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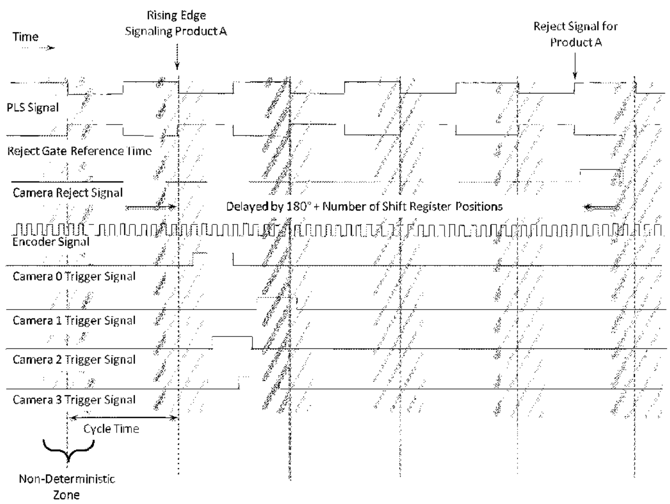

Figure 13

(57) **Abstract**: A machine vision system for use in a high speed production system, such as disposable diaper manufacture, makes it possible to reject only single defective products as part of a single cull operation. To achieve single cull capability, a nondeterministic zone in which a reject signal from a relatively asynchronous machine vision system is input to a reject gate control and activation system is avoided. This machine vision system reject signal is also delayed relative to a camera trigger signal by a time or position delay in addition to shift register delays dictated by system parameters.

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SINGLE CULLING MECHANISM FOR USE WITH MACHINE VISION ON PRODUCTION LINE

[0001] CROSS REFERENCE TO PRIOR CO-PENDING PATENT APPLICATIONS

[0002] This application claims the benefit of prior co-pending US Provisional Patent Application 61,464,928 filed on March 11, 2011.

[0003] BACKGROUND OF THE INVENTION

[0004] A system and method for reliably and robustly implementing a "single cull" on a high-speed manufacturing production line comprises an improvement over current inspection systems, especially machine vision inspection systems. It is a common practice in high-speed manufacturing to inspect a product with a machine vision inspection system and physically reject a product from the production line when a defective product is detected. However, because of certain uncertainties inherent in the propagation of a reject signal between the inspection system and the reject gate, it is a common practice to reject three or more products when only one defective product is detected. The system and method according to the present invention will facilitate a single cull of all defective products only and is comprised of one or more CCD cameras, an image processing computer with hardware and an adaptive phasing module means for addressing problems encountered in prior art systems. The uncertainty or non-deterministic aspects of the reject signal propagation can be avoided by processing the camera reject signal based on current conditions.

[0005] In the field of high-speed manufacturing, and in particular diaper manufacturing, it is common to inspect products during manufacture using a variety of methods and later reject a defective product. One such prior art method is shown in Figure 7. However, due to certain inherent uncertainties it is very challenging to reliably and deterministically reject the correct product 100% of the time when a reject signal is sent from the inspection device. To alleviate this problem, it is a general practice of the industry to reject one or more proximate products, such as diapers, both preceding and following the supposed defective product. In this way, the manufacturer is assured that the defective product is removed from the production line. However, this practice also causes the waste generated by a single defective product to increase by a factor of 3 or 5. Enacting the single cull for inspecting the manufacture of diapers will result in a66% to 80% reduction in diaper waste because it will be unnecessary to reject product, which while known to be satisfactory, must also be rejected to insure that individual defective products are eliminated. A single cull capability translates to remarkable potential savings to diaper manufacturers with significant environmental impact.

[0006] In order to achieve this improvement, we have invented a way to synchronize the reject signals from the CCD cameras and the timing of the cull signal, which is dictated by the response time of the reject gate and the phase (timing) of product, such as diapers, as they pass through the reject gate. Further integration requires timing of the reject signal for each camera. The reject signal is controlled by the trigger signal, which is established by a combination of the camera mechanical position and the phase of the diapers when they pass before the camera. Due to these constraints, in certain scenarios the synchronization of the timing between machine vision cameras and the reject gate may become non-deterministic. Although often overlooked, this scenario could lead to a mis-sychronization which would allow a defective product to pass the reject gate as well as requiring rejection of otherwise satisfactory product. There has been a recognized need for implementation of single culling across the industry, and especially for the mass production of disposable diapers.

[0007] As production lines get faster, the timing required to control the reject gate is getting increasingly more difficult. Figure 1 illustrates the timing requirement of the cull signal at the reject gate. The cull signal must be issued at the precise time, taking into account the delay of the cull action response time due to such characteristics as the reject gate mechanism, in order to catch the defective product while it moves through the reject gate at high speed.

[0008] At the inspection station, the timing for the image capture is controlled by the trigger signal in response to the production line system programmable logic controller (PLC), which is input to the camera. The required phasing of the trigger signal is dictated by the position of the camera and the required timing to capture a complete view of the product. As illustrated in Figure 2, the reference time of the trigger signal is in the abstract is independent of the Reject Gate Reference Time, which is a production line system parameter and not a characteristic of the camera or of the machine vision system used on the production line. However, the trigger signal is referenced to the Reject Gate Reference Time for specific applications. The difference between the two Reference Times is dependent upon the mounting position of the camera along the travel direction of the web. The relative position between the reference time of the Reject Gate and the Camera Trigger is a function of the distance between the camera and the reject gate and the length of the product. The Reference Time Difference is the distance between the camera station and the reject gate subtracted from the closest multiples of the product length and divided by the velocity or speed of the production line. Since product lengths vary depending on product styles produced on the same production line, it is impractical to control the distance of the camera from the Reject Gate. Furthermore, the position of the camera is determined by the available space at the production line where certain components must be inspected. Yet, as will be shown below, the Reference Time Difference between the Reject Gate and the Camera Trigger is very critical to the success of achieving single culling.

[0009] Figure 3 shows the Reject Signal Shift Mechanism for synchronizing the signal from the camera station to the reject gate. For proper operation, the Reference Time Difference between the reject gate and the camera trigger must not exceed a certain maximum value. The maximum value is determined by a combination of the timing requirement for the shift register operation and the minimum cycle time. The minimum cycle time is dictated by the fastest line speed while running the smallest product.

[0010] Figure 3 appears to show the camera reject signal at the same time as the camera trigger signal. However, the camera reject signal shown in Figure 3 is actually the reject signal for a previous camera image, which is saved to be output from the machine vision system at a constant time.

[0011] The simplest arrangement is that the Camera Reject Signal is sent from the machine vision system as soon as the image processing is complete. This is inferior to the typical arrangement which is employed in the current invention and in other machine vision systems where the Camera Reject Signal is at least held until the next Camera Trigger is received. This is important because at least the Camera Reject Signal will be output at a consistent time. In the simplest arrangement, the Camera Reject Signal could be output at any time in the product cycle.

[0012] The phasing of the Camera Trigger Reference Time must be adjusted to allow the camera to capture a full product view. As illustrated in Figure 4, the "Reference Time difference between the reject gate and Camera Trigger" plus the required "Setup Time" must be less than the product cycle time. The Setup Time is the minimum amount of time the reject signal must be ready before the Reject PLC shift register clock event in order for the signal to be reliably, or deterministically, sampled. The Hold Time is the minimum amount of time the reject signal must be valid after the Reject PLC shift register clock event in order for the signal to be deterministically sampled. The combination of the Setup Time and Hold Time create a relatively short, but real period of time in which the sampling of the machine vision or camera reject signal is non-deterministic, so that a satisfactory product might be culled instead of an adjacent defective product. This fact cannot be ignored if single culling is to be successfully and reliably implemented.

[0013] One prior art solution is to physically reposition the camera along the production line such that the phase of the Camera Trigger Reference Time is correspondingly adjusted such that the Camera Reject Signal is safely outside of the Non-Deterministic Zone, as illustrated in Figure 5.This solution requires that the cameras be re-positioned to different locations for different product sizes. However, because of the tight space where the camera is mounted, this cannot be easily accomplished.

[0014] The inherent uncertainty in rejection of the correct and defective product when a reject signal is received from the inspection system is due more to the integration of each sub-system on the production line than a deficiency within any single component. Therefore, to overcome these short-comings a new integration scheme must be created.

[0015] First consider the common arrangement shown in Figure 7. The cameras are triggered to capture an image based on a signal from the production line programmable limit switch (PLS) which is activated by mechanical rotation of the machine components, and therefore the PLS will generate a repetitive or cyclical signal which can be referenced by the Machine Vision System and will activate system components. If the inspection system detects a defective product, the reject signal is sent to the Main PLC. The Main PLC in-turn sends a reject signal to the Reject PLC. The Reject PLC must keep track of each product in the production line in order to associate a reject signal from the inspection system with a product on the production line. This is accomplished through use of a shift register in the Reject PLC. The underlying challenge is that the PLS, Inspection System, Main PLC and Reject PLC are all essentially independent and asynchronous devices. In some situations, the duties of the Reject PLC may be handled by the Reject PLC, but the same underlying challenges still exist.

[0016] SUMMARY OF THE INVENTION

[0017] A machine vision system according to this invention is used for rejecting only individual defective products manufactured on a continuous production line, including production line electronic control apparatus, without rejecting proximate product that are not defective as a safeguard against failure to reject a defective product. The machine vision system includes an input for receiving cyclical reject gate reference time signals that comprise a parameter of the production line. A camera, which is part of the machine vision system, receives a camera trigger signal for activating the camera. The camera trigger signal is referenced to the cyclical reject gate reference time signals. An output from the machine vision system sends a camera reject signal to the production line electronic control apparatus during a second reject reference time cycle subsequent to a first reject time cycle in which the camera is activated for activation of a single reject gate to cull only one individual product at a time without culling the proximate products that are not defective. The camera reject signal is delayed relative to the camera trigger signal in addition to the delay between the first and second reference time cycles to avoid a non-deterministic time zone proximate to receipt of a new reject gate reference time signal indicating a new reject gate cycle, so that the reject signal is sent during a time period in which a reject gate can be activated only during the passage of a single defective product.

