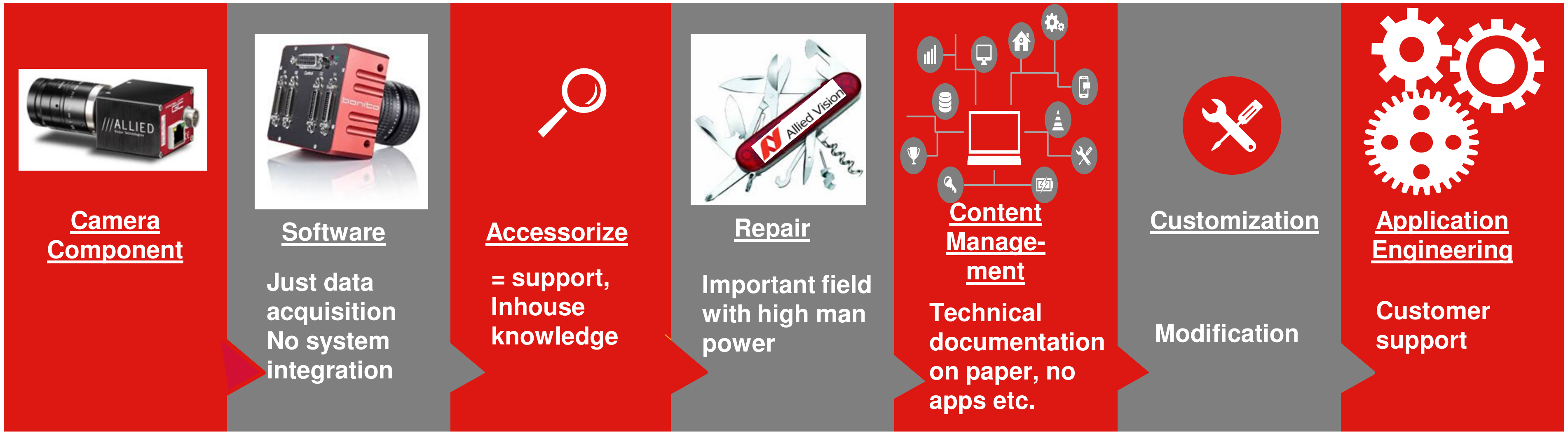


Fig. 5.2. Current Value Chain of Allied Vision

5.3. SWOT analysis

A SWOT Analysis is a strategic planning tool used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or in a business venture.

In this current project, we include SWOT analysis because it involves monitoring the market environment for Allied Vision in the Industry 4.0 scenario. It considers both the internal and external factors that may have an impact on the business. The key goal of SWOT analysis is to identify these internal and external factors that are important in achieving success with the establishing and expanding the market potential of cameras. Internal factors includes the 'Strength' and 'weaknesses', while external factors includes ' Opportunities' and 'Threats'.

In the below shown diagram, each category of this SWOT analysis could be expanded. Allied Vision can then assess the results to decide if they can use their strengths to take advantage of the opportunities and introduce themselves in Industry 4.0 market field. After assessing the results, they may decide that the weaknesses and threats need to be addressed before they can make any changes to their existing product line.

The following 8 steps were considered in performing SWOT analysis:

1. Decide on the objective of SWOT analysis
2. Research on Allied Vision business, industry and market potential
3. List Allied Vision's business's strengths
4. List Allied Vision's business's weaknesses
5. List potential opportunities for Allied Vision in industry 4.0 scenario
6. List potential threats to Allied Vision business
7. Establish priorities from the SWOT
8. Develop a strategy to address issues in the SWOT (not in our scope)

Although, a strategy was not developed within this project framework. The next steps for Allied Vision could be that they follow the below mentioned questions in order to develop a strategy from the generic SWOT analysis as seen in figure 5.3. The questions to be answered are:

- How can Allied Vision use the strengths to take advantage of the opportunities identified?
- How can Allied Vision use these strengths to overcome the threats identified?
- What do Allied Vision need to do to overcome the identified weaknesses in order to take advantage of the opportunities?
- How will Allied Vision minimize our weaknesses to overcome the identified threats?

Fig. 5.3. SWOT Analysis

5.4. Business changes

Major Business Changes identified for Allied Vision technologies can be seen in the following diagram:

