CONSIDER THIS BEFORE STARTING YOUR NEXT VISION SYSTEM PROJECT

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Before jumping into your vision system project, take a moment to review the following topics. These points will help focus your thoughts on specific aspects of vision systems in the context of your application, environment and employees. We hope to assist you in developing the right solution.

1. **What fundamental problems are we trying to solve?**

   Understanding what tasks you expect a vision system to perform is the first step in defining your application. Are you in need of reliable and consistent quality control inspections of your product? Do you need to verify that text or barcodes are correctly printed on your packaging? Perhaps you need to automate the process of picking and placing components? Defining your expectations early in the project is critical.

2. **What types of inspections do we need to perform?**

   Vision systems are used for a broad range of applications, including attribute inspections, pattern matching, parts sortation, dimensional measurement (sometimes called gauging), and guided motion systems (such as robotic pick-and-place). The feature sets of some vision systems have expanded to include the decoding of 1D symbologies (i.e. UPC, Interleaved 2 of 5, etc.) and 2D symbologies (i.e. Data Matrix, QR Code, etc.). Optical character recognition (OCR) and optical character verification (OCV) are also supported in some vision systems. Many vision systems have tools to perform a combination or all of these inspections.

   Also think about what inspections you may need to perform in the future. You might only need to perform presence/absence testing of a part feature today, but what if down the road your customer requires more involved inspections, such as dimensional measurement or barcode verification? Understanding what will be demanded of your vision system – both in the short and long term – will inform your vision hardware selection process. *Each vendor offers several vision system product lines with specific feature sets tailored towards a target application range and price point, so be sure to match a system to your inspection needs.*

3. **Is a vision system *really* the right choice for my application?**

   Before assuming that a vision system is your only path to a solution, take a step back. Ask yourself if the problem could be solved by a sensor or series of sensors. If a sensor is a viable option, then the end result would be a simpler, lower cost solution that will probably be easier to support. There are many types of sensor technologies available: ultrasonic, photoelectric, time-of-flight, color, contrast, fiber, laser, capacitive and inductive proximity sensors– to name a few – that are worth investigating.

4. **If a sensor isn't enough, but a vision system is too much for us, do we have other options?**

   Yes. Some of the leading vision system vendors have been offering ***vision sensors***, which fill the product gap between a sensor and a vision system. These vision sensors are generally useful at identifying if attributes are present or absent, but stop short of giving you detailed information about the inspection. For example, a vision sensor could tell you if a hole was drilled and tapped. Or it could tell you if a bottle was missing from inside a case of beer or soda. Or it could tell you that a printer printed *something* in the "BEST IF USED BY" textbox. But don't expect to determine the details of the thread pitch or if the correct date was printed on the box. If you need a more detailed feature set, then set your sights on a vision *system* instead of a vision *sensor*.

5. **Do I need a *color* vision system?**

   Vision systems (or their respective cameras) come in two general flavors – grayscale and color. Each pixel in a grayscale camera is assigned a numeric value proportional to its brightness level (for example WHITE=255 and BLACK=0, with shades of gray falling somewhere in between). For most applications, grayscale is sufficient. However, color vision systems are essential if you need to sort, grade, inspect or measure based on color attributes. One example is the sortation of fruits based on color (ripeness) level. Color vision systems are also needed whenever you need to differentiate one feature from another based on color. Although grayscale systems can solve certain color applications –*IF there is sufficient difference in brightness between the colors involved* – there are many applications where this is not possible. Instead, one must rely on colors attributes, such as hue and saturation. For example, if you need to confirm that all pins on an electronic connector have received gold plating over the base metal, then color vision systems become the proper choice. Another example would be the inspection of a multi-coil, multi-turn toroidal transformer that is wound with different color copper wires, where you need to perform a wrap count for each wire color.

   Also keep in mind that some color vision systems have the capability of converting an image to grayscale, for use with algorithms that perform better in the grayscale domain.

6. **How will I know if a vision system will solve my application?**

   In a word … **TESTING**. *Preliminary evaluation with your product is essential to determining what approaches and vision hardware are suitable to solving your application.* Provide samples of your product to those tasked with performing the evaluation. Samples should include not only good pieces, but also pieces containing representative defects or features that you wish to detect. Let the evaluator know what variations to expect, both in the acceptable and unacceptable products. Physical samples of those variations may also be needed for testing.

7. **What environment will the vision system be subjected to?**

This is a very important question. Just like other electronic devices, vision systems have specifications that define their allowable operating environment. This includes temperature, humidity, vibration, and exposure to dust and liquids. Third-party manufacturers also offer ruggedized housings for your camera and lighting, should the application require the additional protection. Such housings or even protective lens shrouds may be required in areas where FDA or other regulatory constraints prevent the direct exposure of the glass lens to the production environment.