[0018] This invention includes a machine vision system for inspecting product on a continuous production line to identify defective products and to cull all defective products at a reject gate on the production line without the need to cull proximate, but non-defective products, in order to insure a complete cull process. The machine vision system has at least one camera. An input to the machine vision system receives cyclical reject gate reference time or position signals that comprise a parameter of the production line to generate a camera trigger signal in response to the cyclical reject gate reference time or position signals. A processor in the machine vision system generates a reject signal for a defective product in response to examination of an image from the camera, the reject signal being sent to the reject gate to cull a defective product. The reject signal is delayed by a constant time or position delay relative to the cyclical reject gate reference time or position signals and to the camera trigger signal to avoid sending the reject signal during a non-deterministic time interval in which a non-defective product may be in the reject gate.

[0019] BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Figure 1 shows Cull Signal Timing at the Reject Gate.

[0021] Figure 2 shows the Reject Timing Signal at the Camera Station.

[0023] Figure 3 shows the Reject Signal Shift Mechanism.

[0024] Figure 4 shows the Camera Trigger Timing Constraint as it relates to a Non-Deterministic Period.

[0025] Figure 5 shows the manner in which the Camera can be repositioned according to the Prior Art.

[0026] Figure 6 shows how an Automatic Delay of the Camera Reject Signal can avoid the non-deterministic zone.

[0027] Figure 7 shows the prior art manner in which an Inspection System, such as a Machine Vision System, can be integrated with production line components that would not be part of the Machine Vision System.

[0028] Figure 8 shows the manner in which an Inspection System, such as a Machine Vision System according to this invention, can be integrated with production line components.

[0029] Figure 9 is a diagram of a first embodiment of Machine Vision Inspection System according to this invention, which includes an Adaptive Phasing Module.

[0030] Figure 10 shows the required input and output of a Machine Vision Inspection System according to a second embodiment of this invention to achieve Single Culling capability.

[0031] Figure 11 is a block diagram of the Machine Vision Inspection System according to the second embodiment of Figure 10 and the manner in which this Machine Vision System interacts with a Production Line Reject PLC.

[0032] Figure 12 shows a timing chart of the system shown in Figures 10 and 11 with one camera.

[0033] Figure 13 shows a timing chart of the system shown in Figures 10 and 11 with four cameras.

[0034] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] To avoid nondeterministic signals, which will adversely affect the ability to cull only a single defective product, the embodiments of this invention introduce a delay in sending a reject signal instead of repositioning machine vision cameras on a high speed production line. Practically the position of the camera cannot be mechanically adjusted to match the signal timing requirements. Alternatively, when the reject signal occurs in the non-deterministic zone as described in Figure 4, the timing of the reject signal must be automatically delayed to the next product cycle (See Cycle Time in Figure 4) relative to the Reject Gate Reference Time in order to ensure a reliable cull. This delay is demonstrated in Figure 6. When this condition occurs the number of required shifts for the Camera Reject Signal must be reduced by one to insure that he camera reject signal is transmitted to the reject PLC at the point where only the defective product will be aligned in the reject gate.

[0036] In a machine vision system, each camera is triggered at a certain time before the product reaches a product reject gate. When the machine vision system detects a rejected product, the reject signal is then entered into a shift register so that the gate can be activated when the defective product reaches the reject gate. The “shift register” is a table inside the PLC which stores the pass/fail status of each product going down the assembly line. As each product approaches the reject gate, the shift register “shifts” based on but not necessarily the same as changes in the reject gate reference time cycles, so that each product is moved to the next row in the table. This is the means for tracking each product. The underlying problem to be solved is that since the Reject PLC and the machine vision system are asynchronous, it is possible that when the camera reject signal for product A is sent from the machine vision system, the Reject PLC enters that result into its shift register under product B. Since all input and output signals are discrete signals only, the timing alone dictates which product corresponds to a signal. The principle of the adaptive phasing module according to a first embodiment of this invention is to estimate the point in time at which the Reject PLC is shifting the shift register from Product A to Product B, and then delay our reject signal to a later time if needed. If a camera reject signal is output just as the Reject PLC shift register is shifting, then it is uncertain as to whether the reject will be attributed to Product A or B.

[0037] In the description on the system above, it is suggested that rather than send our output to the PLC, we will bypass the Main PLC and send the output directly to the reject PLC. Some production lines might have only 1 PLC controlling both the production line operation as well as the reject operation. In either case, the issue is the same. Therefore, to achieve single culling, the machine visions system must be able to automatically:

[0038] (i) Detect, based on pre-determined Setup Time and Hold Time requirement setting of the Reject PLC, that the Camera Reject Signal has violated the timing requirement for the Reject Gate. (The calculation is based on the timing difference between the rising edge of the Reject Gate Reference Time and the Camera Trigger Reference Time along with the setup-time and hold-time requirement settings.)

[0039] (ii) Calculate the additional delay duration required to bring the Camera Reject Signal to meet the timing requirement.

[0040] (iii) Delay the Camera Reject Signal by a calculated duration taking into account the mechanical/electronic response time of the reject gate.

[0041] (iv) Reduce the number of output shift delays in the machine vision system by one when timing violation occurs.

[0042] According to a first embodiment of this invention an Adaptive Phasing Module is introduced in-between the Main Production Line PLC and the Production Line Reject PLC. The Reject PLC will generate the reject gate timing signal referenced earlier and send it to the adaptive phasing module, and in turn to the inspection system. The inspection system will then use the reject gate timing signal to trigger each camera. Since each camera can be positioned at any point on the production line, it is necessary that each camera can be triggered by the inspection system at any time during the product cycle. If the Reject PLC for a particular production line is not able to provide a consistent Reject Gate Reference Time, for instance by varying one or more milliseconds, the PLS may be configured to derive a more consistent signal that will comprise and can be referred to as a Reject Gate Reference Time Signal for the purposes of this invention.

[0043] The inspection system will phase, or delay, the activation/trigger of each camera based on input from an encoder signal from the production line system so that camera images are synchronized with the product motion as required. The encoder signal tells the machine vision system the product position. Specifically, the encoder is mounted on a shaft of the production line and sends a signal back to the machine vision system. The encoder sends a fixed number of pulses for each rotation of the shaft. For a line scan camera, each pulse will trigger the line scan camera to capture one line of the image. The PLC gives a frame trigger to tell the cameras when the beginning of a product is in front of the camera, but the encoder generates the line triggers which activate the camera to capture each line of the image. But the encoder signal can also be used to simply track the movement of the product by distance rather than time. This is a more accurate measurement because the product does may not be traveling at a constant speed.

[0044] The phase of each camera trigger signal must be set a priori during the initial setup of the inspection system in order that each camera is taking a picture of one complete product. If a defective product is detected, the camera reject signal will be adaptively phased based on the reject gate timing signal and known information such as the Reject PLC required Setup and Hold Times. The inspection system will then send a single reject signal to the Reject PLC by way of the Adaptive Phasing Module at a time dictated by the specified number of cycles to account for the travel of a rejected product from the camera inspection location to the rejection gate plus an additional delay to avoid a nondeterministic zone, thus bypassing the Main PLC. By avoiding dependence on the PLS and the Main PLC, two elements of uncertainty are avoided. By automatically phasing the inspection system reject signal to avoid the non-deterministic zone of the Reject PLC, the last significant element of uncertainty has been avoided.

[0045] Consider further that other devices communicating with the Main PLC may also generate a reject signal. The reject signal from the Main PLC will be sent to the Adaptive Phasing Module and automatically phased if the signal falls in the non-deterministic zone of the Reject PLC. In this way, the Adaptive Phasing Module will not only reduce the uncertainty related to inspection system rejects, but for any reject signal coming from the Main PLC.

[0046] Figure 9 describes the Adaptive Phasing Technology in more detail. As explained above, the Adaptive Phasing Module receives the Main Production Line PLC reject Signal, as well as an “enable” input. This Main Production Line PLC reject signal refers to reject signals initiated by systems other than the Machine Vision System of this invention, which can be used with other reject signal generating systems or mechanisms. The enable input allows the Main PLC to disable the Adaptive Phasing Module from sending reject signals to the Reject PLC. The Adaptive Phasing Module also takes the reject gate timing signal from the Reject PLC and the encoder signal and sends them to the inspection system. In this embodiment, the inspection system is a Machine Vision System, such as the Sentry 9000 system from AccuSentry using the SmartVisionSystem network and described in more detail in US Patent Application 13/066,172 filed on April 8, 2011, incorporated herein by reference. The encoder signal and reject gate timing signal are sent to the SVP camera controller of the SVM machine vision image processing computer. The camera controller contains a field-programmable gate array (FPGA) which will compute the phasing of the camera triggers and control the phasing of the inspection system reject signal, as well as the Main PLC reject signal, based on system parameters, such as the position of the camera or cameras and the reject gate. The camera controller interfaces with the Sentry 9000 software and the SVP-IO Input-Output controller. The Input-Output Controller sends and receives discrete input and output signals. In the SmartVisionSystem network from AccuSentry, area scan and line scan cameras can be interchangeably daisy-chained together and require a single camera controller card. In this arrangement, the product images from each camera are transferred to the machine vision image processing computer to be processed to determine the pass or reject stated of each product. The image processing computer may be running image processing software, such as Sentry 9000, from AccuSentry, Inc. Sentry 9000 allows the user to interface with the hardware to configure the various image capture parameters such as camera exposure time, camera image dimensions, camera frame trigger selection, camera line trigger selection (for line scan cameras), camera signal gain, camera binning, etc. Parameters relating to discrete high-speed IO signals such as reject codes for particular defects, output signal delays and durations, shift register positions, camera overrun or failure output signals, etc. are also configurable. Sentry 9000 contains a graphical user interface (GUI) and a platform for developing complex image processing algorithms using a progression of pre-defined tools for detection and measurement of various image elements. Additionally, Sentry 9000 is capable of communicating with various other factory devices using a variety of communication protocols such as RS-232, TCP/IP, Ethernet/IP, OPC, RSLinx, and Modbus. Sentry 9000 is also capable of building a Human-Machine Interface (HMI) to allow manufacturing technicians and operators to safely and efficiently interface with the machine vision system. Typically, the image processing computer will be outfitted with a touch-screen display.