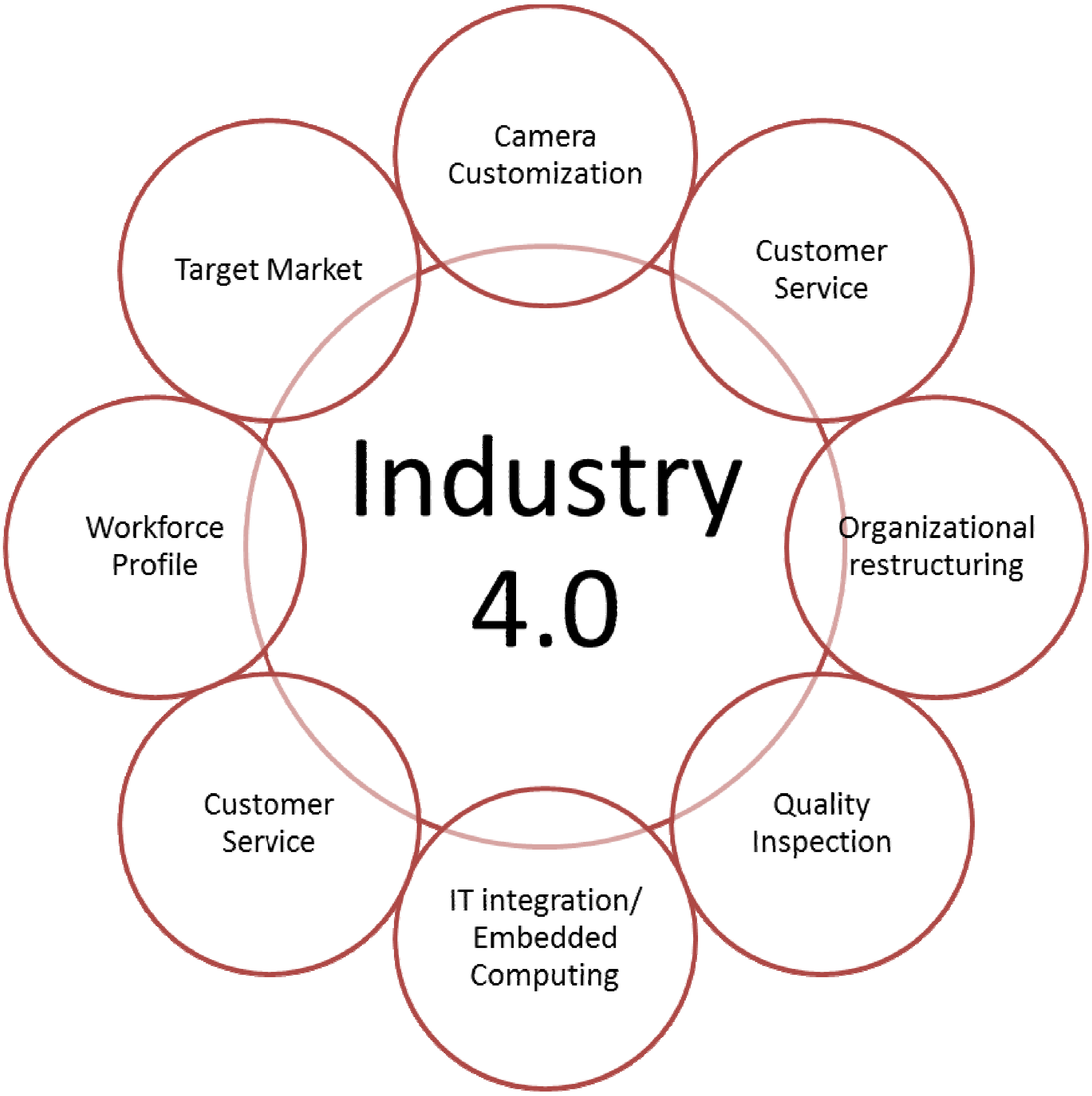


Fig. 5.4. Business Changes

1. Camera Customization

Industry 4.0 brings more freedom and flexibility into the production process. So it will become possible to create products tailored to segment-by-one customer needs at relatively low marginal cost.5Industry 4.0 is based on new and radically changed processes in manufacturing companies. In this concept, data is gathered from suppliers, customers and the company itself

[5]https://www.rolandberger.com/media/pdf/Roland_Berger_TAB_Industry_4_0_20140403.pdf

and evaluated before being linked up with real production. The latter is increasingly using new technologies such as sensors. Cameras play an important role as a sensing device in industry 4.0. These cameras are in-turn developed together with embedded software to tailor to customer needs. Cameras are varied, and so are their functions. Customizing these cameras, could be among the important change Allied Vision could foresee, when compared to their current manufacturing methodology.

2. Customer Service

Customized sensors (cameras) and automated data transfer of data from the sensors to connected planning and manufacturing systems, could be further integrated with customer service. This brings a level of complexity to the Allied Vision camera customer service. Having been interlinked together with the IT infrastructure, it could be possible that the current model of customer service will see a change in terms of processes, and knowledge expertise requirement.

3. Network Restructuring

Vertical networks: One of the main characteristic of industry 4.0 is he vertical networking of smart production systems in the factories of the future. It uses cyber-physical production systems (CPPSs) to enable plats to react rapidly to changes in demand. Smart factories automate production that is customized and individualized. These require a high level of integration using smart sensor technology, which has to be developed in conjunction with the sensor cameras.

Horizontal network: A change will be seen in the horizontal networks of creating global value chains, including integration of various business partners and customers, along with new business cooperation models.

4. Quality Inspection

Industry 4.0 requires an extensive data and maximum transparency from suppliers for their seamless quality monitoring throughout the value chain. This could pressurize Allied Vision Technologies to increase their bar on product quality. Increasing quality and flexibility for the customers means reduced cost and reduced cost to connect to the manufacturing systems, and thereby preventing system failures. Therefore, delivering high quality cameras and increasing quality standards /inspection could be seen in the futuristic business operations of Allied Vision.

5. IT integration/Embedded Computing

Only some of a manufacturer's sensors and machines are networked and make use of embedded computing. They are typically organized in a vertical automation pyramid in which sensors and field devices with limited intelligence and automation controllers feed into an overarching manufacturing-process control system. But with the Industrial Internet of Things, more devices—sometimes including even unfinished products—will be enriched with embedded computing and connected using standard technologies. This allows field devices to communicate and interact both with one another and with more centralized controllers, as necessary. It also decentralizes analytics and decision making, enabling real-time responses.

Manufacturing-system suppliers need to understand how they can employ technologies in new use cases to offer the greatest benefits to their customers. These technologies can be leveraged for different offerings, such as the enhancement of networked embedded systems and automation, the development of new software products, and the delivery of new services, such as analytics-driven services. To build these offers, they must put the right foundations in place:

1. Define which business model to leverage for their enhanced or new offers.
2. Build the technological foundation, such as the tool base for analytics.
3. Build the right organization structure and capabilities.
4. Develop partnerships that are essential in the digital world.
5. Participate in and shape technological standardization.

In parallel, system suppliers need to build a scenario-based vision of the long-term industry evolution and ensure that their strategy will prepare them for the most likely scenarios.

6. **Customer Service**

A holistic business approach to increase product and service performance. The approach enables full management of a product's entire life cycle from design to service within distinct scenarios. For example, "Responsive Manufacturing" delivers end-to-end processes integrating the plan-to-produce process. Embedded quality and compliance controls enable manufacturers to address nonconformance through corrective and preventive actions while simultaneously setting more predictable and shorter cycle times, helping to both improve asset utilization and support on-time delivery.

