# *Vision System Selection Requirements & Implementation In Industrial Automation*

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***Abstract*** — *The vision systems are part of a new revolution in automation. With the capability of being implemented practically to any application, the benefit of using this kind of systems are multiple but the ones which came out from the rest are the following: the precision in the identification on characters in the different applications, also it allows a very fast recognition and processing. For the precision and huge capabilities, these systems are in a very high demand. But the real challenge is to find the proper system for the specific application, which will allow that selected combination of components execute in the optimal level of performance required for the selected application.*

***Key Terms*** — *Automation, Process, System, Vision.*

## RESEARCH DESCRIPTION

This research will bring a comprehensive study in the vision system area. It will allow a better understanding of what is a vision system what are their components and how they contribute to the vision process.

## RESEARCH OBJECTIVES

The research objective are the identification of components (tooling, hardware, software, etc.) and consideration (restrain identification, testing and safety approach) to be take place in to vision system integration to automated process.

## RESEARCH CONTRIBUTIONS

This will contribute to the application of this technology in the field, to upgrade an existing system or to replace a mechanical method. It also will bring more specific knowledge in what is require and how must be prepared to the implementation on this kind of systems. The application of these systems will lead to a better machine/process performance depending in de application. The typical benefits from the application include waste reduction; reduce process timing, accuracy in measure, etc. All this improves normally lead to a substantial economic benefit to the enterprise.

## RESEARCH BACKGROUND

To fully understand what are the requirements and restrains in the implementation of the vision system. The most important is recognizing what vision system does. There is went the term "GIGI" is introduced. This term define the four main applications of the vision system, which are the followings:

- **Gauge:** In the gauging area it allow the precise dimensioning, which allow the automation of metrology and data recording ensuring exact tolerance in diameters, bushings, gabs, threads, ect. But how much accurately a gauge could be performed? To adequately understand how accuracy work is imperative to comprehend that accuracy is a function of Field of View (FOV), Camera Resolution (Megapixels), Image Quality, Vision Tool Accuracy and Factor of 10 (Tolerance vs. Accuracy). The next example Equation (1) demonstrated the concept:

$$FOV_{horizontal} = X\,(inch)$$
$$Accuracy_{Vision\_Tool} = \frac{1}{10}\,pixel$$
$$\#Pixels_{horizontal} = Y\,(pixels)$$
$$Accuracy_{horizontal} = \frac{FOV \times Accuracy_{Vision\_Tool}}{\#Pixels}$$
$$Accuracy_{horizontal} = \frac{X'' \times \frac{1}{10}\,pixel}{Y\,(pixels)} \tag{1}$$

- **Inspect:** The inspection is one of the more common applications, the completeness & quality verification like, assembly verification, components presence, fill levels, positioning, defect detection, surface inspection, orientation and foreign matters inspections.
- **Guide:** The guidance application is often use in the robotic industry for robotic guiding, 2D & 3D picking (pick and place), alignment, leveling, conveyer tracking, palletizing/de-palletizing and components assembly.
- **Identify:** The identification is also with the inspection the more used application often use in the packaging industry or areas, it allow the identification of product, via read codes (bar codes, 2D matrix, labels, part marks, ect.). Also it read and confirms specific characters, this help in the liability of the data used in package or products, parts authenticity and helps in the process & inventory controls.

To make possible all this application are use what is known as vision tools. The vision tools are a series of algorithms structured in the software that could vary depending of the system used. But basically is the mounting block of all vision system. All vision tool analyze specific set of pixels within a predetermine region, it analyze the data and make decision based on predetermine parameters. The following are types of vision tool they will vary depending in the application, product line and manufacturer:

- Image processing
- Positioning
- Counting
- Measurement
- ID and Optical Character Verification / Optical Character Recognition (OCV/OCR)
- Defect detection (Specific Tools)
- Color Recognition (Specific Tools)

## PROJECT METHODOLOGY

To develop the design project a Qualitative methodology approach was followed. The data was gathered and categorized. This will bring perspective in the evaluation of the data and the understanding of the study. Also provide comprehension in the respective categorization.

## LITERATURE REVIEW

Subsequently the clarification of the capabilities & applications of a vision system, is imperative to understand how is structured. The vision system is divided in four (4) primary components which depends one from the others to provide a quality image and the proper evaluation of it, this components are:

- **Computer or Process Logic Control (PLC):** It is the brain of the system, it analyze the image send from the camera and make decision base in the predetermine parameters defined by the vision tool, is where the vision tool reside (some vision systems have embedded in the "CCI" the vision tool).
- **Camera Computer Interface (CCI):** This is basically the camera, it capture the image thru the lens or optics to be send and processing by the computer.
- **Optics:** The optics is the mean use by the camera to process the image before its capture. It's grounded by his fundamental parameters of optics selection, Field of View (FOV), Resolution, Working Distance (WD) and Depth of Field (DOF).
- **Lighting:** This is practically the heart of the image; the light reflects on the object past thru the optic to be capture by the camera sensor to create the image, it could be the difference of an effective vision system. The proper lighting makes more cost effective system.