[0047] A second embodiment of this invention eliminates the separate Adaptive Phasing Module with an alternate version that is both more reliable and easier to set-up. In this second embodiment the “Adaptive Phasing Module” will not be a separate device, but rather its functionality will be included on the Machine Vision camera controller. The cameras will not be triggered by the Production Line PLS, but rather, all cameras will be triggered based on the reject gate timing signal. The cameras triggers will be generated by the camera controllers and will be independently phased within the machine vision system using the encoder input.

[0048] This second embodiment can also be used in the inspection of a mass produced product such as a disposable diaper. A typical baby diaper is constructed from numerous components. Some components inside the finished product, and therefore are only observable at an earlier point of manufacture. For this reason, in order to inspect that every component is correct, is usually necessary to install multiple cameras at different points of the production line. By placing cameras earlier in the manufacturing process, when certain defects are created, they can be corrected sooner resulting in fewer defective products. In other situations, a particular defect is indicative of a continuous problem. By inspecting for this defect as early in the production line as possible, this defect can be detected as soon as possible. In certain situations excessive unplanned downtime can be avoided by pro-actively shutting the production line down before this problem propagates down the production line to cause a much bigger problem such as material jams or web breaks.

[0049] The camera reject signal in this second embodiment will no longer be adaptively phased based on the PLC setup and hold time requirements. Instead the camera reject signal will be phased such that it is always output 180 degrees out of phase from the camera trigger signal. Except for extremely high speed applications with a product cycle time on the order of 10ms or less, this simplification will be more than adequate. This system is especially suited for use with typical product cycle times in absorbent hygiene manufacturing are 50ms and up, depending on the size of the product.

[0050] Ancillary capabilities can also be added to the system. For example, the single cull system will be capable of acting as a PLS to send output signals at any point in the cycle time. Camera reject signal could be delayed by position alone, rather than by product. The system can be configured to reject two products when a defect is detected on the border between two discrete products, and it cannot be determine with certainty that the second product is not also defective.

[0051] In this second embodiment of the single cull system, there will be a single camera trigger signal input into the Machine Vision System for each camera, and a single camera reject signal output from the Machine Vision System, as shown in Figure 10. The camera trigger signal will be the reject gate reference time signal from the Reject PLC, which is a parameter of the Production Line System that will be used with this new Machine Vision System. This Machine Vision System will also have input from an encoder on the production line. This will be the same encoder used by the line scan cameras to generate line triggers. This Machine Vision System itself will generate a frame trigger for each camera at the appropriate time, based on pre-determined positional delays from the reject gate reference time signal. After processing each camera's image, this Machine Vision System will generate a single pass or fail camera reject signal. This one camera reject signal will be output to the reject PLC. However, the camera reject signal will be delayed by 180°, which (for typical absorbent hygiene manufacturing speeds) will safely avoid the non-deterministic timing zone. The reject PLC may now check the status of this camera reject signal and enter the pass or fail state into its shift register without risk of erroneous accounting. The machine vision system may also contain a shift register with a configurable number of positions. The purpose of this shift register is to allow the machine vision system to buffer multiple images. Firstly, this allows the image acquisition to be performed while an earlier image is simultaneously processed. Secondly, the processing time of a particular image may exceed the product cycle time without necessarily causing an overrun state. It is worth noting that when the machine vision system is in an overrun state and is not able to process the images fast enough, the machine vision system must send a reject signal since it cannot be determined that a product is not defective. The cost of each machine vision system overrun is one or more rejected products.

[0052] Figure 11 is a diagram of the second system and method. The SVP camera controller communicates with the cameras and the encoder. By way of the SVP-IO cardio controller, the Reject Gate Reference Time signal and the Camera Reject Signal are input from and output to the Reject PLC. An FPGA on the SVP camera controller will control the timing of the camera frame triggers and Camera Reject Signal. For a timing chart of the SVM Machine Vision System, see Figure 12. The rising edge of the Reject Gate Reference Time indicates the beginning of each product. From this time, the machine vision system can generate a trigger signal for Camera 0 at the correct positional delay. After the machine vision system processes the Camera 0 image and determines the pass or reject result, this result is held in a shift register inside the machine vision system. In the current example, the shift register contains three positions. The Camera Reject Signal is therefore delayed by three product cycles plus 180° before sending. In this manner, the output is sent at a time when the Reject PLC can deterministically register the pass or fail signal to the correct product.

[0053] By extension, a similar timing chart in which multiple cameras are utilized is given in Figure 13. Note that the camera trigger signals are individually delayed by position using a predetermined phase delay and the encoder signal. Because the camera images and inspection results are buffered in the SVM Machine Vision System, the effects of this phasing are invisible to the user.

[0054] The advantages of this arrangement include the following. The system can reliably reject a single product, even when critical system parameters such as the camera trigger phasing are adjusted. Using existing methods, the system must be wired for both a camera trigger signal and a camera reject signal for each camera. Therefore a four camera system would require 8 signals, whereas use of the proposed method and system would require only 2 signals. In situations where the system is not, or cannot be integrated with a PLC, camera reject signals can be output with an entirely position based (as opposed to product based) delay. The system can generate position based output signals for any purpose, replicating the function a PLS. This capability is valuable when a production line does not have an easily adjustable PLS, or does not have any free channels on the existing PLS.

[0055] Other implementations are compatible with this system and method with only slight variations.

[0056] Although the purpose of this system is to facilitate the culling of a single product, certain situations might dictate that multiple products should be rejected. For example, when a certain kind of defect is detected at the end of one product, it might stand to reason that the beginning of the next product will also exhibit the same defect. Therefore, if the inspection of the camera images for either product detects this type of defect, the system can send reject signals for both products even if no defects were detected in the corresponding other image. For example, when the system is used to inspect a product, such as a diaper that is assembled from multiple components, a material splice for one component might span across two products. If the inspection system detects a material splice at either the beginning or end of a product, it would be safest to also reject the corresponding leading or following product. If the material splice was detected in the center portion of a product and was not close to either end, then rejection of a single product is sufficient to ensure that the material splice is not sent to an end-customer.

[0057] In some cases, the Main PLC might control the reject gate, and would therefore also serve as the Reject PLC.

[0058] In some cases, the Reference Gate Reference Time signal may be provided from the PLS rather than the Reject PLC.

[0059] The Camera Reject Signal might be delayed by more or less than 180° to account for a special situation, such as a very high-speed application where the sum of the PLC setup time and hold time comprises a significant portion of the overall product cycle time. For example, if the PLC hold and setup times comprise more than 10% of the product cycle time.

[0060] Although multiple camera inspections require only one Camera Reject Signal, the system could also send a separate Camera Reject Signals for each camera. Additionally, each the system could send multiple output signals for each camera to indicate the reject reason or an overrun state.

[0061] This Machine Vision System may communicate with the Main PLC, Reject PLC or any other factory device to communicate a variety of information. For example, production date, defect counters, product styles, enable/disable of any or all inspections, heartbeat, camera overrun, etc. may be communicated. This data may be communicated by Discrete IO signals, RS-232, TCP/IP, OPC, EthernetIP, Profinet, Modbus, etc.

[0062] Another common machine vision system is the “smart camera” arrangement. In this setup, the only component is the camera itself, which also controls the IO and processes the images. Obviously this system consists of a single camera, but in other regards it would have the same challenges for single culling as the system we describe in the patent and the same approach to avoiding nondeterministic zones can be applied to a smart camera arrangement.

THE CLAIMS

1. A machine vision system for use in rejecting only individual defective products manufactured on a continuous production line, including production line electronic control apparatus, without rejecting proximate product that are not defective as a safeguard against failure to reject a defective product, the machine vision system comprising:

an input for receiving cyclical reject gate reference time signals that comprise a parameter of the production line;

a camera receiving a camera trigger signal for activating the camera, the camera trigger signal being referenced to the cyclical reject gate reference time signals;

an output from the machine vision system for outputting a camera reject signal to the production line electronic control apparatus during a second reject reference time cycle subsequent to a first reject time cycle in which the camera is activated for activation of a single reject gate to cull only one individual product at a time without culling the proximate products that are not defective;

wherein the camera reject signal is delayed relative to the camera trigger signal in addition to the delay between the first and second reference time cycles to avoid a non-deterministic time zone proximate to receipt of a new reject gate reference time signal indicating a new reject gate cycle, so that the reject signal is sent during a time period in which a reject gate can be activated only during the passage of a single defective product.

2. The machine vision system of Claim 1 wherein the additional delay of the camera reject signal relative to the camera trigger signal is a delay of 180 degrees of the cyclical reject gate reference time signals.

3. The machine vision system of Claim 2 wherein a camera controller in the machine vision system determines the additional delay of the camera reject signal relative to the camera trigger signal.

4. The machine vision system of Claim 3 wherein the camera controller determines the delay based on an input of an encoder signal input to the camera controller from the production line system.

5. The machine vision system of Claim 4 wherein the camera trigger signal is the reject gate reference time signal.

6. The machine vision system of Claim 2 wherein the camera controller generates a frame trigger for multiple cameras.

7. The machine vision system of Claim 6 wherein a single pass or fail camera reject signal will be generated processing images from multiple cameras.

8. The machine vision system of Claims 2 wherein the machine vision system includes a shift register that is asynchronous relative to the cyclical reject gate reference time signals.

