



Davide Nardelli

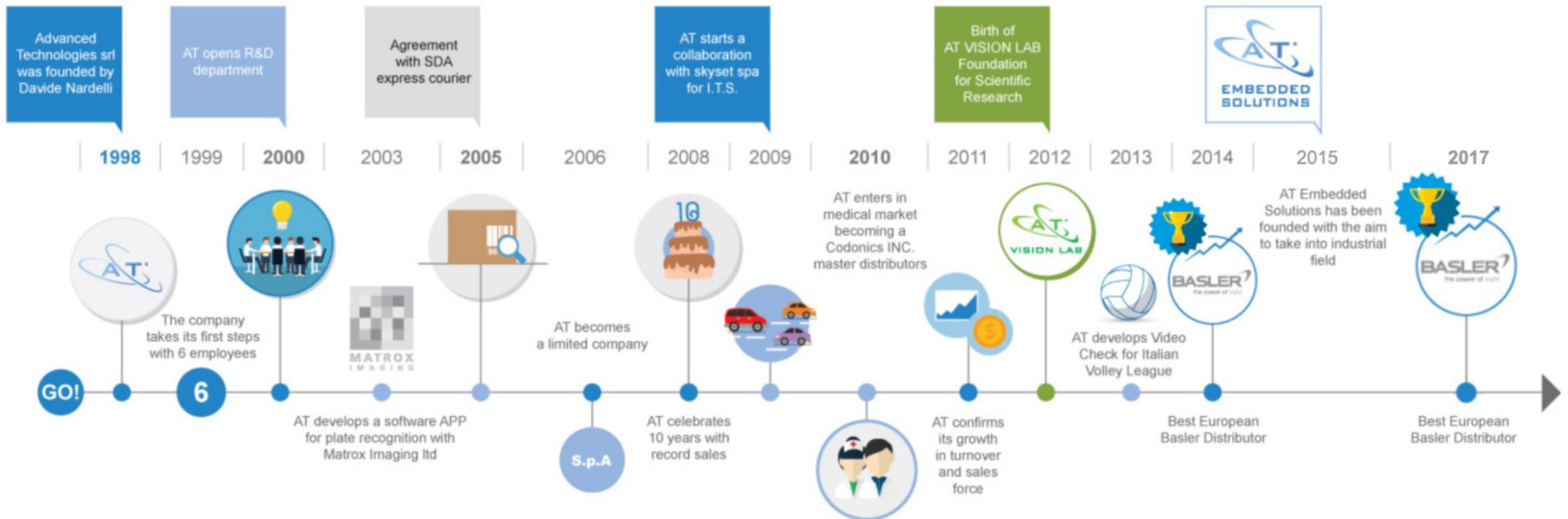
ADVANCED TECHNOLOGIES

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VISION EXPERTS



# Advanced Technologies - Milestones



# AT at a glance



# Industrial Vision Systems

There are many definitions about the systems that use «Imaging» algorithms in the industrial field:

**"Industrial Vision" - "Machine Vision" - "Smart Sensor" - etc.**

But they all refer to the use of technologies and methodologies used to extract information from an image.

# Industrial Vision Systems

The information extracted can be a simple signal ON / OFF  
(good or bad)

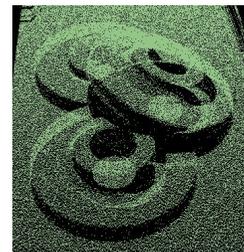
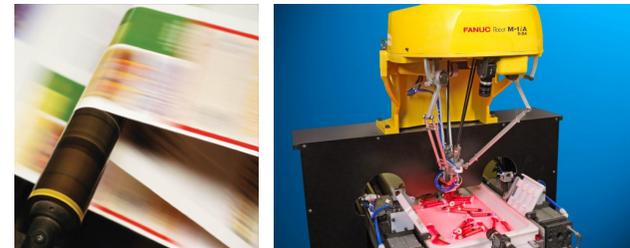
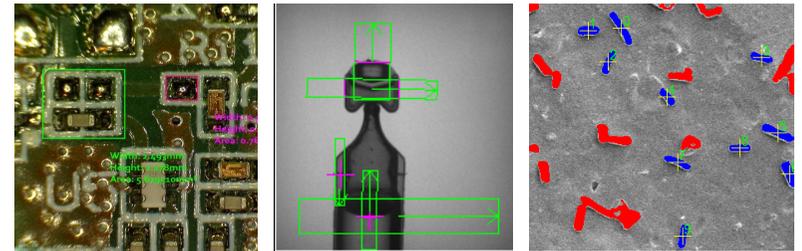
or

a complex list of data and instructions to extract detailed  
information to be used in classification and quality control.

# Industrial Vision Systems

some examples...

- Check the presence/absence of a component on an electronic PCB
- Measurement of a mechanical part
- Counting of particles in suspension in a pharmaceutical liquid, Vial Inspections
- Print Inspection
- Check defects on a plastic and / or fabric film
- Pick & Place





# Industrial Vision Systems

The target of a **Vision System**  
is that the result must be  
**certain and repeatable**

# Industrial Vision Systems

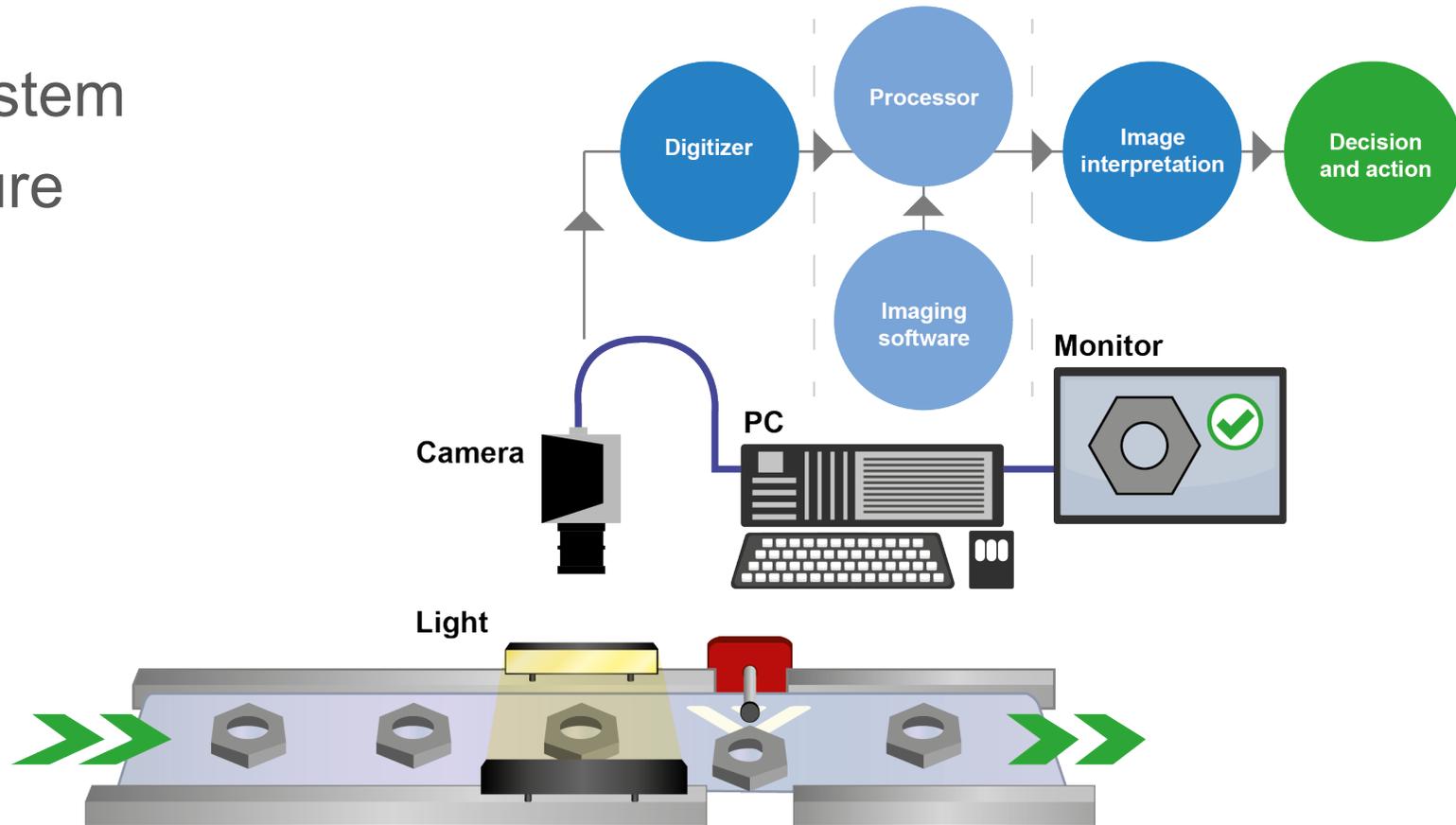
The brain of a vision system is mainly based on  
[Image Processing algorithms](#)