Also consider the physical space in which the camera is mounted. The footprint of each camera varies significantly amongst the different vendors and their product offerings. Some space-constrained applications require the use of a remote camera head, which is separate from the vision system's processor.

8. **Is dedicated lighting really that important in a vision application?**

Controlled lighting is **ABSOLUTELY ESSENTIAL** to a having a reliable and successful vision application. This fact cannot be overstated.

Part of a successful vision project entails testing your product with a variety of dedicated light sources to achieve the optimal lighting effect for your inspection objectives. Time spent during this lighting selection process is a worthy investment.

Achieving controlled lighting also entails the practice of shielding or filtering out ambient light that is variable in both wavelength and amplitude. Sunlight and overhead fluorescent lights, while they may look stable to the eye, do not serve as a controlled or stable light source for a vision application. Fluorescent lighting can wreak havoc on color inspections. Be wary of shadows cast by moving workers or equipment. Physically shield the inspection area from undesirable external light contributions, such as overhead lights or warning strobes.

When selecting dedicated vision lighting, one must consider 4 general attributes: emission source, wavelength, brightness, and form factor. Vision lighting is available in a variety of emission types, but the LED format is the most popular today. This is due to a host of factors such as stability, efficiency, lifespan, ruggedness, compactness, wavelength options, and manufacturing costs. LEDs come in several wavelength choices, with white, red, green, and blue being the most common. One would select an LED wavelength based on the colors in your product, camera's CCD wavelength sensitivity, ambient light filtering needs, and also your inspection objectives. For example, if your objective was to accentuate and detect fine scratches on glass plates, blue wavelength lighting would be the appropriate choice.

Lighting form factors and positioning techniques are combined to achieve the desired lighting effect. A different vision light and technique may be required based on your inspection objectives, even for identical targets. For example, you may need one lighting design if your objective is to perform optical character verification (OCV) on the text stamped on a coin. But you would use a totally different lighting technique if your objective was to measure the coin's diameter.

9. What do the terms Working Distance, Image Resolution, and Field of View mean?

Working Distance is a term commonly used to quantify the distance from the camera to the target.

The Field of View is the physical region that the camera sees when fixtured at a specific Working Distance. The Field of View is a function of the camera's imaging element design, lens, and Working Distance. It is often stated as a planar rectangular region, X units wide by Y units high. For typical lenses, the field of view decreases as the working distance decreases. Some vision system manufacturers provide handy online resources that calculate the Field of View when the user specifies a given camera model, lens, and Working Distance.

Image resolution quantifies the level of detail that can be captured by the vision system. This detail granularity is a property of the camera's CCD or CMOS imaging device onto which the light is focused. Resolution is typically specified as X pixels wide by Y pixels high or alternatively stated as the product of X and Y. The more pixels one uses to represent the image in the Field of View, the greater the detail that can be resolved.

In general, one wishes to have more resolution rather than less when doing image inspections. However, greater resolution requires more computational power to process the additional data in a timely fashion and thus results in higher cost hardware. While more resolution is often better, there is a limit to the value of increasing the system resolution. For example, having "too much" resolution can actually be a detriment to some OCR and OCV algorithms ability to work well.

10. What's important when considering a lens?

Some folks choose a lens based on the focal length necessary to achieve the desired Field of View and the selection process ends there. But there is more to lens selection.

A lens is designed to focus the image on a CCD or CMOS array at a specific distance from the lens. The selection process must start with narrowing down those lens types that are compatible with the camera you have selected. In some cases, your lens options may be expanded if you opt to use a spacer or "ring kit" between the camera lens mount and a non-native type of lens.

Be sure to choose a lens that has variable focus and aperture settings.

The amount of distortion in your image depends on the lens you select. These distortions are non-linear and worsen moving away from the optical axis. Lower distortion lenses generally cost more, but some applications require them. For example, having a low distortion lens is often critical in pick-and-place (positioning) applications and also in measurement (gauging) applications.

Applications that require higher resolution cameras also demand that the user supply a lens suitable for resolving the necessary detail. Lens manufacturers typically provide resolution specs that aid in the selection process.

Some applications require special-purpose lenses. For example, inspections such as measurement or pick-and-place may require a telecentric lens. This lens type allows for constant magnification, regardless of the working distance and target position within the field of view. Bottle sealing surface inspection is one application that benefits from the use of a telecentric lens to eliminate the difficulties caused by perspective distortion.

11. How will the vision system know when to acquire an image?

Vision systems typically rely on an external means to detect that the part is within the field of view and to trigger the vision system to acquire an image at the proper time. Such signals often comes from a part-detecting sensor, but can also be derived from a PLC, motion control system, or another vision system.