9. The machine vision system of Claim 2 wherein the camera controller includes a field programmable gate array.

10. The machine vision system of Claim 2 wherein the controller outputs position based output system other than the camera reject signal.

11. The machine vision system of Claim 1 wherein the additional delay of the camera reject signal relative to the camera trigger signal is other than 180 degrees of the cyclical reject gate reference time signals.

12. The machine vision system of Claim 1 wherein the additional delay between the camera trigger signal and the camera reject signal is greater than the sum of the set up time and the hold time for a signal transmitted to the reject gate.

13. The machine vision system of Claim 1 including an adaptive phasing module separate from the camera controller.

14. The machine vision system of Claim 13 wherein the adaptive phasing module receives inputs from a production line main programmable logic controller and communicates both inputs and outputs to a production line reject programmable logic controller and the camera controller.

15. The machine vision system of Claim 14 wherein a single reject signal is sent by the adaptive phasing module to the reject programmable logic controller, bypassing the production line main programmable logic controller.

16. A machine vision system for inspecting product on a continuous production line to identify defective products and to cull all defective products at a reject gate on the production line without the need to cull proximate, but non-defective products, in order to insure a complete cull

process, the machine vision system comprising:

at least one camera;

an input to the machine vision system for receiving cyclical reject gate reference position signals that comprise a parameter of the production line to generate a camera trigger signal in response to the cyclical reject gate reference position signals;

a processor in the machine vision system for generating a reject signal for a defective product in response to examination of an image from the camera, the reject signal being sent to the reject gate to cull a defective product;

wherein the reject signal is delayed by a constant delay relative to the cyclical reject gate reference position signals to avoid sending the reject signal during a non-deterministic interval including a reject signal set up time plus a reject signal hold time in which a non-defective product may be in the reject gate.

17. A machine vision system for inspecting product on a continuous production line to identify defective products and to cull all defective products at a reject gate on the production line without the need to cull proximate, but non-defective products, in order to insure a complete cull process, the machine vision system comprising:

at least one camera;

an input to the machine vision system for receiving cyclical reject gate reference time signals that comprise a parameter of the production line to generate a camera trigger signal in response to the cyclical reject gate reference time signals;

a processor in the machine vision system for generating a reject signal for a defective product in response to examination of an image from the camera, the reject signal being sent to the reject gate to cull a defective product;

wherein the reject signal is delayed by a constant time delay relative to the cyclical reject gate reference time signals and to the camera trigger signal to avoid sending the reject signal during a non-deterministic time interval in which a non-defective product may be in the reject gate.

18. The machine vision system of Claim 17 wherein the constant time delay is a constant phase angle of the cyclical reject gate reference time signal.

19. The machine vision system of Claim 18 wherein the constant time delay is equal to a fraction of a cycle of the reject gate reference time signals.

20. The machine vision system of Claim 17 wherein the time delay includes the set up time and the hold time which together comprise the non-deterministic time interval.

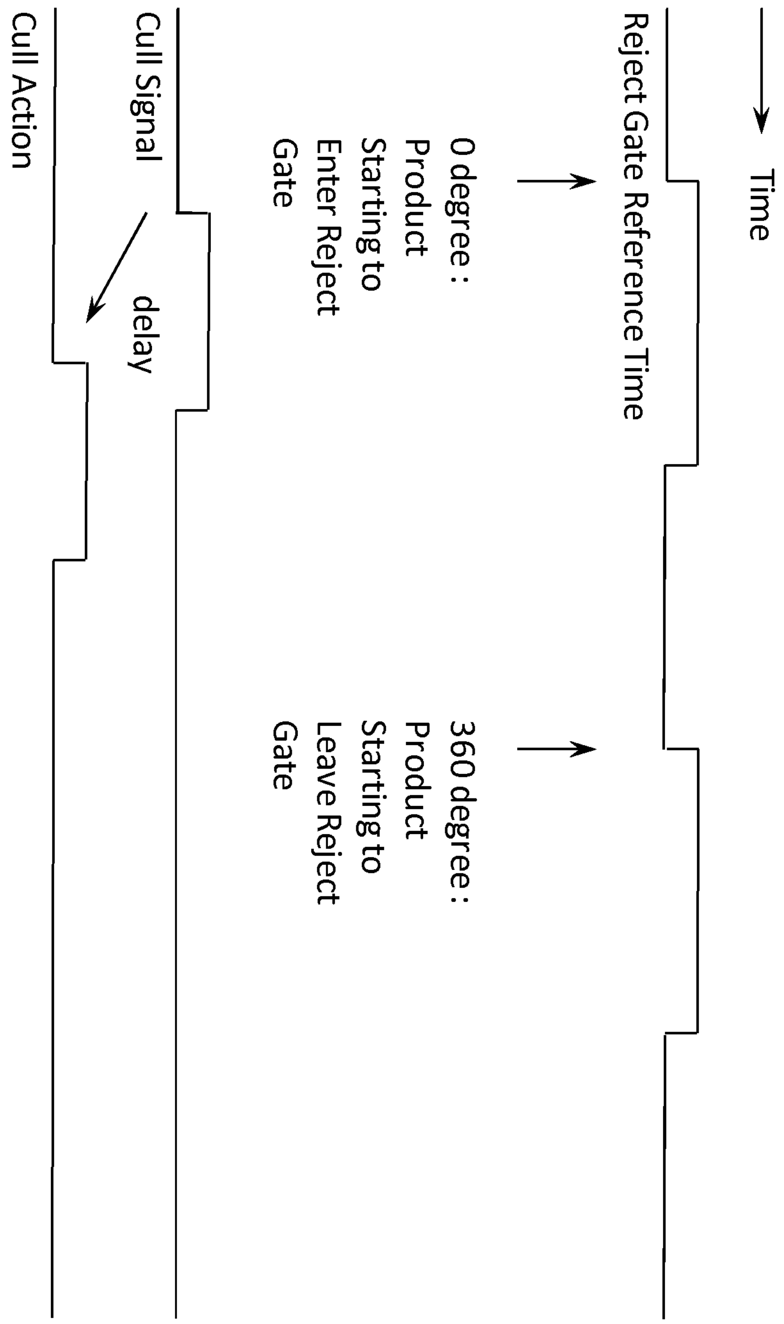

Figure 1. Cull Signal Timing at the Reject Gate

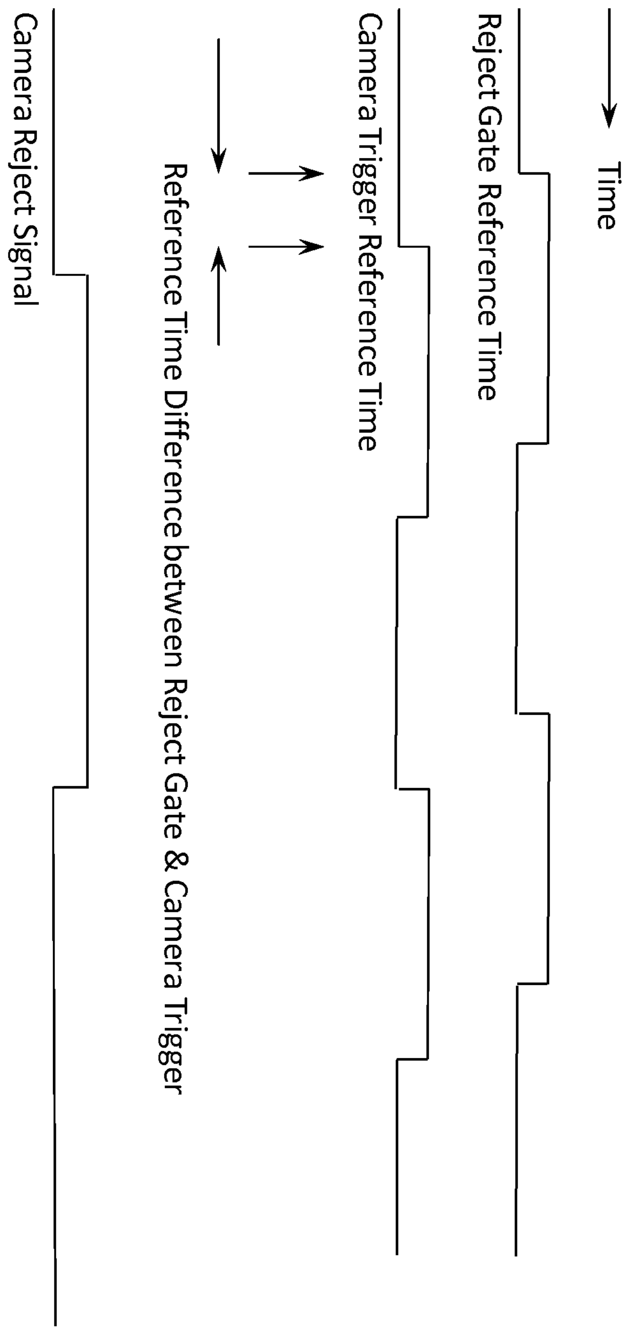

Figure 2. Reject Signal Timing at the Camera Station.