7. **Workforce profile**

Producers have to set priorities among their production processes and enhance their workforce's competencies, as follows:

Identify key areas for improvement, such as flexibility, speed, productivity, and quality. Then, consider how the nine pillars of technological advancement can drive improvement in the designated areas. Avoid becoming stuck in incremental approaches; instead, consider more fundamental changes enabled by a combination of the nine technologies.

a. Analyze the long-term impact on the workforce and conduct strategic workforce planning.
b. Adapt roles, recruiting, and vocational training to prepare the workforce with the additional IT skills that will be required.

8. **Target Market**

Another important aspect to be considered in terms of business changes is the target market. While Allied Vision try to retain their current customers and satisfy their needs, there is a huge potential beyond the current framework to expand their market in by highlighting their development in the field of industry 4.0. Hence, our suggestion would be that Allied Vision could invest more towards advertising their products and realizing current customers and potential customers towards their research and progress in adapting cutting edge technologies. While these improvements already hold significant potential for existing industries, emerging fields could use Industry 4.0 technology to disrupt existing standards using innovative factory layouts and production processes.

5.5. Future Business model

The future business model was created on the basis of the current business model. For its creation, influences from the following chapters have been considered:

- General Industry 4.0 trends (chapter 3.2.)
- Changes in Machine Vision due to Industry 4.0 (Chapter 4)
- SWOT-analysis (chapter 5.3.)
- Business Changes (chapter 5.4.)

Main changes are marked in red color. It may either be a new aspect in the business model or it indicates a necessary intensification.

[Key Activities]: **Intensified Customization**

Allied Vision already puts a high effort on customization. Nevertheless this aspect will become more and more important and has to be considered and intensified.

- Driven by the trend of mass customization
- Modularization can help to handle complexity
- New generation of robotics with need for specific vision units

[Key Partners]: **Suppliers for smart camera components**

- ROM, RAM, SDcards, etc

[Key Partners]: **Software partners**

- Various types of partnerships between Allied Vision and software development companies that specialize in industrial applications might be necessary
- This will reduce the cost of software development and at the same time provide better quality software for camera applications
- However, an own software expertise is vital as well

[Key Resources]: **IT expertise**

- Vital

[Value Proposition]: **Trusted technology partner that drives standardization**

[Customer Relationship]: **Fast & efficient repair, Excellent customer support**

- in combination with trusted technology partner
- Remote Service and Monitoring
- Software on the camera sends status information over the IoS from the customer to Allied Vision for various purposes

[Customer Relationship]: **Intensified Collaboration along the Supply Chain**

- Horizontal Integration
- New Supply Chain Management Tools and Partnerships with specific key partners

[Channels]: **eCommerce**

[Revenue Streams]:

- Intensified service orientation is expected.

Designed for: Allied Vision Technologies GmbH | **Designed by:** FfE-Team | **On:** Oct.2015

Key Activities:

- Design and develop-ment of hard-, soft-, firmware, sensor integr.
- Manufacturing of the MV component camera
- Intensified Customization
- Customer support
- Repair
- Content Management (Techn. Documentation)

Key Partners:

- Suppliers for smart camera components
- SW-Partners
- Key Customers

Key Resources:

- Know-how about sensor, FPGA compontents
- IT expertise

Values Propositions:

- MV cameras for applications on and off the factory floor
- Help the customer to solve his vision problem by being a trusted partner
- Offer the most effective accessorize to the compontent camera: cables, objects, software
- Trusted technology partner that drives standardization

Customer Relationships:

- Trusted partner to the customer
- Fast & efficient repair
- Excellent customer supp
- Intensified collaboration along the supply chain

Channels:

- Sales representatives and offices
- Sales through distributers
- eCommerce
- Exhibitions

Customer Segments:

- Sales regions: Asia, NAFTA, EMEA
- Market segments: Industrial, Medical..
- OEM customers
- System integrator (SW companies)
- Distributers, also offering lighting, cables, etc.
- Direct customers industrial, medical,

Cost Structure:

- Material purchasing costs: electronics, sensors

Revenue Streams:

- Sales per shipped cameras
- Service models

Fig 5.5. Future Business Model

5.6. Future Value Chain

The future Value Chain was created on the basis of the current Value Chain. For its creation, influences from the following chapters have been considered:

- General Industry 4.0 trends (chapter 3.2.)
- Changes in Machine Vision due to Industry 4.0 (Chapter 4)
- SWOT-analysis (chapter 5.3.)
- Business Changes (chapter 5.4.)
- Future Business Model (chapter 5.5.)

1. **Camera components:**

   - Will remain a high competency of the company for the foreseeable future. Since the main product of Allied Vision is industrial camera, it will be the focus of research and development now and also in the future.
   - New components for smart cameras
   - Also the prime focus on modular cameras might be the prime job instead of its current cameras for specific application

2. **Software:**

   - Software is a core feature in the context of Industry 4.0.
   - Various types of partnerships between Allied Vision and software development companies that specialize in industrial applications might be necessary.
   - This will reduce the cost of software development and at the same time provide better quality software for camera applications

3. **Accessorize:**

   - Accessorize will change significantly. Acquiring external knowledge and increasing the profile of the employees will be one of the major challenges to handle the digital transformation.

4. **Repair:**

   - The Repair process will be made more efficient in the future. Since the camera is connected to the cloud, it reports errors and possible solutions over the IoT and IoS to the Allied Vision service engineers.

- Thus the servicemen are more prepared and informed about the problem before they even arrive at the customer's place (if still necessary).