That applied individually or combined in more complex logics  
allow data extraction

A good knowledge of mathematics is important for developing  
Machine Vision Application

# Industrial Vision Systems

## Vision System Architecture



# Vision System Architecture

All these technologies can be found already combined  
for example in the Smart Sensors and Smart Cameras

or

appropriately selected and assembled to  
meet specific requirements

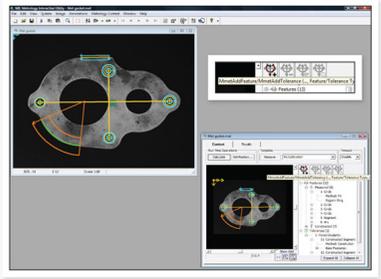
«Vision Components»

# Smart Sensor



Designed to perform single functions, e.g.: Barcode reading, OCR

# Vision Components

<p>Light</p> 	<p>Lens</p> 	<p>Camera</p>  <p>USB GIGE Link FireWire</p>
<p>Frame Grabber</p> 	<p>Computer</p> 	<p>Image Processing software</p> 

# Design a vision system - 2D

## Step 1: Choosing the right camera

Sensor resolution and speed are imposed by the type of analysis and by the production cycle time

- 1. The accuracy of the analysis must be defined: e.g., measurement of an object with a precision of 0.1 mm
- 2. You must define the "field of View" where there is the object : e.g., 100x50 mm
- 3. The theoretical minimum resolution is calculated: 1000x500 pixels
- 4. The effective resolution is normally calculated as twice the minimum theoretical resolution: 2000x1000 pixels = 2MPixel
- 5. The cycle time depends on the capacity of the production line: e.g. 200 pcs/sec = 200 frames per second (fps)
- 6. Select the camera that meets the above requirements

# Design a vision system - 2D

## Step 1: Choosing the right camera

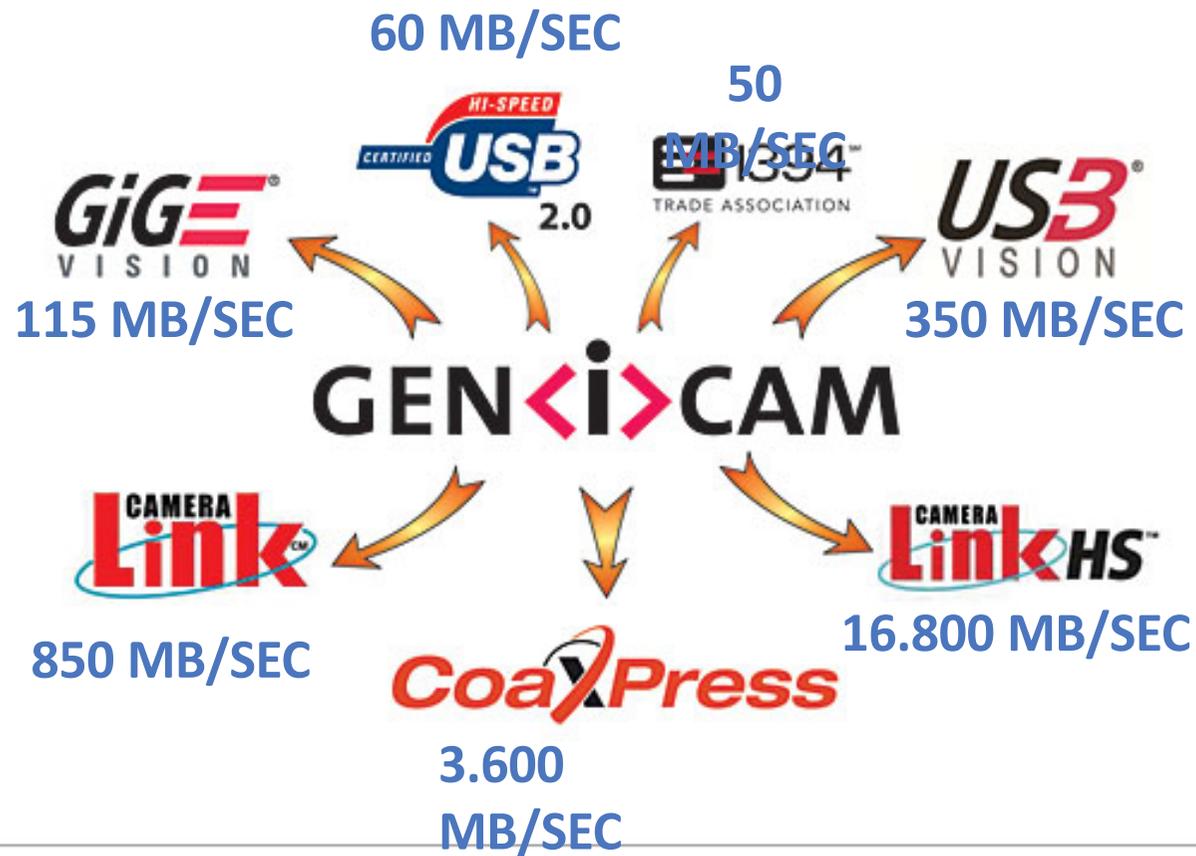
Resolution: 2000x1000 pixel equal to 2MP  
 Speed: 200 fps  
 Total Throughput: 400 MB/sec

In this case the speed in fps imposes the acquisition standard:  
**GigE, USB3, CameraLink, CoaxExpress**

Model	Resolution HxV	Resolution	Sensor	fps	Mono/color	Interface
<a href="#">acA2000-50gm</a>	2048 px x 1088 px	2 MP	CMV2000	50 fps	Mono	GigE
<a href="#">acA2000-165um</a>	2048 px x 1088 px	2 MP	CMV2000	165 fps	Mono	USB 3.0
<a href="#">acA2000-340km</a>	2048 px x 1088 px	2 MP	CMV2000	340 fps	Mono	Camera Link