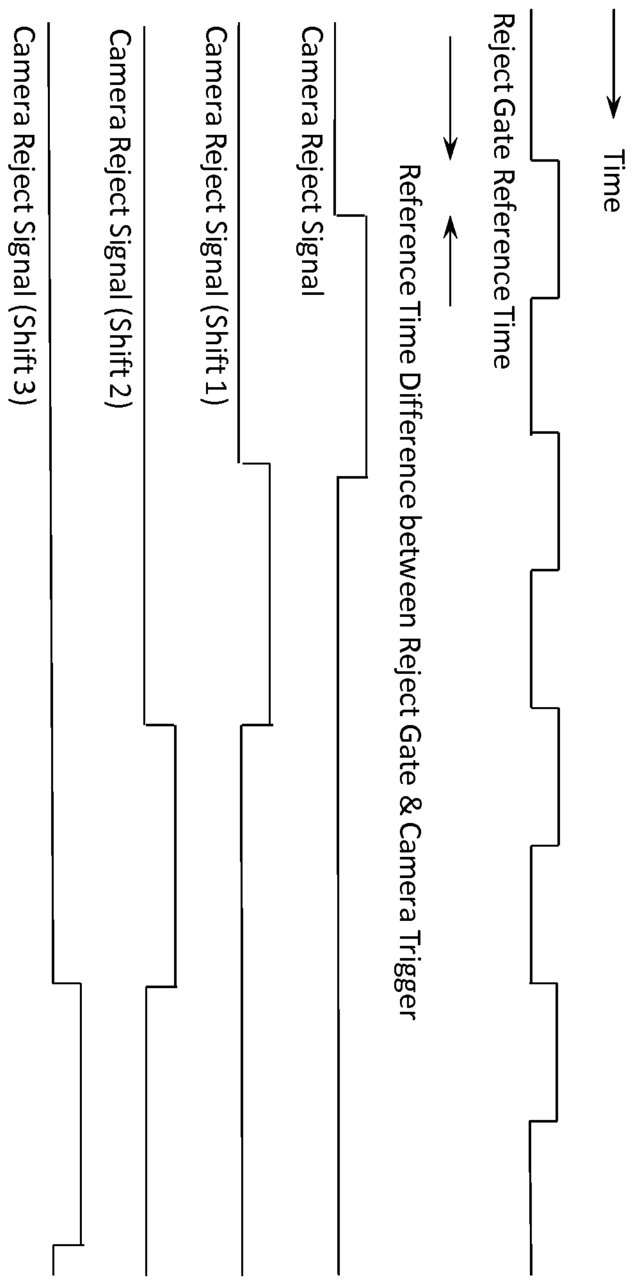

Figure 3. Reject Signal Shift Mechanism

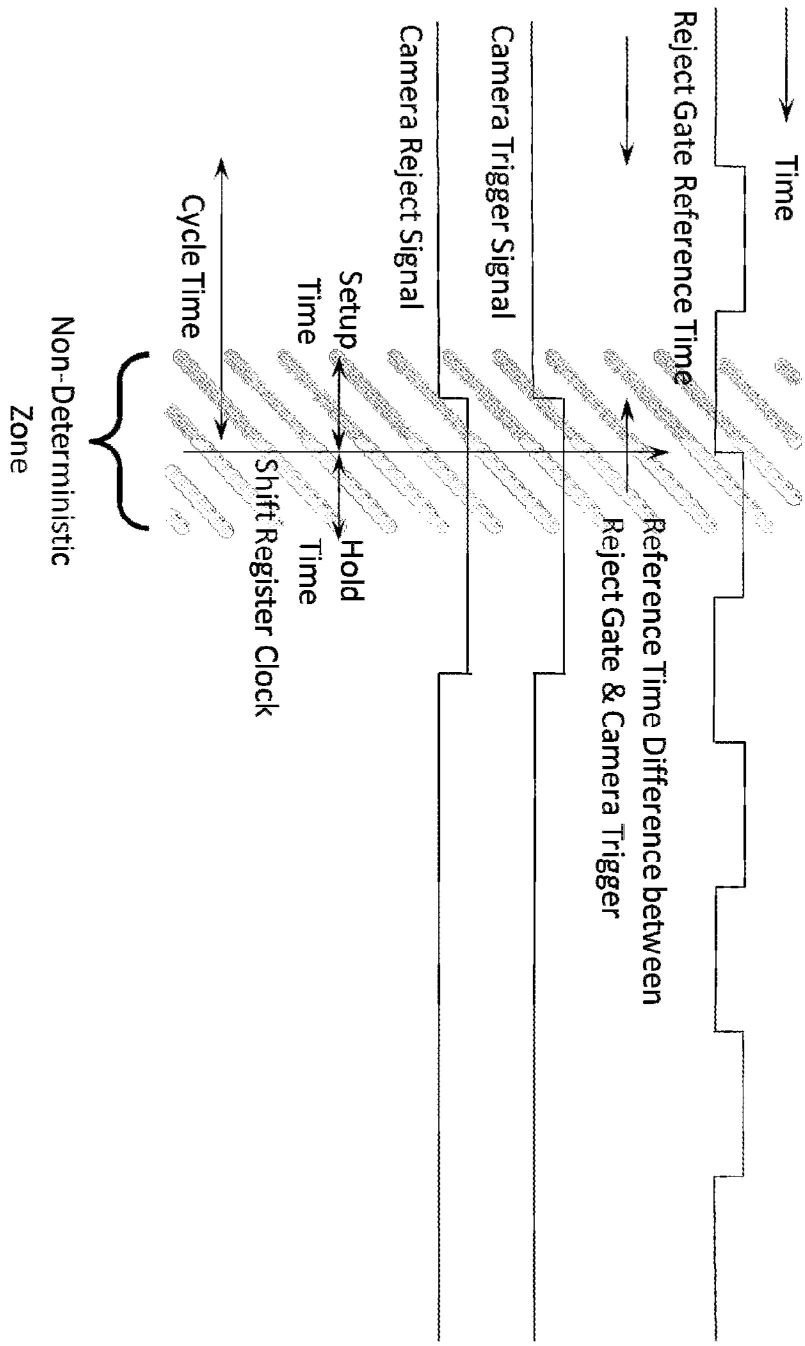

Figure 4. Camera Trigger Time Constraint

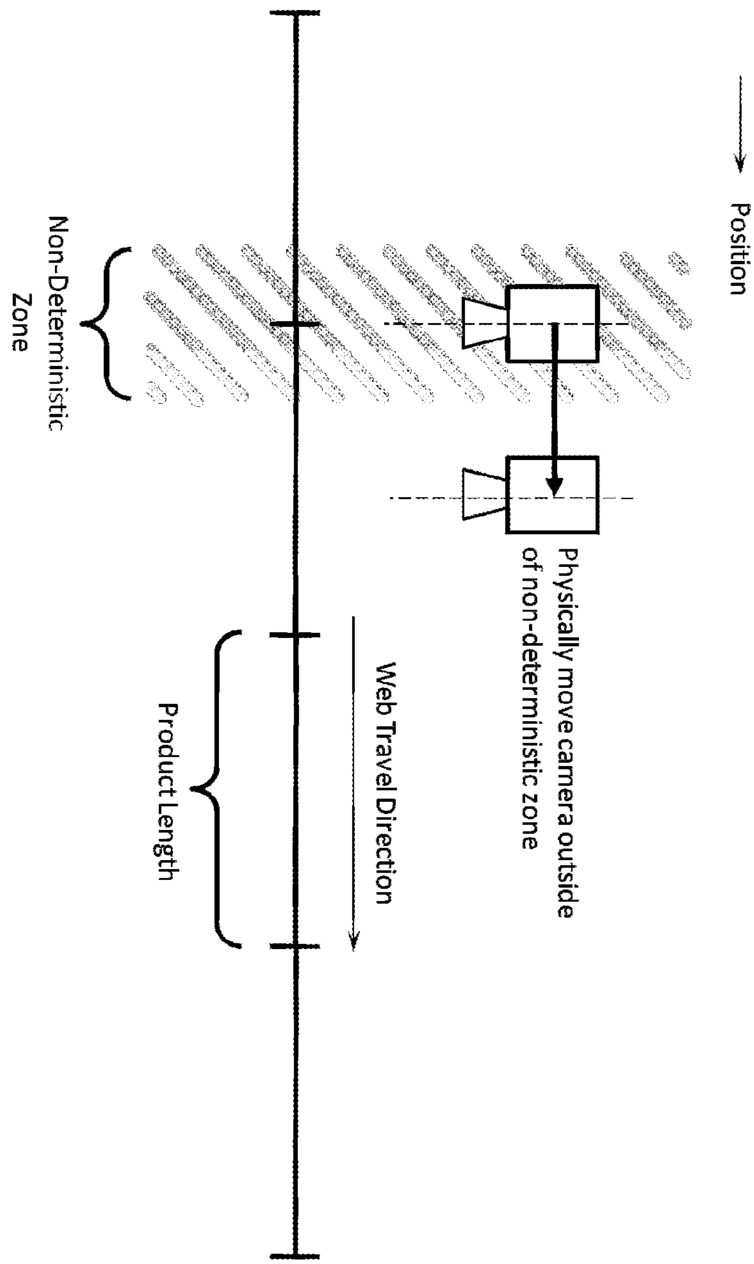

Figure 5. Reposition Camera to move reject signal out of non-deterministic zone. (Prior Art)