To have an effective vision system it requires a good quality image which is equal to the combination of image resolution, contrast, distortion, perspective and depth of field (DOF).

- The resolution is the measure or the ability to reproduce object detail.
- The contrast describe the separation in intensity between black and whites of the

image, it is also measure by percent (%) and defined by the Equation (2).

$$Contrast_{\%} = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \quad (2)$$

$I = Intensity$

As show in Figure 1, the greater the difference in intensity between blacks and white lines, better is the contrast in the image. [1]

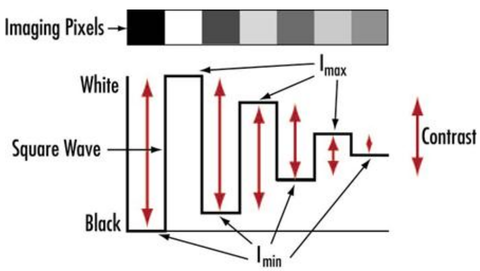


**Figure 1**
**Contrast Intensity Min vs. Intensity Max**

- **Depth of field (DOF)** is the maximum object depth that can be maintained in the desired focus, see Figure 2.

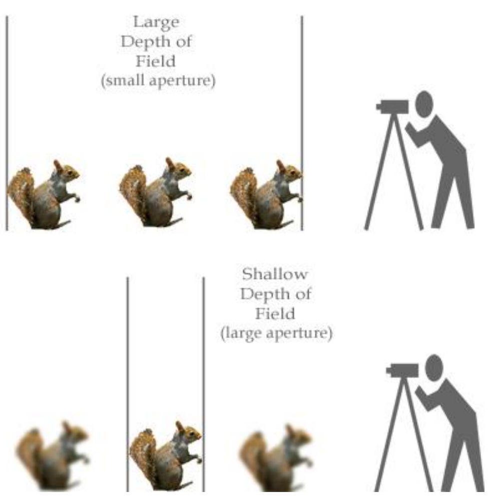


**Figure 2**
**Depth of Field Proportion**

- **Perspective** is the relation of the image from the camera standpoint some errors could derivate from it, if the correct perspective is not in place. This error typically occurred went the camera is not perpendicular to the FOV.
- **Distortion** is a geometric aberration the information is misplaced in the image (unequal magnification thru the image) but it characterized by no information lost, see Figure 3.

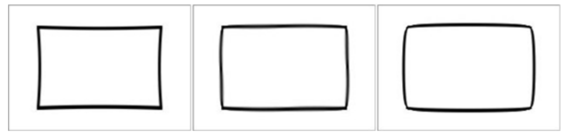

**Figure 3**
**Examples of Distortion, from Left to Right Pincushion, Wave and Barrel**

- **Field of View (FOV)** is the area that will be view by the monitor and describe how much image could be captured. As show in Figure 4.
- **Working Distance (WD)** is the distance from the end of the lens to the object that will be inspected. As show in Figure 4.

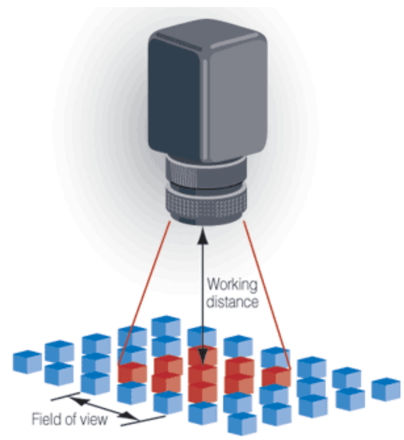


**Figure 4**
**Examples of Field of View & Working Distance**

## Lighting For machine Vision

Based on a normal daily perspective, the light from the environment is use to perceive. From a machine/vision system perspective is something unwanted. The light from the environment have too much variation that could affect image outcome. For this kind of application is required a controlled light source, which help in the accentuation of predetermined features. This standardization of the lighting will provide a control environment that brings repeatability in the image capturing process.

It’s important to understand that unless the optic and the lighting are not designed/selected together, it is very challenging or difficult achieve a match between them. The lighting is as important as the optics, because it carries the primary information. [2]

For the correct lighting selection is essential recognize how light interact with objects. The light is reflected by objects in two different ways specular and diffuse reflection:

- **Direct/Specular Reflection:** The direct/ specular reflection is characterized for its brightness. It is bright, because the intensity of the object reflection is almost equal to the intensity of the light source. This kind of behavior are present in Flat and shiny surface.