5. **Content Management:**

- Content Management Software desirable
- Technical documentation will be done electronically through a common portal, to which all customers of Allied Vision have access.
- All existing paperwork could be scanned and stored for future reference.
- Complexity Management essential

6. **Customization:**

- A highly modular product structure in combination with a customization tool simplifies processes and increases efficiency
- Responsive Manufacturing delivers end-to-end processes integrating the plan-to-produce process. Embedded quality and compliance controls enable manufacturers to address nonconformance through corrective and preventive actions while simultaneously setting more predictable and shorter cycle times

7. **Application Engineering:**

- Application engineering will have a change in the way it is used in Allied Vision.
- Since the product is modular and not application specific, the application engineer will have increased work to configure the camera for particular applications in industry.
- appropriate software tool desirable

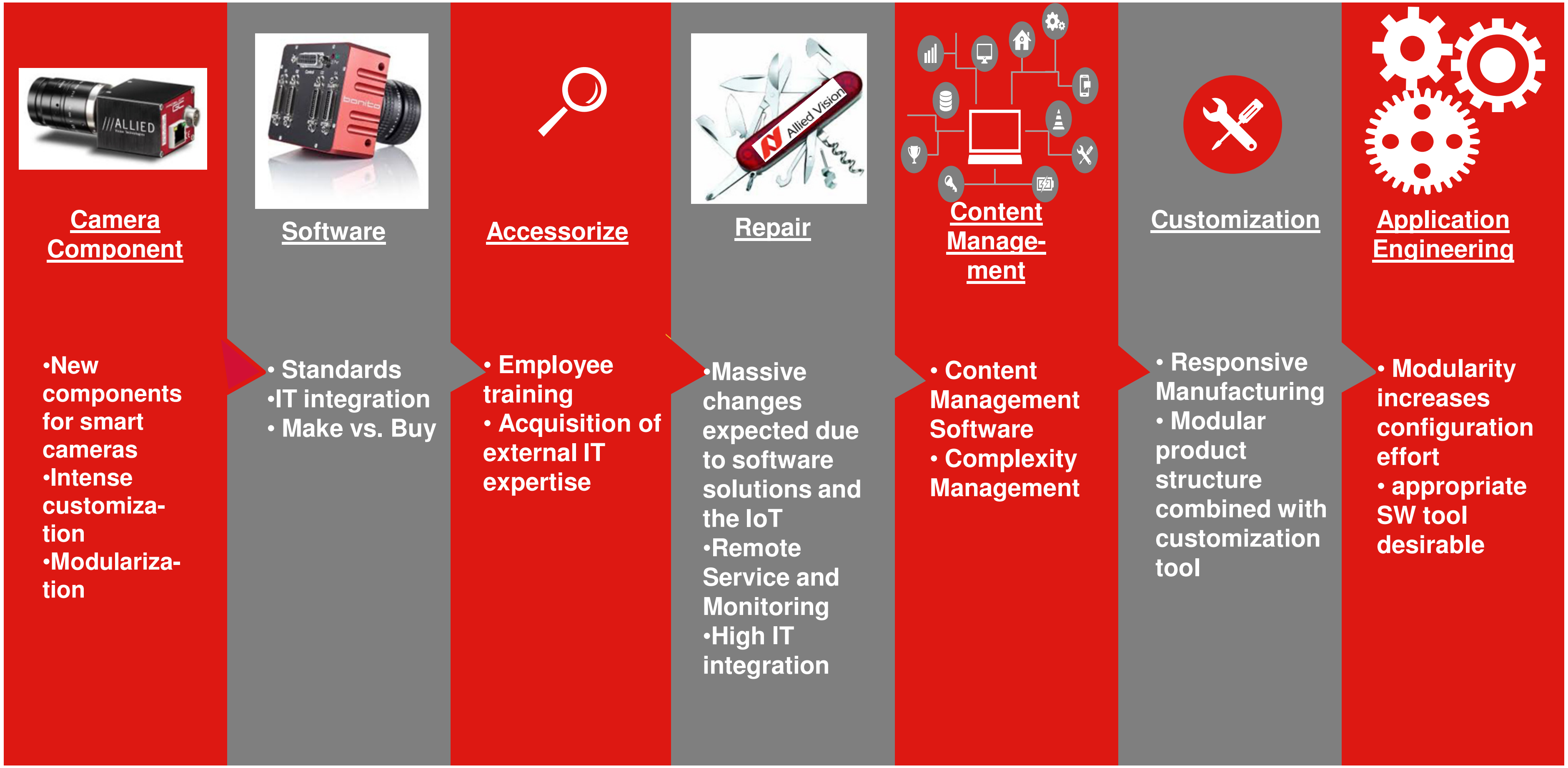


Fig. 5.6. Future Value Chain

5.7. Business Recommendations

The technologies in Industry 4.0 bare a high potential and a huge variety of possibilities.

We highly recommend Allied Vision to take advantage of the possible efficiency increases in the area of remote services and monitoring. Using the internet of things and service to acquire data from machine vision units on the shop floor from customers and the analysis of these data offers far reaching benefits.

An enhancement and enrichment of the organization with IT expertise is crucial. Acquiring partnerships with IT collaborators could lead to a sustainable market position.

The biggest stumbling block on the way to a digital transformation is the lack of awareness and commitment for the necessity of a digital transformation. Thus, the management has to be convinced to take action.

Most important is building up a Digitalization Strategy as the success factors for the digital transformation read as follows:

1. Strategy
2. Leadership
3. Products
4. People
5. Culture
6. Operations
7. Governance
8. Technology

The future will in general bring a higher service orientation. Allied Vision does have a good base to start from as the company is one of the best in class in customer support. If the right standards are chosen and actions are taken far-seeing, Allied Vision will be able to strengthen its market position until the fifth industrial revolution.

6. Summary

The aim of this project work was to develop a base for strategy to Allied Vision Technologies. This was mainly covered by identifying and analyzing the usage of Allied Vision Technology product, i.e., Cameras within Industry 4.0 concept. The research is comprised of the following: a thorough literature research on Industry 4.0, understanding the background of Allied Vision and its business model, and thereby developing scenarios for application of cameras, which act as a sensing device in Industry 4.0.

The project initially reviewed the status quo of machine vision by reviewing the technical specifications of cameras that are being applied in the current condition. At the later stage, competitor (Basler, Baumer, and IDS) cameras were also analyzed. This competitor analysis gave a sense of feel to the project team on the current position of Allied Vision products in the market. It was seen that the cameras produced by Allied Vision and the competitors were almost on the same benchmark.