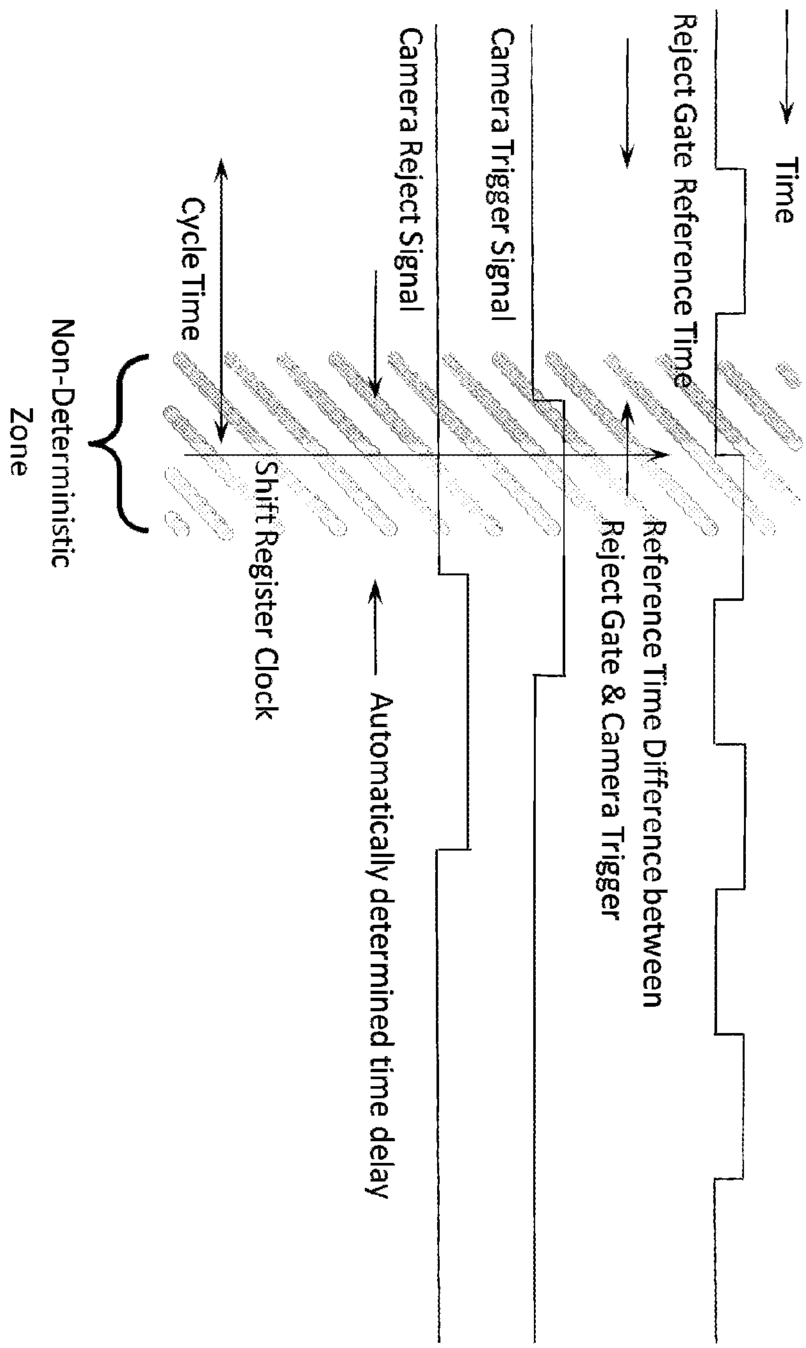

Figure 6. Automatic delay to move reject signal out of non-deterministic zone.

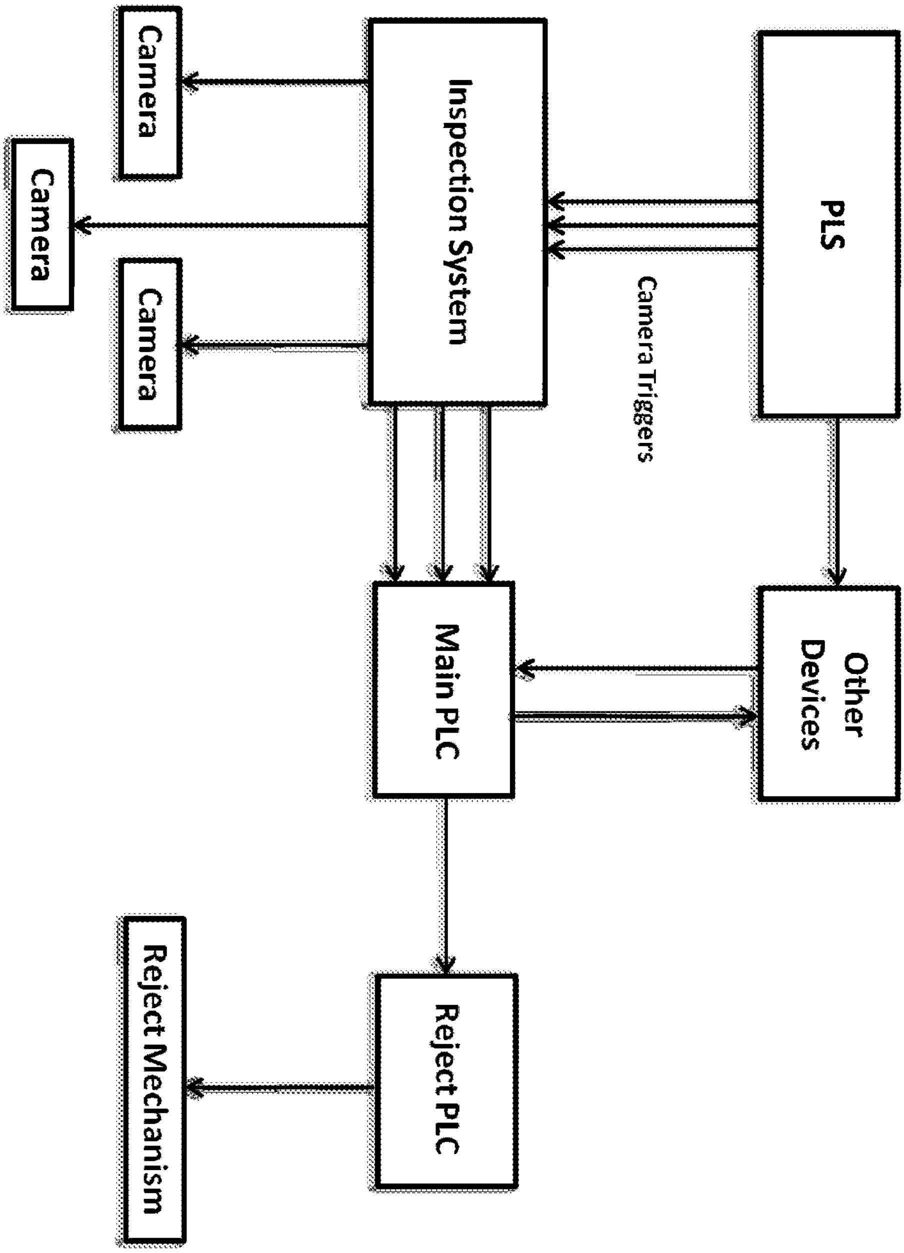

Figure 7. Typical prior art integration of inspection system and production line components

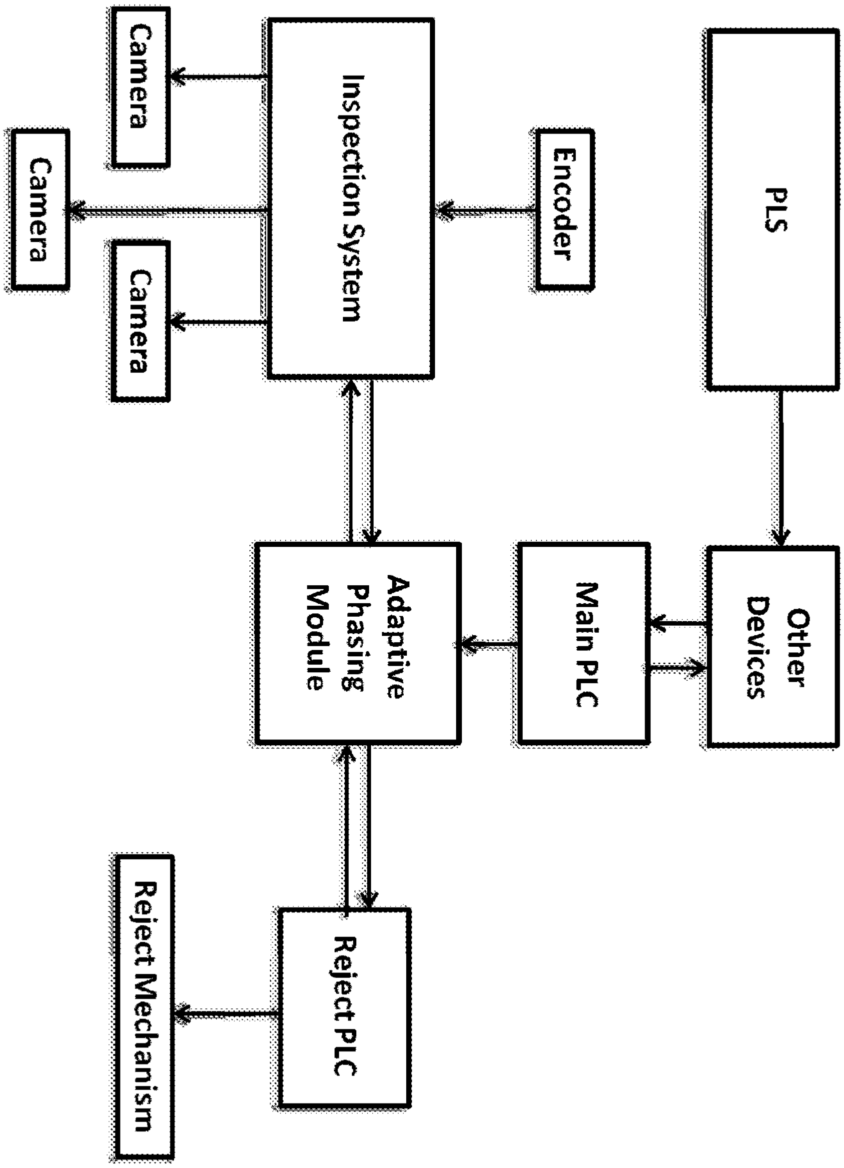

Figure 8. Proposed integration of inspection system and production line components