Some vision systems can alternatively operate in a mode where they are continuously self-triggering, although this method is rarely practiced.

Additionally, some vision sensors contain a software-based "part detect" feature which self triggers an inspection once the trained part or part feature enters the field of view.

12. Do I need to fixture my part when presenting it to the camera?

Whether or not you need to mechanically fixture your part relative to the vision system is case-specific.

Although many advanced vision systems have the capability of locating your part within the Field of View and then repositioning the various inspection tools to their desired locations, this has its limitations and is not a blanket panacea. Light distribution and its effects on the part may vary appreciably if the part is placed at different regions throughout the Field of View. The desired lighting effect on the part may exist within a very limited region. Variations in lighting often translate to decreasing the inspection system's reliability. Also, some parts do not have distinctive enough features to allow the vision system to locate its position and orientation within the entire field of view.

When performing measurements, part fixturing becomes more important or even essential. Optical distortions caused by the lens will introduce measurement irregularities as the part is moved throughout the Field of View. With standard lenses, moving the part closer to or further from the lens introduces error because the engineering unit-to-pixel scaling no longer matches the scaling as determined when the system was commissioned.

For most applications where the part moves past the camera during the inspection, it is common to employ a mechanical means to guide and orient the part prior to the inspection station. This approach provides some orientation and positional consistency to allow for repeatable part inspections.

13. Is it important to know how fast my part moves past the camera?

Yes. The camera's CCD exposure time (electronic shutter speed) should be set to minimize the extent to which "pixel blur" occurs. The longer the exposure time is, the greater the extent the image will be blurred if either the camera or the part is moving. Vision system inspection tools often rely of finding edges in the image. The more crisp the image, the better your chances are of vision tools working successfully and repeatable.

Keep in mind that as you decrease the exposure time, more light will be needed to maintain the same image exposure. This can be achieved by changing the brightness of your vision lighting and/or opening up the lens aperture.

The velocity of your part also becomes important if you need to track the part to a reject or diverter station. If the part is being transported on a conveying system, then an encoder or similar device may be needed for part tracking. Although some vision *sensors* can accept an encoder input, part tracking is commonly handled by a Programmable Logic Controller (PLC) or Programmable Automation Controller (PAC).

Your part rate may define your options in suitable vision systems. Vendors offer vision system with different processor speeds to accommodate for applications requiring faster inspections.

14. Why would I want to strobe a vision light?

Strobing is a feature that is provided on some vision-based LED lighting systems. It allows you to control the *duration* that the LED light is on. Sometimes the LED on-duration is specified by a dedicated lighting controller, but usually it is driven by a vision system output. By limiting the duration that the LEDs are on, the designer can then drive the LEDs with *more* current than is permissible during a constant on condition. This results in greater light output while using the same LEDs. Strobing is useful when trying to "freeze" the motion of your target, by increasing the light output when there is a need for decreased exposure times. Although strobe lights allow the user to adjust the on-duration of the LEDs, they seldom allow the user to adjust the brightness during that strobe period. The amount of current sent to the LEDs is limited by the designer's calculations intended to keep the LED within their safe operating range.

Strobing also has the benefit of extending the lifespan of your lighting unit, by reducing the duration that the LEDs are on.

There are two notable drawbacks to strobing. Some individuals may not tolerate the flashing of the LED lights – either in frequency or amplitude. In such cases, one should shield the lights from personnel or keep the lights on steady. The second drawback is that the brightness of light *may* experience variability from one strobe event to the next – particularly if your power supply is not stiff enough, (i.e. lacks sufficient capacitance and recovery properties). Your lighting must be consistent for reliable inspections; therefore if variability in the light intensity is observed, then measures should be taken to resolve this problem.

Also note that certain lower cost vision systems and vision sensors do not have the integral capability of strobing an external light.

15. If we need to inspect different parts, does the vision system become part of our changeover process?

Yes. In most cases, product changeover will require interaction with the vision system.

In the simplest of cases, the user may need to select a job file from a list of pre-programmed jobs that an engineer has already created for each of your product types. If the inspection process involves pattern matching, then the user may need to retrain the reference pattern.

In more complex changeovers, additional steps may need to be taken. This includes modifying part fixturing (such as jigs or guide rails), modifying the illumination, and tweaking of the lens focus and aperture settings.

Keep in mind that something as basic as a change in paint color applied to an otherwise identical part may require a change in your vision setup. In general, your vision application should be set up, trained, and tested for the specific product that you are running. It is important to discuss with your vision system integrator your product variations and changeover processes.