This project was conducted to analyze the market potential of Allied Vision cameras in Industry 4.0. A deep understanding on Industry 4.0, an emerging cutting edge technology was researched in this point of view. The potentiality and trends of Industry 4.0 was studied. This helped to gather information on the interfaces, and upcoming trends in Industry 4.0. A rough framework of Industry 4.0 was considered from this for further work.

The changes that emerge from Industry 4.0, is the focus for the project, and how it influences Allied Vision. Therefore, changes in machine vision were identified and scenarios were developed based on this. It includes augmented reality, intra logistics, and smart cameras. Under these scenarios, the camera applications analyzed in depth and the potentiality is identified.

After analyzing all this, business development became the focal point of study. The current business model and value chain formed the basis for this. After a SWOT-analysis and a study of business trends, possibilities of a future business model and a future value chain were developed.

7. List of references

Adil Shafi, (2004),"Machine vision in automotive manufacturing", Sensor Review, Vol. 24 Iss 4 pp. 337 – 342

Bauer, W., et al.(2014):*Industrie 4.0 - Volkswirtschaftliches Potenzial für Deutschland.*[Hrsg.] BITCOM und Fraunhofer IAO. Berlin

Bauernhansl, T. (2014): Die Vierte Industrielle Revolution – Der Weg in ein wertschaffendes Produktionsparadigma. In: T. Bauernhansl, M. ten Hompel und B. Vogel-Heuser [Hrsg.] *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration.* Wiesbaden: Springer Vieweg, S. 5-35.

Belbachir, A. (2010). *Smart cameras*. New York: Springer.

Bischoff, J., et al. (2015):*Erschließen der Potenziale der Anwendung von Industrie 4.0 im Mittelstand.*Bischoff, S. [Hrsg.] Mülheim an der Ruhr.

European Machinae Vision Association, www.emva.org. EMVA Standart 1288, Standartfor Characterization of Image Sensors and Cameras, 3.1 edition, November 2012.

Feld, Joachim. "PROFINET-scalable factory communication for all applications." Factory Communication Systems, 2004. Proceedings. 2004 IEEE International Workshop on. IEEE, 2004.

Hermann, M., Pentek, T. und Otto, B. (2015): Design Principles for Industrie 4.0 Scenarios: A Literature Review. Dortmund

Hornberg, A. (2006). Handbook of machine vision. Weinheim: Wiley-VCH;

Kleinemeier, M. (2014): Von der Automatisierungspyramide zu Unternehmenssteuerungsnetzwerken. In: T. Bauernhansl, M. ten Hompel und B. Vogel-Heuser [Hrsg.] *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration.* Wiesbaden: Springer Vieweg, S. 571-579.

Schlick, J., et al. (2014): Industrie 4.0 in der praktischen Anwendung. In: T. Bauernhansl, M. ten Hompel und B. Vogel-Heuser [Hrsg.] *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration.* Wiesbaden: Springer Vieweg, S. 57-84.

Waizmann, Stefan: How to Automate Manufacturing with Imaging; White paper from FRAMOS

http://www.baslerweb.com/de

http://de.wikipedia.org/wiki/Basler_AG

http://www.baslerweb.com/linklist/3/7/8/1/6/GB2014_de_offen.pdf http://www.baumer.com/de-de/

http://de.wikipedia.org/wiki/Baumer_Group

https://de.ids-imaging.com/

http://www.rtaautomation.com/technologies/profinet-cba/

http://www.rtaautomation.com/technologies/profinet-io/

http://www.mvtec.com/products/merlic/product-information/tools-and-features/

pco.edge scientific CMOS camera, Datenblatt.
http://www.pco.de/de/kategorien/scmoskameras/pcoedge

pco.edgescientific CMOS camera, unser manual.
http://www.pco.de/manuals/pcoedge/

8. Appendix

8.1. Appendix A: Camera and Sensor parameters

Parameter	Explanation see below the table [23],[20],[24]
Sensor size [number of pixels x number of pixels]	1.
Pixel size [m]	2.
Shutter modes	3.
Fullwell capacity [e^-/pixel]	4.
Quantum efficiency	5.
Darkcurrent [e^-/s]	6.
A/D conversiongain [e^-/digital count]	7.
Noise [e^-/s]	8.
Signal-Noise-Ratio	9.
Dynamic range [dB]	10.
Framerate [frame/s]	11.
Exposuretime [s]	12.

Explanation of the Camera- and Sensor-parameters

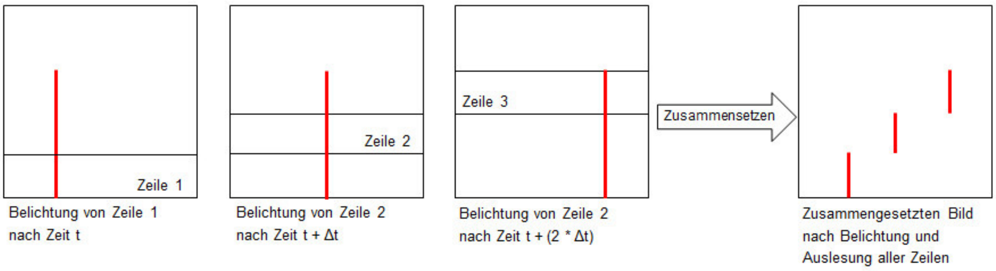
1. *Sensor size[number of pixels x number of pixels]:* The *sensor size* is given in two-dimensional coordinates, e.g. 2560 x 2160. That means that there are 2560 pixel in horizontal and 2160 pixel in vertical. In this case there are 5529600 Pixel, so 5.5 megapixels, in total. This number shows how many pixels can be displayed by a sensor or a screen. The more pixels can be displayed in a picture, the more detailed it is. So the *sensor size* can be seen as a value for the level of details of the sensor and is in general named as resolution.

2. *Pixel size [m]:* The *pixel size* gives the dimension of each pixel. So is sets the minimal size of a structure which can be shown.
   The combination of sensor Size and Pixel Size can be seen as a value for the image quality.