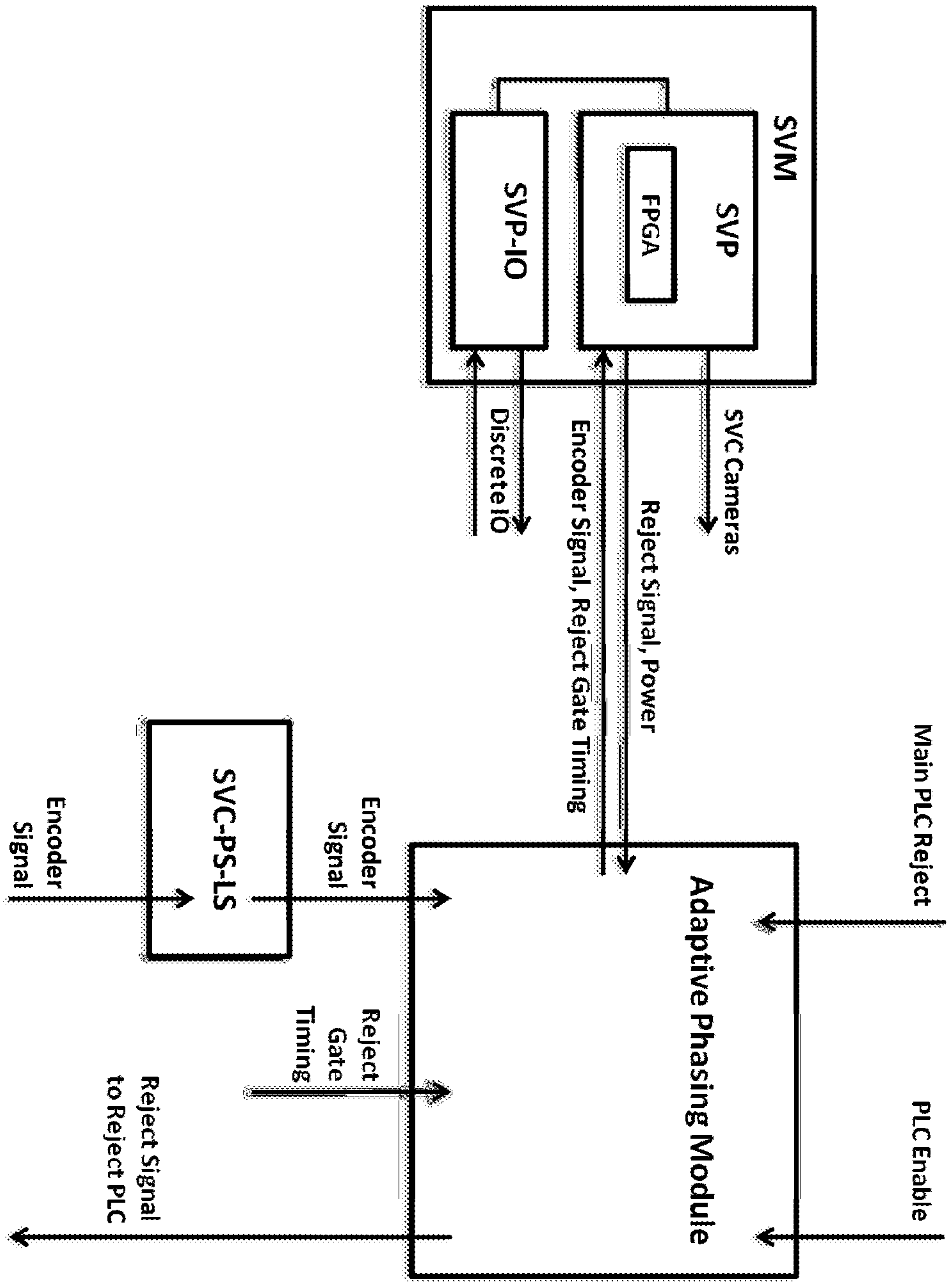

Figure 9. Detailed diagram of inspection system (SVM) and Adaptive Phasing Module

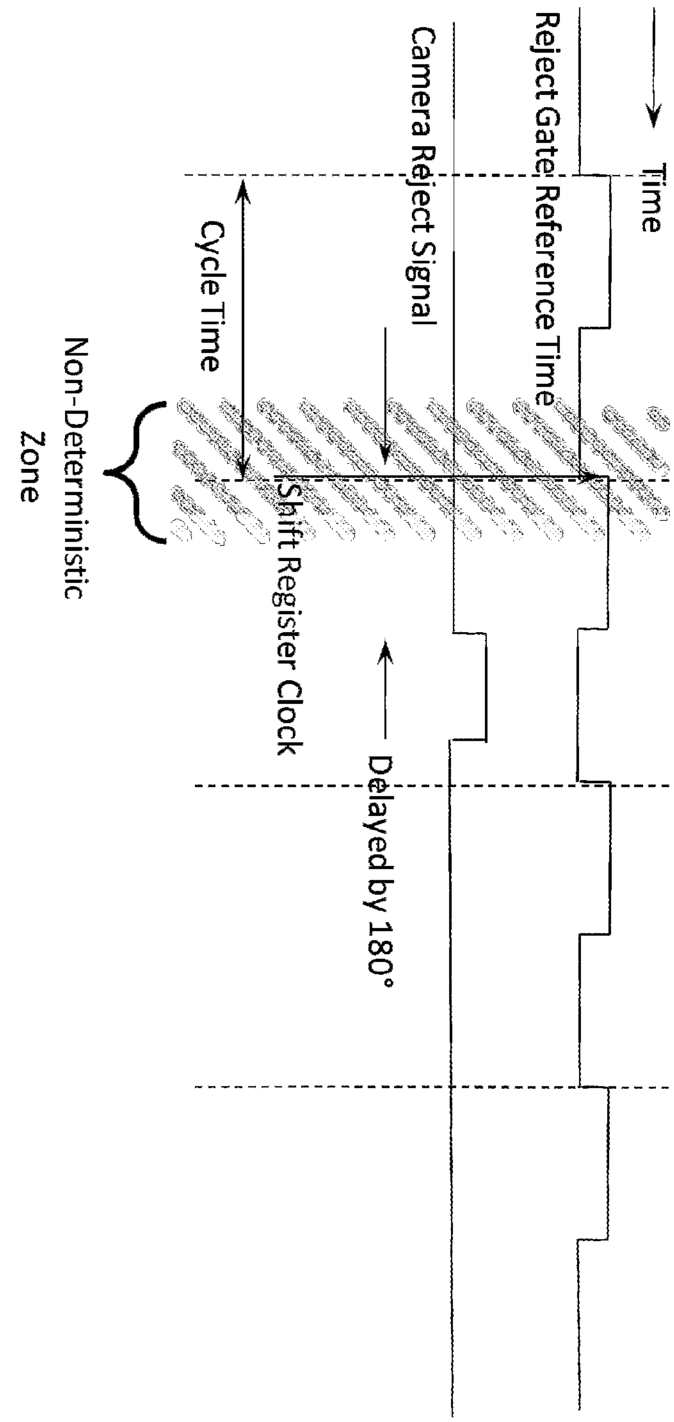

Figure 10. Required IO between SVM and Reject PLC for Single Culling system

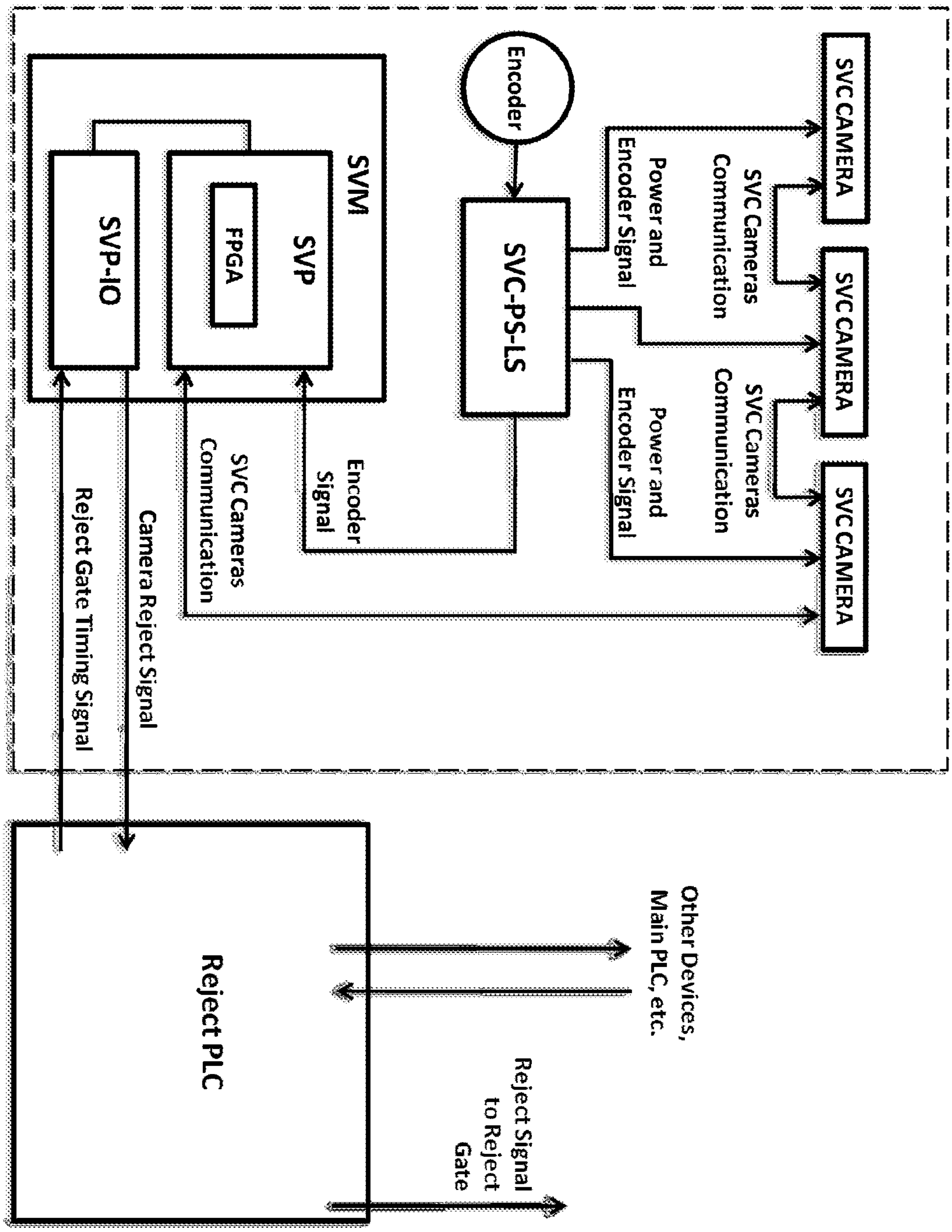

Figure 11. Block diagram of Machine Vision System integration with Reject PLC for Single Culling System