# Industrial Vision - Standard Interfaces

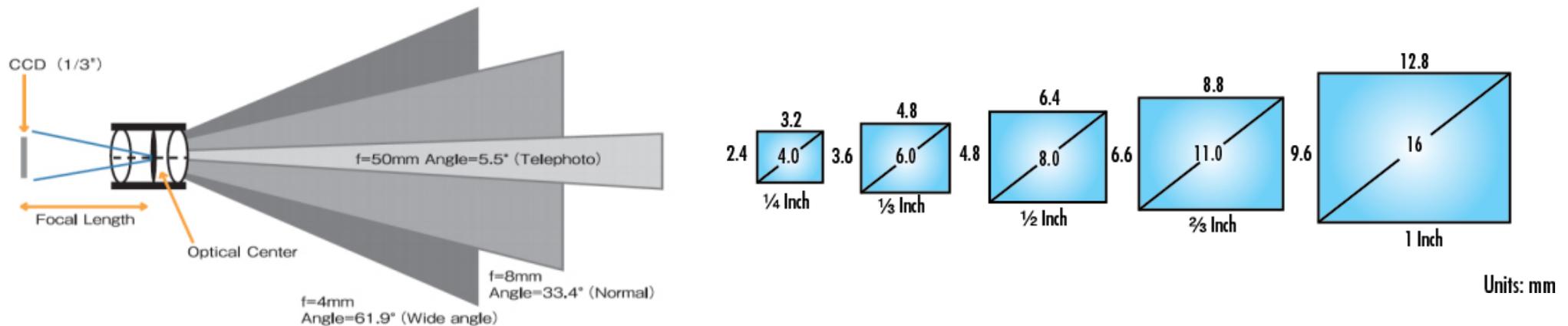
Bandwidth



# Design a vision system - 2D

## Step 2: Choosing the right lens

To choose the right lens it is important to know the sensore size and the working distance



# Design a vision system - 2D

## Step 2: Choosing the right lens

The following formula allows us to calculate the focal length  $f$  of the lens

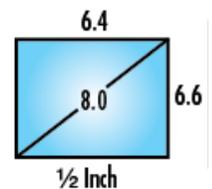
$$f = h \frac{D}{H}$$

$h$  = the horizontal dimension of the sensor (e.g., sensor  $\frac{1}{2}$ " = 6.4 mm)

$D$  = working distance (let us assume 188 mm)

$H$  = horizontal dimension of the working area (e.g., 100 mm)

$$f = 6,4 \frac{188}{100} = 12 \text{ mm}$$



# Design a vision system - 2D

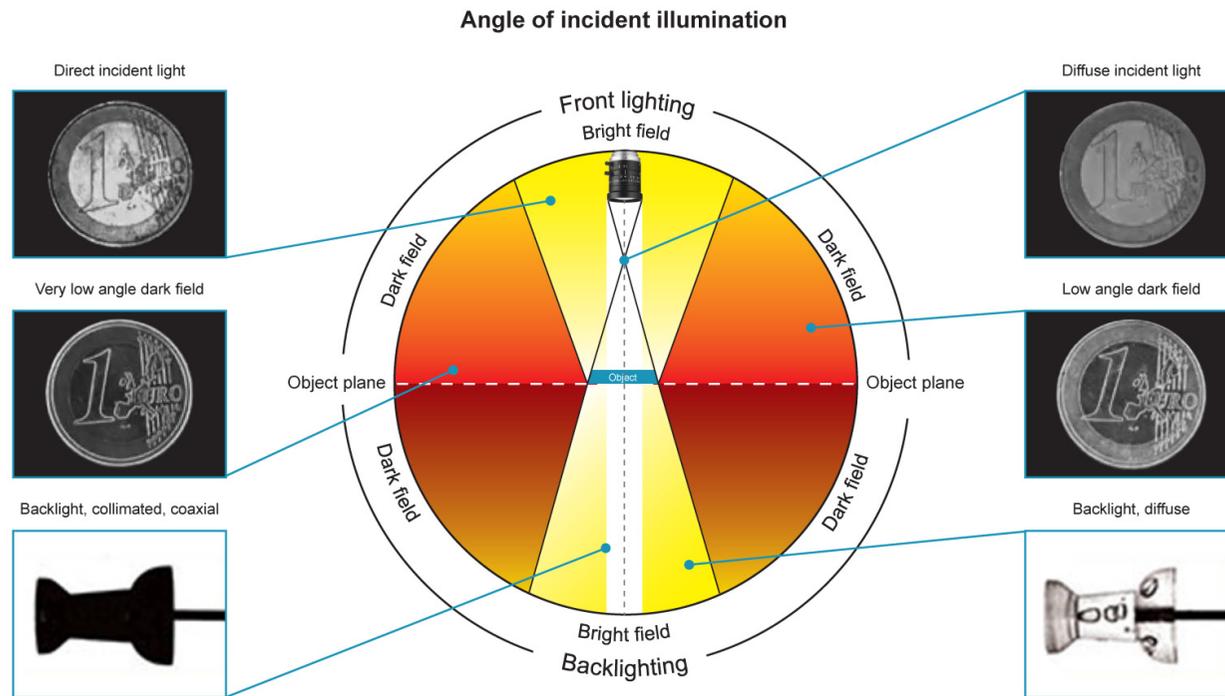
## Step 3: Choosing the right lighting

There are multiple lighting techniques that allow you to effectively highlight some details of the objects to inspect



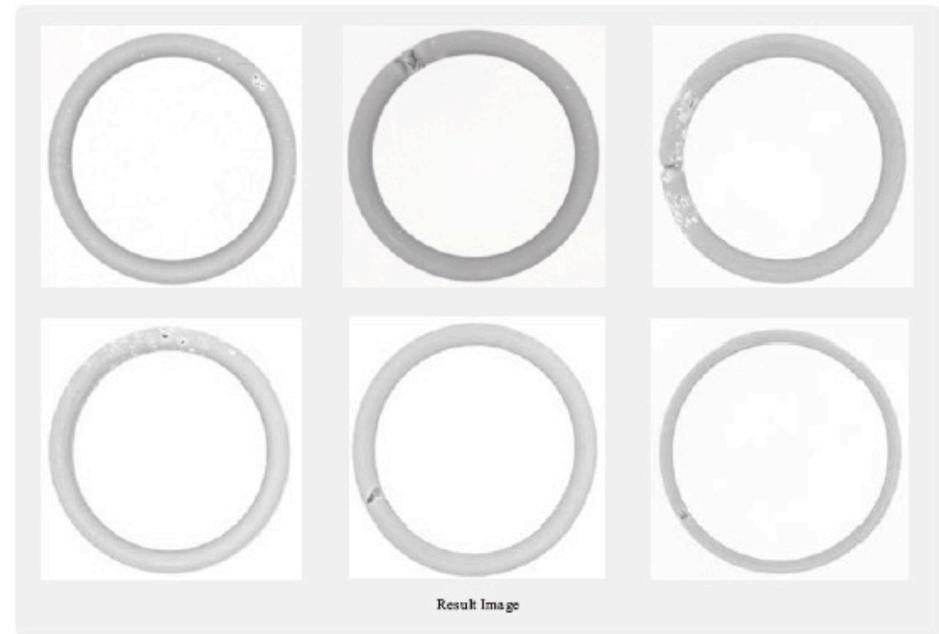
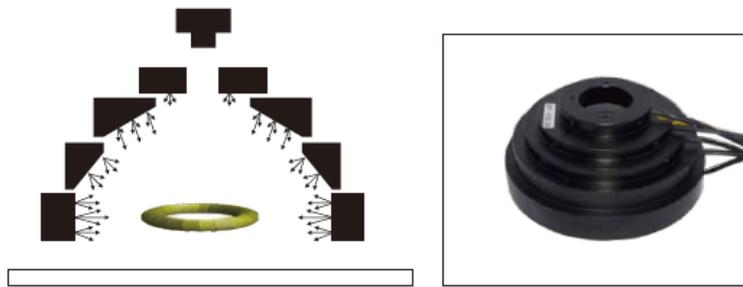
# Design a vision system - 2D