3. *Shutter modes:* The difference in shutter modes are the way of pixel-exposure. The distinction is between rolling-shutter- (RS) and global-shutter-mode (GS). In RS the exposure happens in lines or columns of pixels of the sensor. After exposure follows the readout of the information. While readout of one line or column the following is further exposed, that means, it keeps on with collecting light. That's leads in an increase of sensitivity of the sensor. Working with RS is no problem when the object stands still. But when it is moving, you will get a so called blooming-effect. While the first line/column is

Figure 8.1: schematic description of the rolling-shutter-effect by line-by-line readout of the sensor

exposed, the object is moving. When the next line/column is exposed this shift of position is collected as well. After the exposition and readout of all lines/columns the image will be putted together by software and here you can't revoke this shift of position. The object seems blurred. This is shown in a schematic way in figure 1.In GS the whole sensor is exposed at the same time. So this effect doesn't appear.



4. *Fullwell capacity (FC) [e⁻/pixel]:* The *fullwell capacity* is the maximum number of electrons, which can be collected in each pixel. The *fullwell capacity* is expressed in [number electrons]. The more electrons a sensor can collect, the longer it takes until he gets overexposed.

5. *Quantum efficiency:*[23]The quantum efficiency specifies, with which probability a photon, which hits a photosensitive pixel, sets free an electron by the inner photoelectric effect. This electron is necessary for detection of the photon. The QE is always between 0 and 1.

$$QE = \eta(\lambda) = \frac{\mu_e}{\mu_p}$$

With μ_e = mean number of collected electrons during exposure

μ_p = mean number of photons hitting the sensor surface.

With $$\mu_p = \frac{ALt_{Bel}}{h\nu} = \frac{ALt_{Bel}}{hc/\lambda} = 50.34 \cdot A[\mu m^2] \cdot t_{Bel}[ms] \cdot \lambda[\mu m] \cdot L[\frac{\mu W}{cm^2}]$$

- A = Pixel area
- L = Radiation density
- t_{Bel} = Exposure time
- h = Planck Constant = 6.6260755 · 10−34J · s
- c = Speed of light
- λ = Wavelength of incoming light

6. *Darkcurrent [e⁻/s]:* The darkcurrent can be divided into two parts. First a constant offset. This offset is necessary hence the analog-digital-converter (ADC), which converts the

analog electron signal in a digital signal for the readout-electronic, doesn't digitalize a zero signal. The ADC can't do this because if his logarithmic character.

The other part is variable. His source is the thermal induced creation of free charge carriers in the semiconductor detector (photodiode). They are generated by thermal movement of the particles which can be unhinged out of the detector grid by e.g. inelastic collision. So an electron flux is generated without extern photons.
That means, the higher the temperature, the higher the darkcurrent. This darkcurrent have to keep small by cooling the sensor. In an ideal scenario with constant cooling e.g. under 0°C, the darkcurrent could be kept constant, in optimum the level of the offset, the variable part of the darkcurrent could be eliminated.

7. *A/D Conversion Gain (CG)[e^-/digital count]:* [23]The CD describes, how many electrons (created in the detector by incoming photons) are necessary to create a digital count in the analog-digital-converter. So the less electrons are necessary, the better is the CG

8. *Noise [e^-/s]:* [23] The number of charge carriers is subjected to a statistic fluctuation, the Poisson distribution. It holds that $\sigma^2_e = \mu_e$, with σ^2_e as the variance of the fluctuation. You get the complete noise of a sensor σ^2_e by adding the noise values of the single parts. In addition to this we have two more noise parts. The noise of the darkcurrent σ^2_d and the noise of the ADC σ^2_q. All this is shown in figure 2.

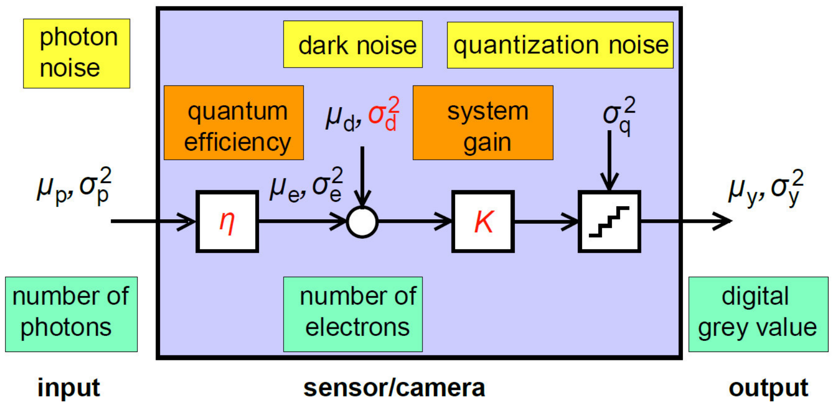


Fig. 8.2. Description of the different noise parts. It always shows the average μ and the variance σ^2[23]

The different terms in figure 2 are:

- μ_p, σ^2_p: The average number of incoming photons μ_p and whose noise part σ^2_p.
- η: The Quantum efficiency of the sensor.

- μ_e, σ^2_e: The average number of electrons μ_e and whose noise part σ^2_e after passing the electronic components of the sensor.
- μ_d, σ^2_d: The average number of the darkcurrent μ_d and whose noise part σ^2_d
- K: Gain of the whole system [DN/e−].
- σ^2_q: The noise part of the ADC during digitalization of the electrons.
- μ_y, σ^2_y: The average digital signal μ_y and whose noise part σ^2_y

9. *Signal-Noise-Ratio (SNR):* The SNR is a value for the quality of a digital signal and is defined as:

$$SNR = \frac{\mu_y - \mu_{y.dark}}{\sigma_y}$$

10. *Dynamic Range (DR) [dB]:* The DR describes the ratio of minimal to maximal number of photons per pixel.