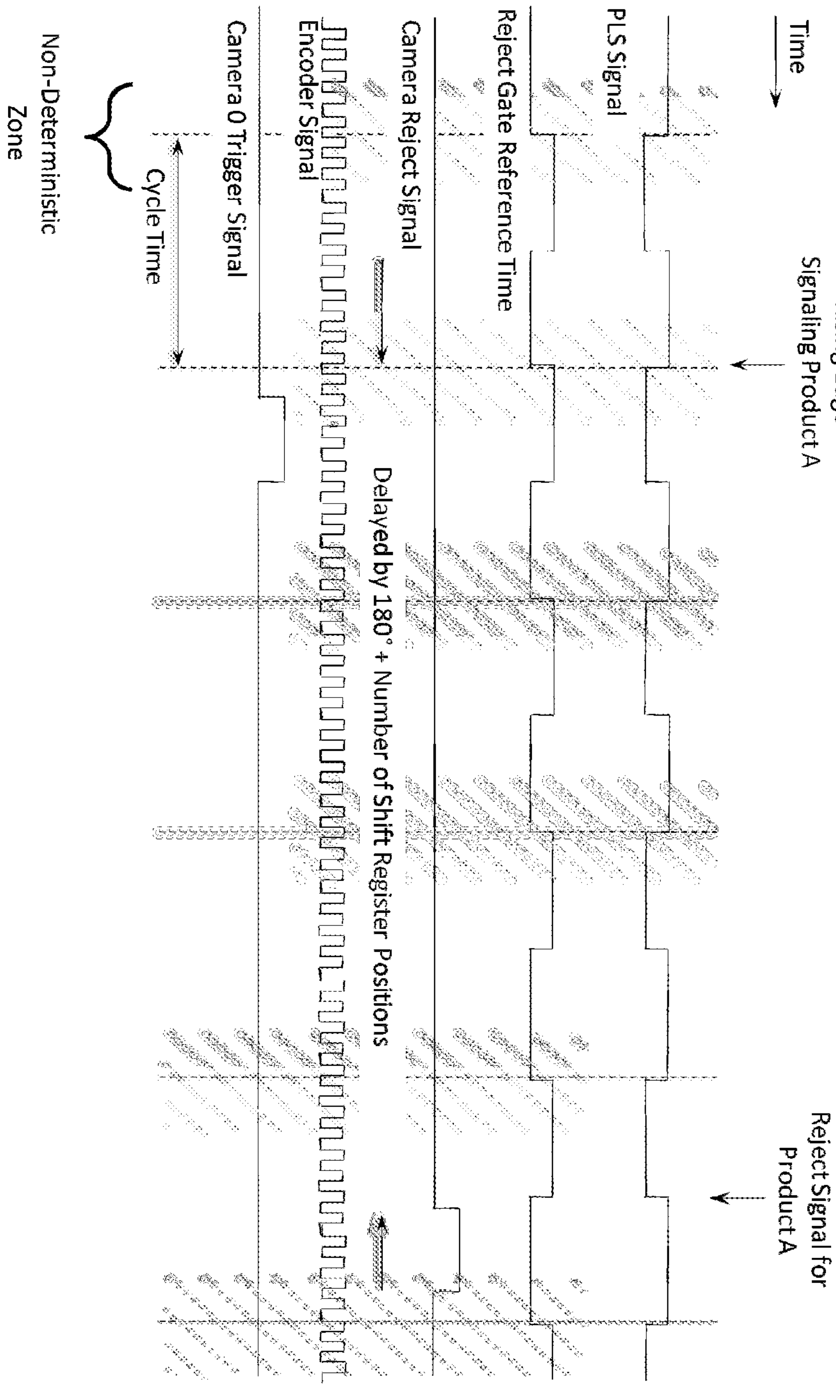

Figure 12. Timing chart showing camera trigger and reject sequence where machine vision system contains a shift register with three positions

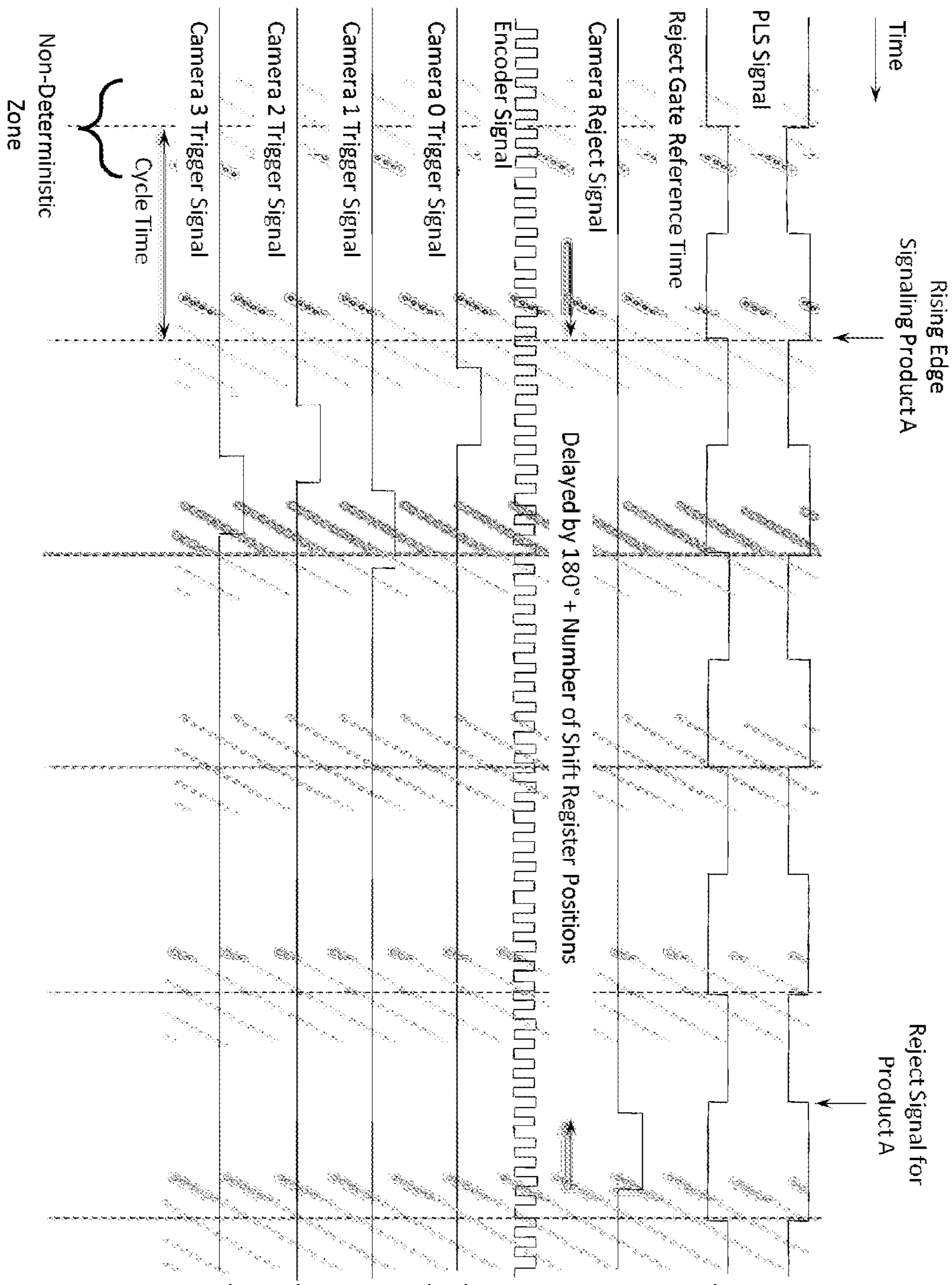

Figure 13. Timing chart showing multiple camera trigger and reject sequence where machine vision system contains a shift register with three positions

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/28709

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G05B 15/00, G05B 19/00 (2012.01)
USPC - 700/259
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): G05B 15/00, G05B 19/00 (2012.01)
USPC: 700/259

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 700/1,56,83,84,110,114,122,124,127,131,143,204,222,244,296 | 356/429-431 | 162/106,138,192,262 | 714/20,38.12,E11.085,E11.086,E11.088,E11.145,E11.18,E11.195,E11.196,E11.207 (view search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(PGPB,USPT,EPAB,JPAB): Google Scholar; machine vision system, FPGA, camera controller, defect, flaw, scratch, reject, production line, conveyor, shift register, camera, time, delay, signal,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 2005/0275834 A1 (SILVER) 15 December 2005 (15.12.2005) entire document, especially Abstract; para [0117], [0120]-[0127], [0132]-[0135], [0216]-[0218], [0366], [0423]-[0427]	1-7, 10-20 -------------- 8, 9
Y	US 6,473,169 B1 (DAWLEY et al.) 29 October 2002 (29.10.2002) entire document, especially Abstract; col. 4, ln 8-16	8
Y	US 2010/0092032 A1 (BOCA) 15 April 2010 (15.04.2010) entire document, especially Abstract; para [0048], [0082]	9
A	US 2008/0182008 A1 (SNOW et aL.) 31 July 2008 (31.07.2008) entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 July 2012 (12.07.2012)	24 JUL 2012

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774