## Step 3: Choosing the right lighting

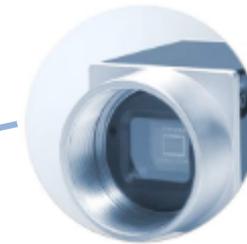
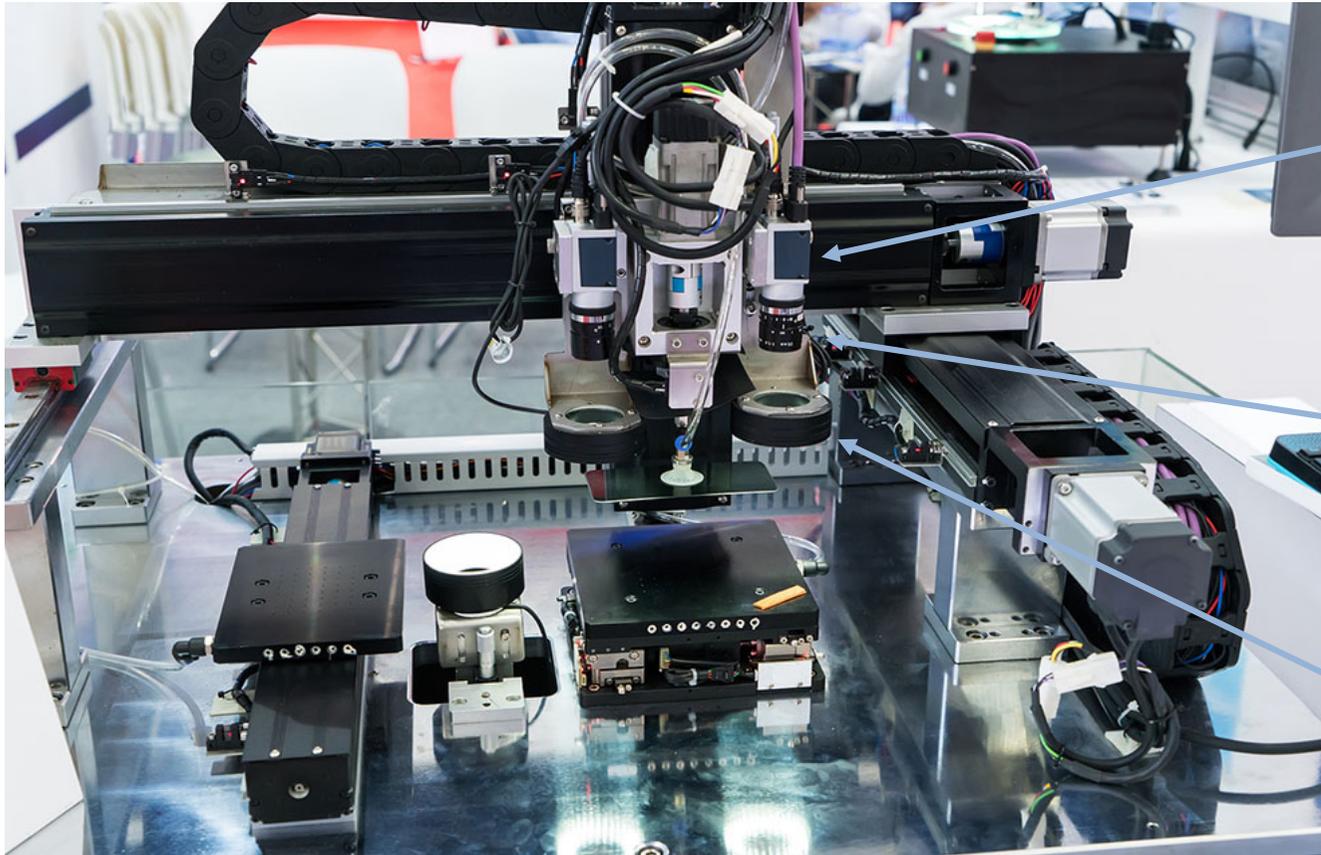


# Design a vision system - 2D

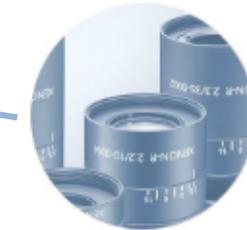
## Step 3: Choosing the right lighting



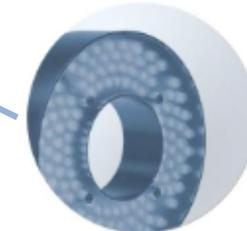
# Industrial Vision Systems



Camera



Lens



Light

# Design a Vision System - 2D

## Step 4: Definition of Image Processing Algorithms

Today, there are many «[Imaging Libraries](#)» which provide all the primitives of «[Image processing](#)» and tools which easily configure complex algorithms for extrapolation of various informations

To respect the time cycle of the system it is important to make a [benchmark](#) of the algorithms, this also allows us to define the necessary computing power

# Design a Vision System - 2D - Imaging Libraries

```

File Modifica Cerca Visualizza Formato Linguaggio Configurazione Strumenti Macro Esegui Plugin Finestra ?
cm_20190507_181958.txt cm_20190507_180614.txt cm_20190507_175231.txt cm_20190507_173954.txt cm_20190507_172623.txt cm_20190507_172131.txt mdiggrab.cpp
1  /*****
2  */
3  /* File name: MDigGrab.cpp
4  */
5  /* Synopsis: This program demonstrates how to grab from a camera in
6  *.....continuous and monoshot mode.
7  */
8  #include <mil.h>
9
10 int MosMain(void)
11 {
12     MIL_ID MilApplication, /* Application identifier. */
13     ..... MilSystem, ..... /* System identifier. .... */
14     ..... MilDisplay, ..... /* Display identifier. .... */
15     ..... MilDigitizer, ..... /* Digitizer identifier. .... */
16     ..... MilImage; ..... /* Image buffer identifier. */
17
18     /* Allocate defaults. */
19     MappAllocDefault(M_DEFAULT, &MilApplication, &MilSystem,
20     ..... &MilDisplay, &MilDigitizer, &MilImage);
21
22     /* Grab continuously. */
23     MdigGrabContinuous(MilDigitizer, MilImage);
24
25     /* When a key is pressed, halt. */
26     MosPrintf(MIL_TEXT("\nDIGITIZER ACQUISITION:\n"));
27     MosPrintf(MIL_TEXT("-----\n\n"));
28     MosPrintf(MIL_TEXT("Continuous image grab in progress.\n"));

```

C++ source file length: 1,721 lines: 54 Ln: 4 Col: 3 Sel: 0|0 Windows (CR LF) UTF-8 INS