11. *Frame Rate (FR) [frames/s]:* The FR is the maximum number of frames, which can be pictured per second. It depends of the shutter mode. The FR in GS is smaller than in RS, because in GS the readout electronic has to wait until all lines/columns are exposed before readout and analysis can start. In RS the analysis can start when the first line/column is exposed. The FR depends on the given exposure time and readout time. Depending on the value of these two, the FR is determined by one of them. In RS as well as in GS. You can see this in figure 3.
When $t_{Belichtung} < t_{Auslese}$ (exposure time < readout time), the FR depends on the time, the readout electronic need to readout all pixels.
If $t_{Belichtung} > t_{Auslese}$ (exposure time > readout time), the exposure time sets the maximum FR. In this case additional a delay-time ($t_{Verzögerung}$) occurs. This time is given by the time which is necessary to reset all parameter for a new picture.

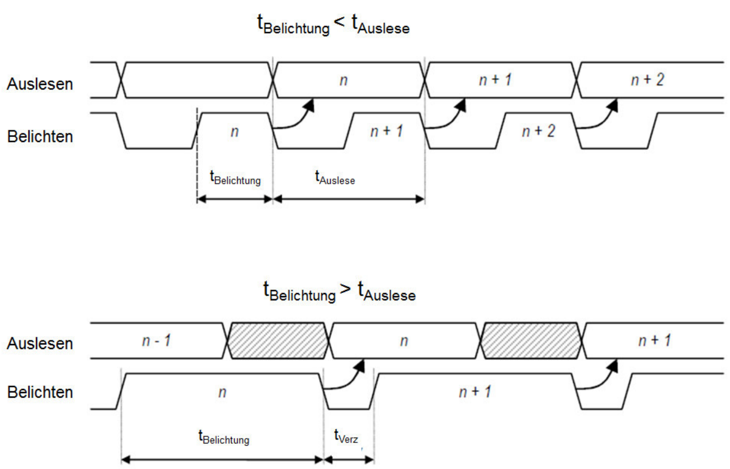


Fig. 8.3. Schematic description of the dependence of the frame rate by the length of exposure time and readout time [20]

12. *Exposure time [s]:* The Exposure time gives the time, the sensor is exposed. The longer it is, the more electrons can be generated in the pixels. So the contrast, the difference between light and dark pixels, increases with longer exposure time.

8.2. Appendix B:

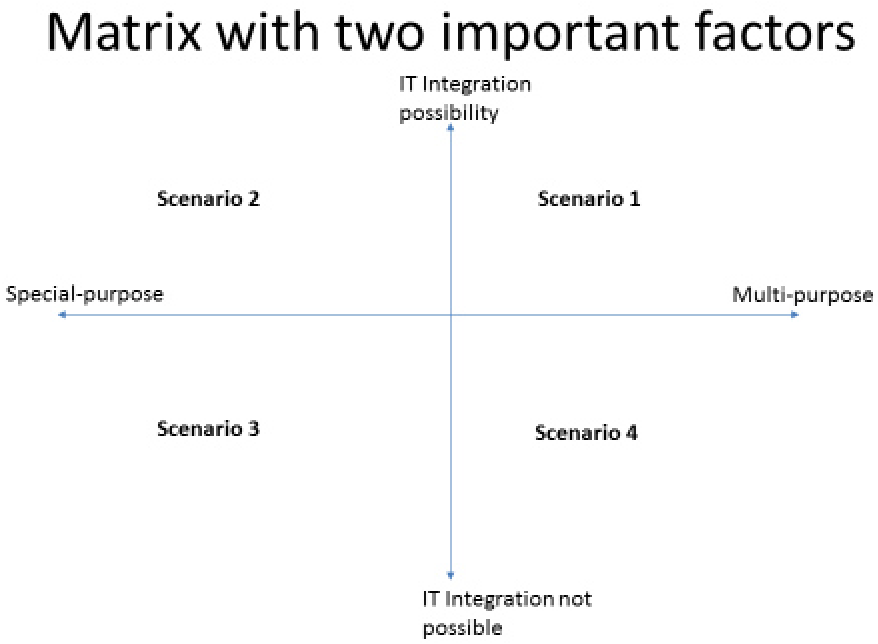


Fig 3: Scenario Planning Matrix

Selection of a Scenario for Allied Vision:

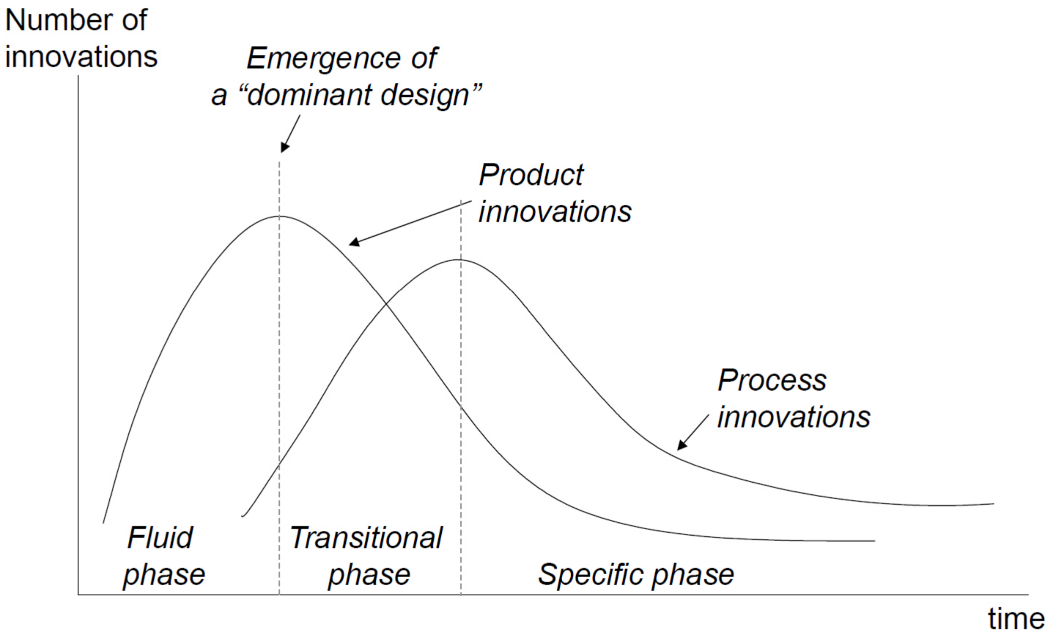


Fig 4: Patterns of Industrial Development

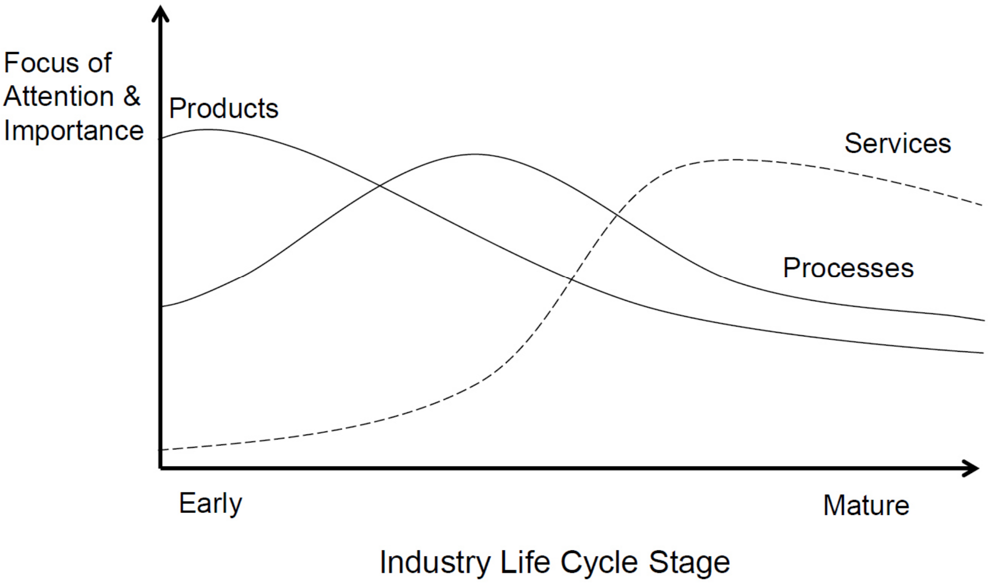


Fig 5: Industry Lifecycle stage

In Fig 4, we can see the three different stages of a product lifecycle in an industry namely, fluid phase, transition phase and specific phase. The three stages are explained below:

1. **Fluid phase:** In this phase rapid innovation of technology takes place and lots of small companies are founded due to the immense potential of an emerging industry. The major characteristics are listed below:-
    - Frequent major changes of the product design take place within the industry

- R&D having no real focus. Flexible but often inefficient production process
- Equipment: general purpose, high skills required
- Plant: small scale
- Competition: based on functional product performance
- Great opportunities for entrepreneurs
- Very many (small) firms

2. **Transitional phase:** In this phase shakeout occurs in the industry and the competition shifts to process. The major characteristics of this phase are listed below:-
   - Major process changes required by rising demand
   - Production process becomes more rigid
   - R&D focus is on specific product features (defined by dominant design)
   - Equipment: automation starts
   - Plant: growing sophistication
   - Competition based on product variations
   - Declining number of firms
   - Increasing cost pressure, shake out likely
   - Alliances and Strategic partnering necessary
3. **Specific phase:** In this phase only a small number of firms are present and the competition shifts to price and service. The major characteristics of this phase are listed below:-
   - Incremental innovations, cumulative improvements in productivity and quality
   - Production process is efficient and capital intensive
   - R&D focus is on incremental improvements, emphasis on process
   - Equipment: special-purpose, automatic
   - Plant: large scale
   - Competition based on price
   - Few large companies
   - Hard times for small-scale companies, only niche strategy viable

In the Fig 5, the industry lifecycle stages are clearly shown, which also follow the three phases described above. First the focus is on products, then it shifts to processes and finally to services in an industry. This is also true for the camera industry.

Phases in the Camera Industry:

Dominant design: Dominant design occurs in the fluid phase of development. It is defined as the design that wins the allegiance of the market place.

- Generates most value for customers
- Defines how a product “must look like” (sometimes also technical standard)
- Reduces the solution space of new products
- Reduces the possibilities of (more radical) product innovations
- Leads to a new competitive focus: reducing production costs by process innovations

A decade ago, there were many Analog cameras. But in the 21st century, there was a shift to digital cameras in the industry which lead to a revolution. Then this became the dominant deign and all cameras now follow this digital standard. The focus is now on process and service improvement rather than innovative technology.

Therefore, Allied Vision is now in the specific phase where the focus is mainly on service and price of its products in a wide variety of applications of Industry 4.0. Thus based on the four possibilities we analysed, combined with the theory of industrial lifecycle, we find that the possibility is the most possible scenario out of the four. Therefore the further decisions will be based on these assumptions

Possibility 1:

- Year 2025: Cameras are multi-functional and applied for all business processes in an industry.
- One camera is used in order confirmation, goods receipt, production, quality and logistics.
- It is integrated to the mainframe of the company and the data gets transferred automatically. This helps reduce the time delay in processing image data individually at each station.
- Allied Vision has started producing cameras in collaboration with google to add cloud services and IT integration.

Possibility 2:

- Cameras become industry specific and application specific. For e.g. they are exclusively produced for automobile market, food and beverage market, etc. Product variety is very high and the market is populated with many small players for each industry
- Integration and IT services are performed by the specific camera manufactures. Camera manufacturers also develop their own IT research department funded by the Industry leaders.

Possibility 3:

- There are two stages in camera manufacturing. First the camera manufacturer produces the camera and then it is given to an IT consultancy. It develops the camera along with the software for specific purposes.
- The specific cameras are however not possible to be integrated and centrally controlled. They are separate for each application and rigid. Hence, each camera is unique