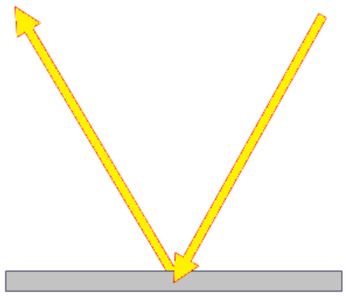

**Figure 5**
**Direct/Specular Reflection**

The best method for lighting specular parts is with diffuse lighting. [3]

- **Scattered/Diffuse Reflection:** The scattered/ diffuse reflection is characterized for a reduction of intensity in relation from it source. The reflection proportion is reduced with the angle.

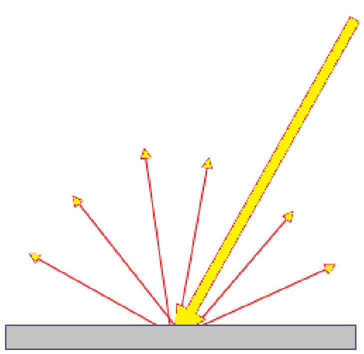

**Figure 6**
**Scattered/Diffuse Reflection**

Other considerations, such as specular elements on the object or the influence of shadows, determine the best approach. [3]

### Wavelength Reflection and Absorption

The light wavelength is composed from different colors in the visible spectrum and the non-visible spectrum (see Figure 7 below). Some material absorb light of certain wavelength and not others, a red object illuminated by white light reflect only the red portion of the light, which is why we see it as red (the other wavelength is absorbed). [4]

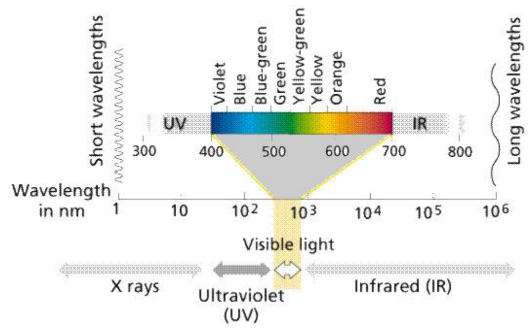


**Figure 7**
**Light Wavelength**

### System Communication and Response

Machine vision acquisition architectures come in many different forms, but they all have the same goal. That goal is to get image data from a physical sensor into processing unit that can process the image and initiate an action. [2]

To create this communication must be in place an architecture which is compose of Camera, Camera Bus, Driver Software, Interface Device, Computer Bus and PC Memory (refer to below Figure 8)

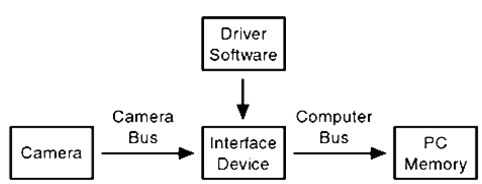


**Figure 8**
**Typical Image Acquisition**
**Architecture (Computer Based)**

The camera function as sensor which communicates with the Driver Software (it also make the interaction with the programmer) thru the camera Bus, (the Bus transform the signal in a matter the receiver understand it) to be send to the PC Memory to initiate action.

The communication is vital in the process timing, every image must be processed before any action or decision is taken. This means that vision system could not be slower that process itself, if the process action point (PAP) which is the critical point of intervention in the process. This will be a limit of the process that will truncate the system response in terms of image &decision processing.

### Requirements & Restrain Identification

There are some questions that must be answer; to understand if the vision system is required or capable to fulfill the specific application and if is physically possible to implement the system based on the environment & equipment restrain. When this kind of evaluation is performed, the following question must be answered:

- What of the four applications for vision system (GIGI) will fit my process?

If the answer not includes neither Gauge, Inspect, Guide or Identify. The vision system will not be required or will not fit the application.

The applications will dictate the limitation in terms of equipment, illumination and tooling.

For part presentation, the crucial factors are part motion, positioning, tolerance and number of parts in view. Number of parts and positioning tolerance are very importance since they could affect field of view (FOV) and depth of field (DOF). [2]

The first restrain is space. How much space the process/equipment has to accommodate the hardware (camera, optics, lighting, CCI, PLC).

Beside the space, the environment needs to be checked for:

- Ambient light
- Dirt or dust that equipment needs to be protected.
- Chock or vibration that affects the part of the equipment.
- Heat or cold
- Necessity of certain protection class.
- Availability of power supply. [2]

After the environment restrains identification, the selection of the equipment will be accordingly to the process limitation, preventing equipment mal function or shortening the system durability and most important avoiding a safety issue.