# Design a Vision System - 2D - Imaging Libraries

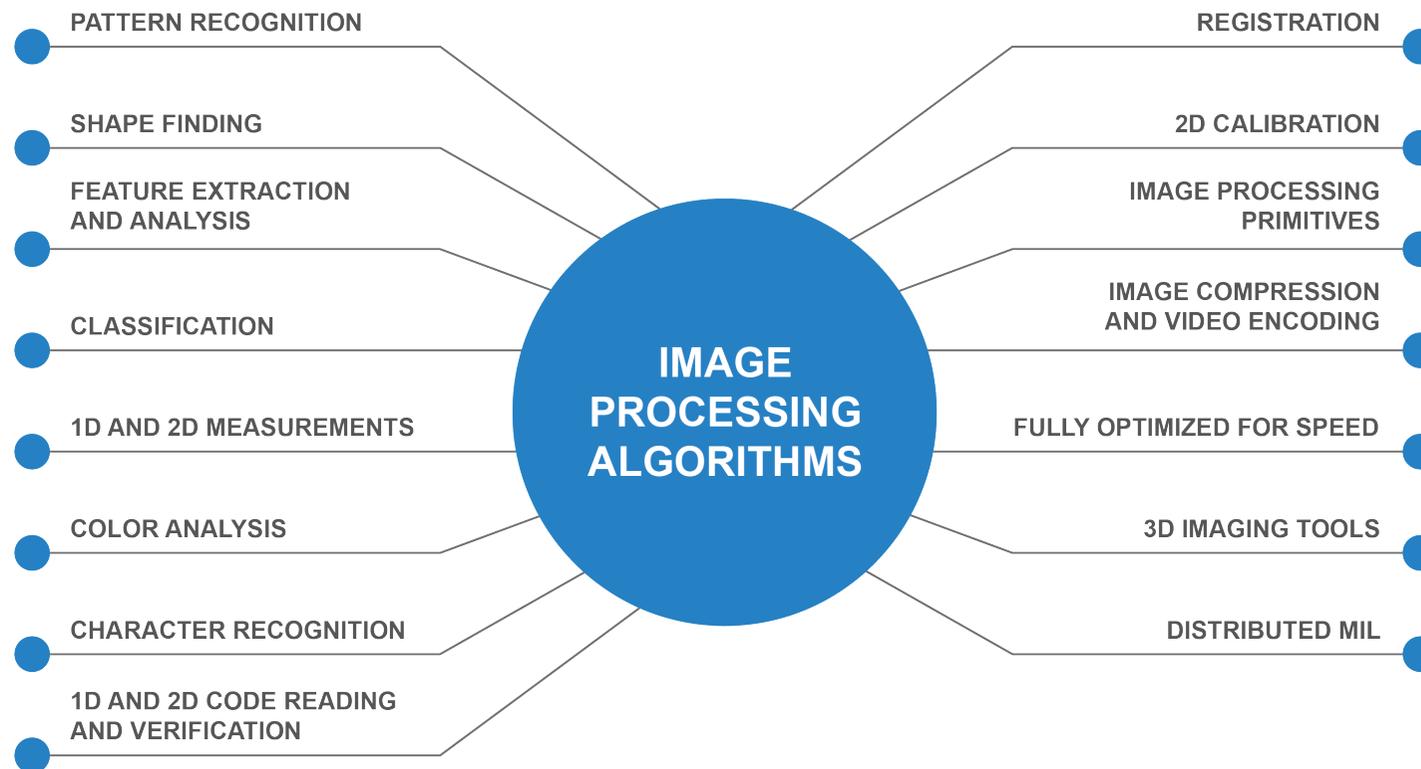
The screenshot displays a vision system software interface with the following components:

- Flowchart:** A process flow starting with 'CAM Camera', followed by 'PAT PatternMatching'. A decision diamond 'BottleLocated' leads to a 'Loop' containing 'FIX Fixture', 'ELOC EdgeLocator', 'MET CapPlacement', 'INTC CapPresent', and 'MEAS SealPresent'. The process ends with 'STA Status'.
- Camera Image:** A grayscale image of a bottle cap with two green bounding boxes and red 'X' marks indicating detected features.
- Annotations Panel:** A list of steps including PAT PatternMatching, Search regions, Model positions, Model boxes, Output coordinates, Other step annotations, CAM Camera, FIX Fixture, ELOC EdgeLocator, MET CapPlacement, INTC CapPresent, and MEAS SealPresent.
- Configuration Panel:** Shows 'PatternMatching' settings with 'Image: Camera.Image', 'Uniform size: False', and 'Master model: None'. It includes 'Models' thumbnails and buttons for 'Edit', 'Rename', 'Delete', 'Add rotated model >>', and 'Add auto model(s) >>'.
- Results Table:** A table with columns: Model, Occurrence Index, Score, X, Y, Angle, Execution Time. It shows multiple rows for 'Model' and 'Model2' with their respective scores and execution times.

Model	Occurrence Index	Score	X	Y	Angle	Execution Time
Model	1	92.6515	149.644	292.607	0	0.000931629 s
Model2	1	97.1606	470.451	312.615	0	
Total found: 2						
Model	1	91.6888	221.243	299.977	0	0.000795437 s
Model2	1	89.8761	519.512	305.642	0	
Total found: 2						
Model	1	89.6099	172.488	308.36	0	0.000727934 s
Model2	1	94.3082	492.56	297.7	0	
Total found: 2						
Model	1	90.8017	164.781	295.087	0	0.000753988 s
Model2	1	95.9918	475.207	296.951	0	
Total found: 2						
Model	1	92.968	187.178	299.576	0	0.00207445 s
Model2	1	91.1958	479.017	304.927	0	
Total found: 2						

# Design a Vision System - 2D

## Step 4: Definition of Image Processing Algorithms



# Design a Vision System - 2D

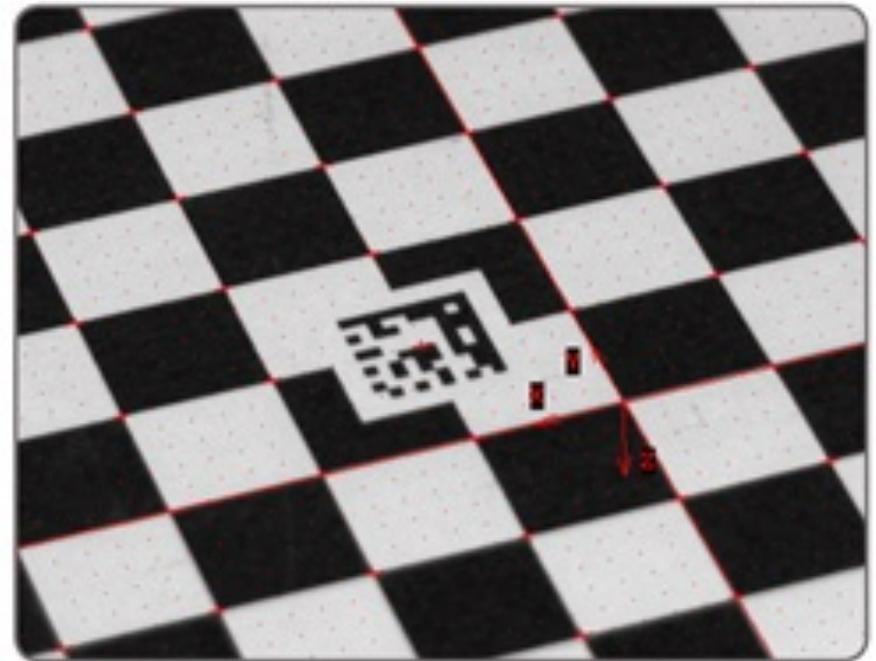
## Definition of Image Processing Algorithms

- **2D calibration**

Calibration is a routine requirement for imaging, a 2D calibration tool to convert results (i.e., positions and measurements) from pixel to real-world units and vice-versa.

The tool can compensate results, and even an image itself, for camera lens and perspective distortions.

Calibration is achieved using an image of a grid or chessboard target, or just a list of known points.



# Design a Vision System - 2D

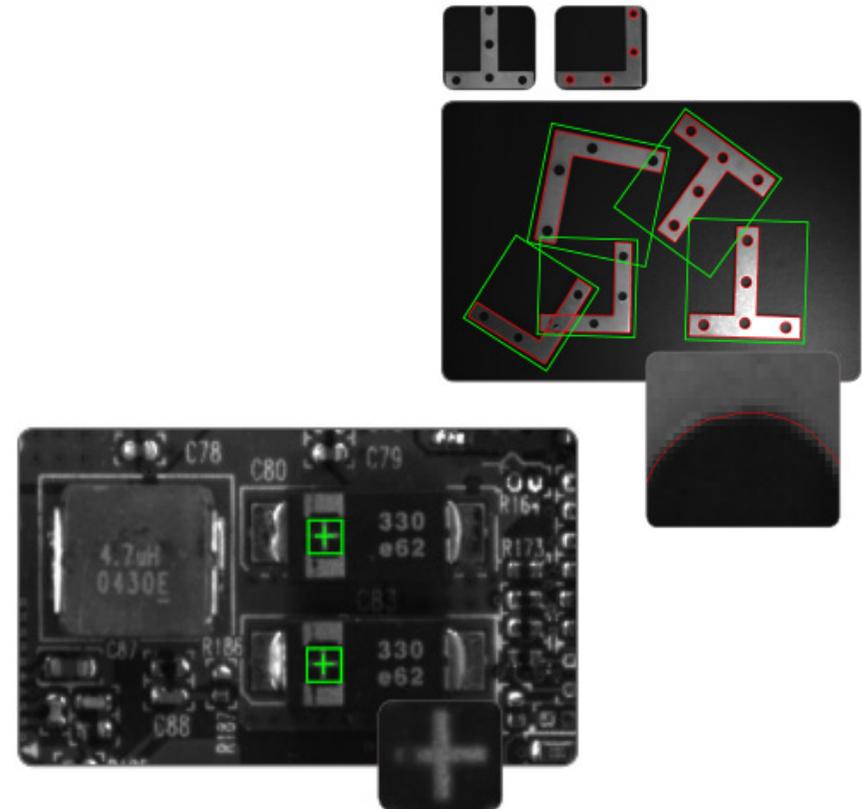
## Definition of Image Processing Algorithms

- **Pattern recognition**

Two tools for performing pattern recognition: Pattern Matching and Geometric Model Finder (GMF).