16. What are my communications requirements?

Before selecting a vision system, it is important to consider what you are going to do with the inspection results! A basic inspection will generate an overall PASS/FAIL binary result that can be communicated through a hard-wired discrete input to a PLC, PAC, motion controller, or other control system. However, more advanced applications, such as part measurement or part location, will require transmission of part location and orientation (X position, Y position, and θ angle). This data is in integer or floating point format and needs to be communicated to another controller. Some communication methods, such as serial or a binary weighted data bus may prove to be too slow or inadequate. Vision system vendors support a variety of modern communications protocols to talk to PLCs and robots. For example, several vision vendors have adopted Ethernet/IP which is supported by many Ethernet capable PLCs and PACs by Rockwell Automation Allen-Bradley and others. Such network-based communication methods allow binary, integer and floating point data to be exchanged quickly and efficiently between the vision system and the target controller.

17. What are my data collection requirements?

Understanding your data collection requirements will help refine your vision system options.

Depending on your application requirements, you may need to collect and archive images and inspection results for every part that you inspect. Some customers may simply want to capture and record images of those parts that fail inspection, for troubleshooting or diagnostic purposes.

Some vision systems can support the transfer of inspection images to an FTP server on your Ethernet network. Some can locally buffer a limited number of images on the vision system for review at a later date.

18. How will my users interact with the vision system?

Unfortunately, the topic of operator interaction with the vision system is often overlooked in the early stages of a vision project. But it is essential to understand what information your operators, technicians, and maintenance personnel will need in order to efficiently use a vision system. Commonly, an image of the inspected part is displayed on a screen, with inspection tools overlayed along with their with respective pass/fail results. Operators commonly want visual feedback regarding the pass/fail status of the parts, while techs and maintenance personnel will need to interact on a deeper level during setup and changeover.

The *manner* in which programmers and end-users interact with vision systems will vary significantly among the competing vendors. For example, one vendor provides a VGA port on their vision system for direct connection to a monitor and also provides a console (multi-button corded pendant) for configuring and navigating the vision environment. No PC is required for this particular platform. Another leading vision vendor provides a PC-based software application for configuring and programming the vision system. This PC application or an Active-X control can then serve as the front-end for the user to set-up and monitor the vision application during production. Other vision systems can interface through USB or Ethernet to a dedicated touchscreen designed by the vendor to serve as the user interface for their vision system.

In summary, it is important to review the types of vision system interfaces that are available and the manner of interacting with them. Make sure they are compatible with your project objectives and your personnel needs prior to committing to a particular hardware platform or vendor.

19. If I have a vision system, why might my application also require a PLC or PAC?

An installed vision system doesn't exist in a vacuum. It is typically part of a process or machine. The inspection results from the vision system are only a small part of the decisions that need to be made to control the machine or process. The decision-making process is commonly performed by a Programmable Logic Controller (PLC) or Programmable Automation Controller (PAC). While limited logic and math capabilities are embedded in some of today's vision system controllers, these should be considered more of an ancillary features and NOT their strong suit. PLCs and PACs are designed specifically for the task of processing logic and performing calculations and should be the first choice when implementing machine or process control. While there are some very simple applications where a vision system may be sufficient and a PLC is not needed, this is the rare exception. Keep in mind that a PLC is constantly repeating the cycle of reading inputs, processing logic, and then updating outputs. In contrast, most vision systems acquire an image, process their inspections, and update their outputs *only on the transition event of an external trigger request.*

The bottom line here is that one should leverage the strength of the respective platforms. Vision systems are great at performing optical inspections and PLCs are great at processing logic and math.

20. What will I need to support a vision system?

The answer to this question varies greatly. It depends on the hardware platform you deploy, the complexity of the application, who will be responsible for programming and configuring the vision system, and the extent of product changeovers and variations.

In all cases, you should have someone on staff that has basic troubleshooting skills. Even if the vision application requires no changes, common troubleshooting tasks involve investigating and answering some basic questions. This includes: Is the vision system powered-up and running? Is the lens cap off? Is the image in focus? Is the inspection trigger sensor correctly positioned and functioning properly? Is the image acquired such that the part is correctly positioned in the field of view to perform an inspection? Is the illumination suitable?

There should also be someone on staff who can periodically challenge the vision system to confirm that it is working properly. This person should verify that good parts receive a passing inspection result and that bad parts receive a failing inspection result. This test should also include confirmation that the control system responds appropriately to the inspection result.

We hope this discussion has been worthwhile for you. Geometric Controls, Inc. (GCI) has extensive experience integrating vision systems into a broad range of applications. We can aid in the entire project lifecycle – from application evaluation to programming, design, documentation, testing, installation, start-up, and support.

Let us help make your next project a success.

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