## Results & Discussion

Based on the design project results, the implementation of a vision system is not just a “Plug and Play” matter; it requires a comprehensive knowledge in different fields like, Optics, Lighting, Vision Tools, programing and process integration experience. Also it explain what are the specific main components required to implement the system and the importance of them, also it make acknowledge in how to make the proper selection of components.

It is very clear that the quantities of variables that will be included in the development of system are many, but with the proper background is possible to implement it without a problem. The most important is understand what are the restrains in terms of process and environment are. This will provide the frame of reference that will delimited the system that could be implemented.

Must be remembered that all parts of the vision system are equally important, if something must be restrain from one side the system should be capable of compensate from another. Practically all the vision system have more or less the same components, the key is selecting the right combination for the application which will optimize the vision tool used in the system. If this exercise is prepared in a comprehensive matter. The vision system implementation will be very less hard worked, less expensive and sustainable.

To provide a structured selection process, a selection chart (see Figure 9 below) was created; it was based on the design project results and is a useful tool that will facilitated the system selection process.

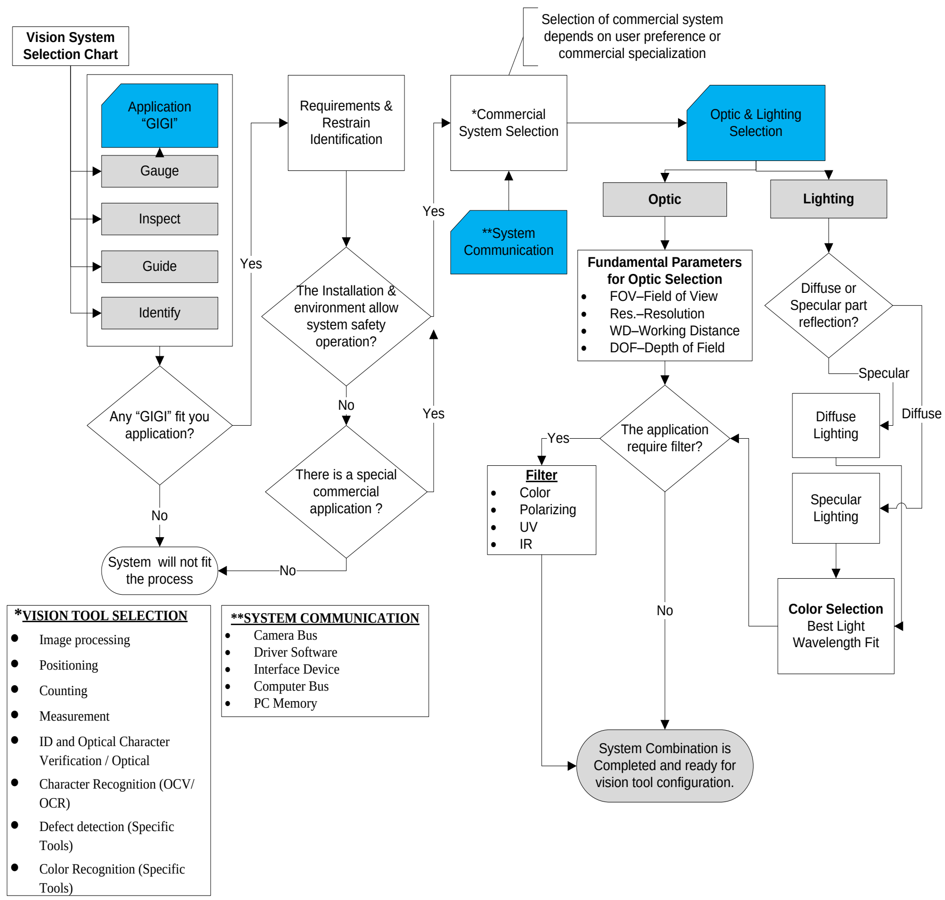


**Figure 9**
**Vision System Selection Chart**

## CONCLUSIONS

In conclusion the vision system is a very broad area of study. It is clear that vision system could be divided in many sub-themes and each one could be researched separately. This research meets his goal of regrouping the main factors & components that contribute to the proper development of a vision system in a general matter. This allows the understanding of the area in question for this reason it make the right contribution to the field. Since usually the knowledge in this area is gathered thru experience and deep study and understanding.

It recommended for futures research in the area, to develop the discussion and the research in one specific application; to be understood by this, in Gauging, Inspecting, Guiding and Identification (GIGI) this will allow a better application understanding and another frame of reference.

## REFERENCES


[1] Hollows, Greg, "Choosing the correct optics", *Vision Systems Design*, ©2004.

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