**The Pattern Matching** tool is based on normalized grayscale correlation (NGC), a classical technique that finds a pattern by looking for a similar spatial distribution of intensity.

**The GMF** tool uses geometric features (e.g., contours) to find an object. The tool quickly and reliably finds multiple models—including multiple occurrences—that are translated, rotated, and/or scaled with sub-pixel accuracy. GMF locates an object that is partially missing and continues to perform when a scene is subject to uneven changes in illumination, thus relaxing lighting requirements.



# Design a Vision System - 2D

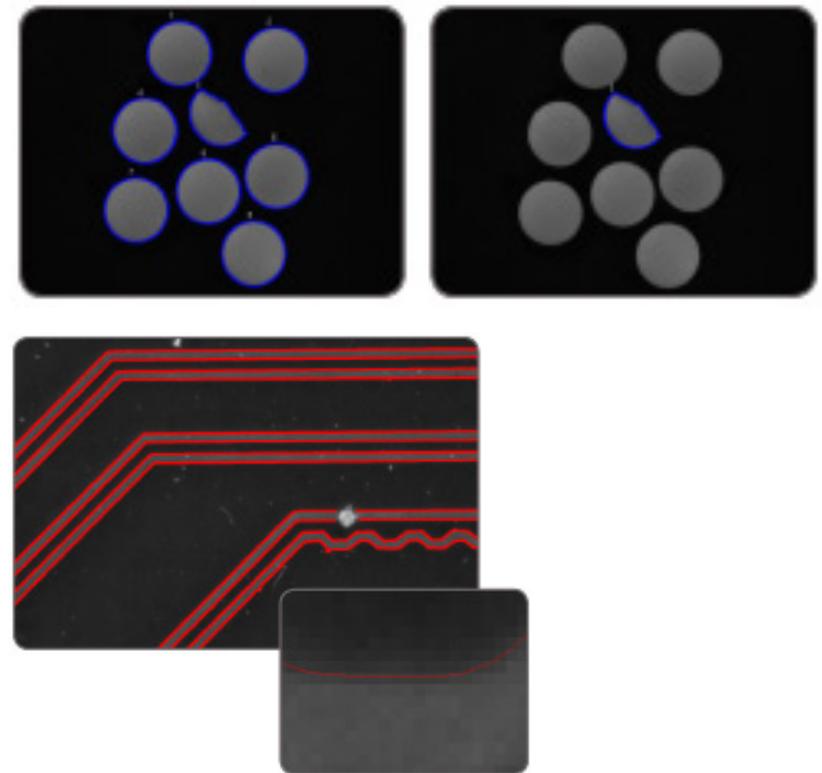
## Definition of Image Processing Algorithms

- **Feature extraction and analysis**

Tools for image analysis: Blob Analysis and Edge Finder. These tools are used to identify and measure basic features for determining object presence and location, and to further examine objects.

**The Blob Analysis** tool works on segmented binary images, where objects are previously separated from the background and one another.

**The Edge Finder** tool is well suited for scenes with changing, uneven illumination. The tool using a gradient-based approach quickly identifies contours, as well as crests or ridges, in monochrome or color images and can measure over 50 characteristics with sub-pixel accuracy. Measurements can be used to sort and select edges.



# Design a Vision System

## Step 5: Choice of acquisition / processing hardware

### Smart Camera



#### **Advantages**

- Sensor, CPU and I/O integrated in a single device
- FanLess
- IP66/IP67

#### **Disadvantages**

- Limited number of sensors
- Average / low CPU performances
- Expensive solution in multi-camera applications
- Dimension

# Design a Vision System

Step 5: Choice of acquisition / processing hardware

Non-expandable embedded PC



## Advantages

- CPU e I/O integrated in a single device
- Certificates **USB VISION** **GiGE VISION**
- Supports 2 cameras
- FanLess

## Disadvantages

- Average / low CPU performances

# Design a Vision System

## Step 5: Choice of acquisition / processing hardware

### Expandable PC embedded



#### Advantages

- CPU and I / O integrated in a single device
- Compliant with **USB VISION** and **GiGE VISION**
- Supports 6/8 cameras
- FanLess
- Expandable with FrameGrabber or GPU

#### Disadvantages

- Average CPU performances

# Design a Vision System

## Step 5: Choice of acquisition / processing hardware

### PC Server

#### Advantages

- CPU with high computing power
- Expandable with n FrameGrabber and / or GPU
- Long life

#### Disadvantages

- High cost
- Large footprint



Four Clusters with:  
- One FPGA (Matrox Radiant eCL)  
- Two CPUs (Matrox SHB-5520)



# ... some application examples

**Bottle Inspection**

Continuous
Monoshot
Trigger

Your Company  
Logo here

**Global results**

Pass

Bottle located	Bottle Located
Cap verification	Cap OK
Seal verification	Seal OK

**Benchmarks**

Analysis time (ms)	3
--------------------	---

video

# ... some application examples

**Metrology 2**

Continuous Monoshot Trigger

Your Company  
Login here

Inspection Results

Part is flipped	<input type="text" value="True"/>
<span style="color: red;">■</span>	Perpendicularity of axes
<span style="color: green;">■</span>	Horizontal Distance
<span style="color: red;">■</span>	Vertical Distance

The screenshot shows a software interface for metrology. The main area displays a 3D model of a black, irregularly shaped part with two circular holes. Three green circles are overlaid on the part, connected by a green line, indicating inspection points. A red circle is also visible on the left side of the part. The interface includes a top navigation bar with 'Continuous', 'Monoshot', and 'Trigger' buttons, and a 'Your Company' login area. On the right, an 'Inspection Results' panel shows a table with four rows: 'Part is flipped' (True), 'Perpendicularity of axes' (red bar), 'Horizontal Distance' (green bar), and 'Vertical Distance' (red bar). At the bottom, there is a toolbar with a play button, a pause button, and a '1-1/1' indicator.

video

# ... some application examples

video

## Perspective correction

**Original Image:**

**Corrected Image:**

Text Not Read

Decoded:

26PM30?

Text Read

Decoded:

PT6103A 12V 9826PM39

The corrected image is generated by the Camera step, using a Calibration file.

ReadOriginal\_Fail

ReadCorrected\_Pass

# ... some application examples

video

**Fruit Inspection**

Continuous
Monoshot
Trigger

Your Company  
Login Here

**Color Match**

Fail

Inspection Result: Not Ripe

Total Count: 1

Total Pass Count: 0

Total Fail Count: 1

Reset Counters

**Statistics**

% of Dark Red:	12.3
% of Red:	3.2
% of Yellow:	0.5
% of Green:	43.6
% of Orange:	40.4

Display: Camera Image --- Click to change

--	--	--	--	--	--	--	--	--	--	--	--

Fail

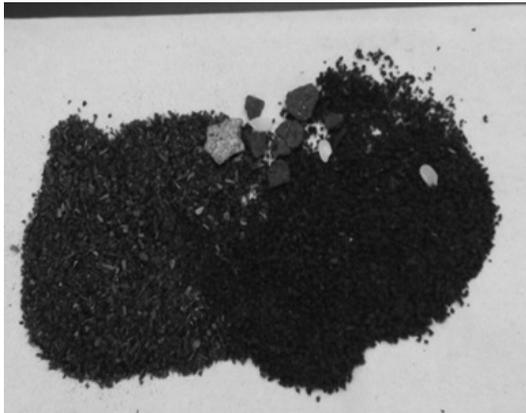
Ripe Fail

Fail

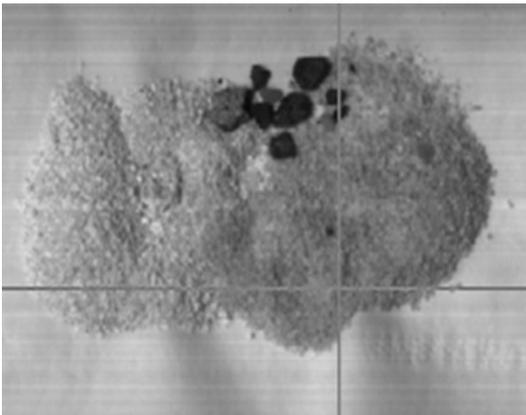
Ripe Fail

<
1 - 1 / 1
>

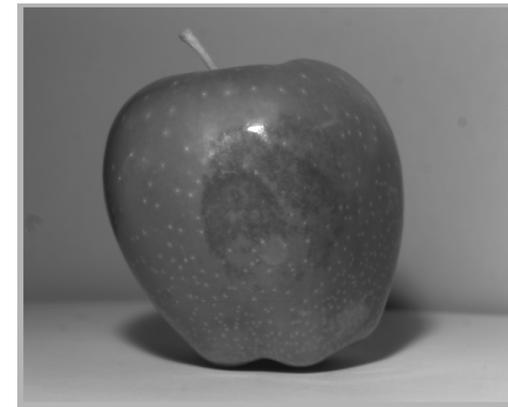
# ... some application examples imaging swir



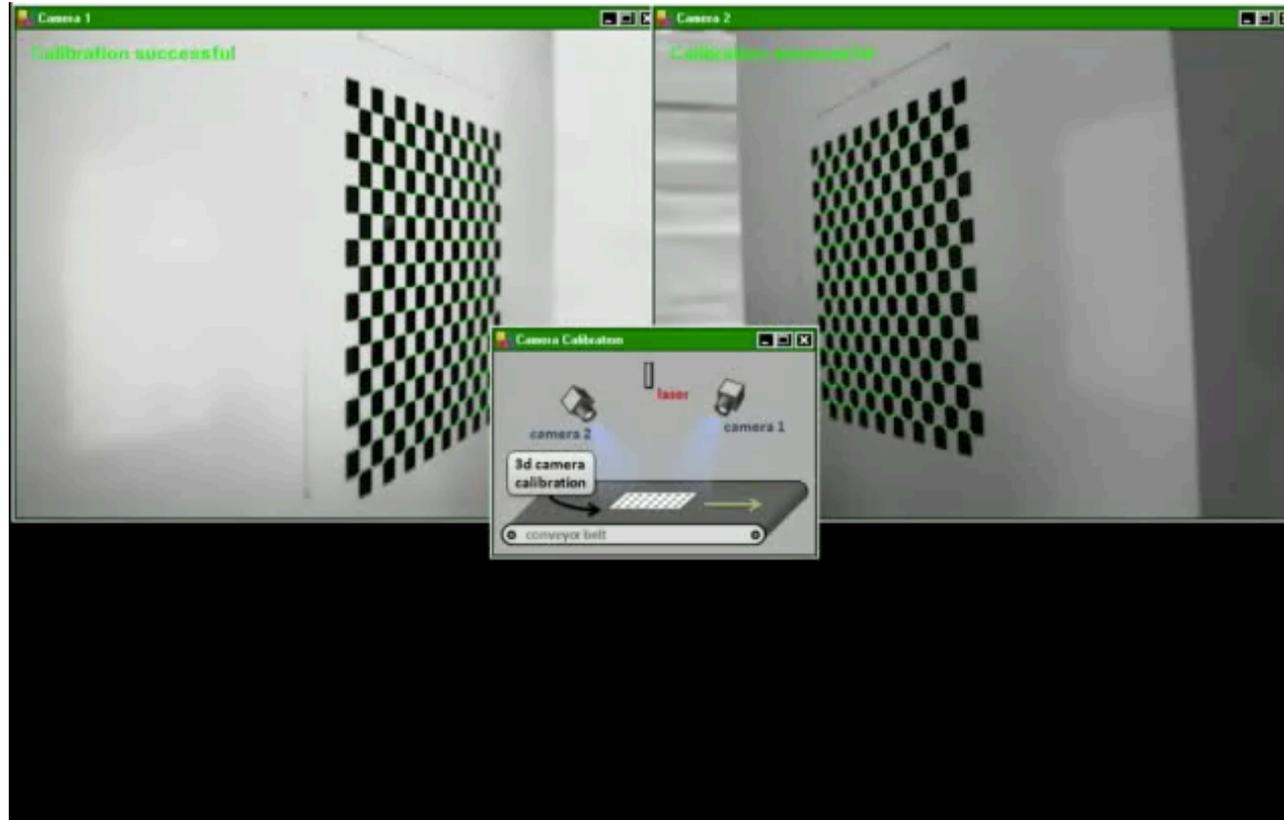
**Image in the  
visible**



**Imaging  
SWIR**



# ... some application examples



video

# Target Markets



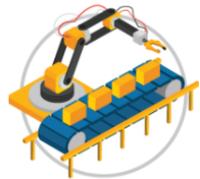
Automation



Automotive



Logistic



Packaging



Food & Beverage



Security



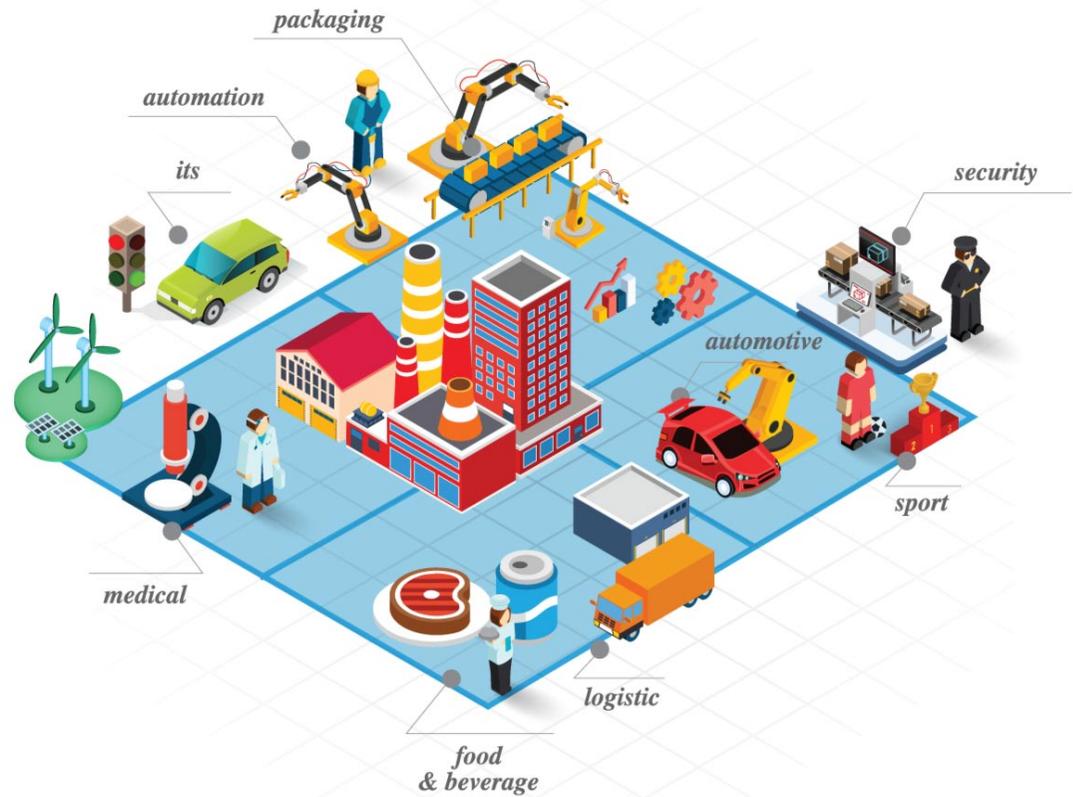
Medical



Sport



ITS

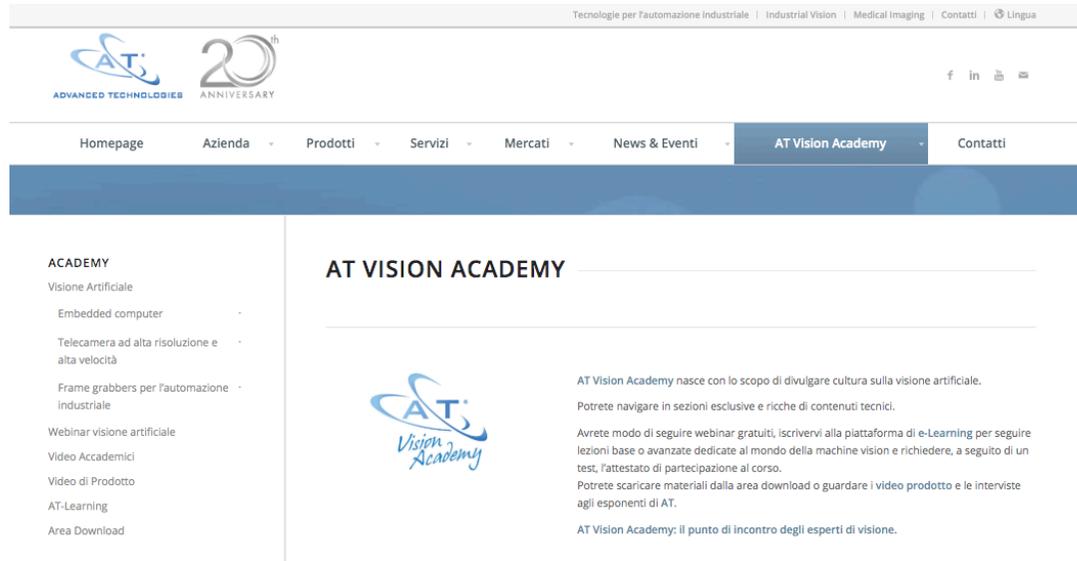


# Making culture of the Artificial Vision

- The AT medium-term target is to become a reference point in the Artificial Vision market, spreading culture and skills inherent to the technology and techniques used in Machine Vision.
- We firmly believe that creating value and skills is the right way to bring our world closer to future Machine Vision engineers.

# AT Vision Academy

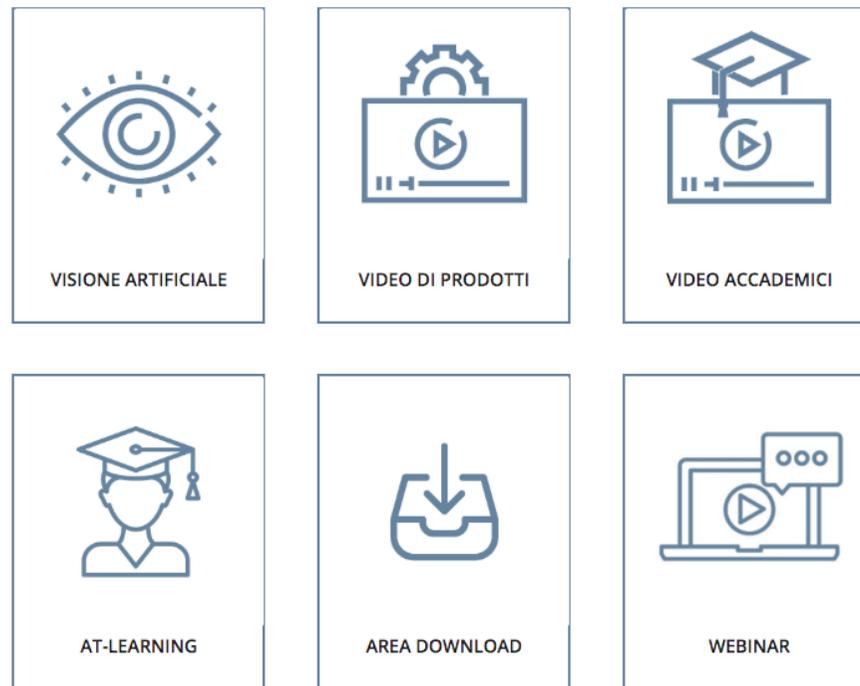
- AT Vision Academy is a section of the [www.adv-tech.it](http://www.adv-tech.it) site dedicated to promote Artificial Vision contents



The screenshot shows the AT Vision Academy website. At the top, there is a navigation bar with links for 'Tecnologie per l'automazione Industriale', 'Industrial Vision', 'Medical Imaging', 'Contatti', and 'Lingua'. Below this is a header section featuring the AT logo, 'ADVANCED TECHNOLOGIES', and a '20<sup>th</sup> ANNIVERSARY' badge. A secondary navigation bar includes 'Homepage', 'Azienda', 'Prodotti', 'Servizi', 'Mercati', 'News & Eventi', 'AT Vision Academy' (highlighted), and 'Contatti'. The main content area is split into two columns. The left column, titled 'ACADEMY', lists various topics: 'Visione Artificiale', 'Embedded computer', 'Telecamera ad alta risoluzione e alta velocità', 'Frame grabbers per l'automazione industriale', 'Webinar visione artificiale', 'Video Accademici', 'Video di Prodotto', 'AT-Learning', and 'Area Download'. The right column, titled 'AT VISION ACADEMY', features the AT Vision Academy logo and a text block: 'AT Vision Academy nasce con lo scopo di divulgare cultura sulla visione artificiale. Potrete navigare in sezioni esclusive e ricche di contenuti tecnici. Avrete modo di seguire webinar gratuiti, iscrivervi alla piattaforma di e-Learning per seguire lezioni base o avanzate dedicate al mondo della machine vision e richiedere, a seguito di un test, l'attestato di partecipazione al corso. Potrete scaricare materiali dalla area download o guardare i video prodotto e le interviste agli esponenti di AT. AT Vision Academy: il punto di incontro degli esperti di visione.'

# AT Vision Academy

- Within AT Vision Academy you can access these sections:



# AT-Learning

- The first Italian e-Learning platform dedicated to the Artificial Vision with basic, intermediate and advanced training about technologies, techniques and software used in Machine Vision
- At the end of each session you will have the opportunity to check your skill and you can have a test that allow you to get the training certificate.

# AT-Learning



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## AT Vision Academy

La prima piattaforma italiana e-Learning sulla visione artificiale



# Conclusion...

An **Industrial Vision** professional  
must develop transversal technical skills

**Mathematics – Computer science – Electronics  
– Optical Physics**

If you are interested in a company internship write to: [job@adv-tech.it](mailto:job@adv-tech.it)

# Follow us!



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