INTEGRATION OF VISION SYSTEM, INTELLIGENT ROBO ACTUATOR, HMI AND PLC TO DESIGN A UNIVERSAL QUALITY INSPECTION OR CONTROL MACHINE

By

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ABSTRACT

In this paper, a universal quality inspection and quality control machine is presented. This machine is a fusion of different technologies such as vision system, programmable logic controller (PLC), Human machine interface (HMI) and Intelligent ROBO Actuators with other types of sensors. The electrical and mechanical design of the machine and plc program is illustrated in detail. Generally, inspection of raw materials or products at any stage in production or manufacturing or assembly industries may be done manually using measuring instruments, or by machines based on laser sensor technology, using probes, weighing scales, etc. Manual process is too slow and meant to test only few batches out of the entire lot which is less effective. Dedicated machines are usually confined to a single type of raw material considering specific property of the component. This option can be expensive when several different raw materials and product at any stage are to be tested at in-feed line. The proposed universal quality inspection machine is designed and implemented in the PLC lab at University of Bridgeport.

Keywords: Universal Quality Inspection or Control Machine, Cognex Vision System, Intelligent ROBO Actuator, Automated Quality Control Machine.

INTRODUCTION

In present times, for many automation industries in the light of highly, competitive and volatile markets, it has become necessary to introduce modularity, flexibility, interchangeability and high degree of modification in the manufacturing process. An inspection of a product or raw material before it goes for further processing, become more important now days due to reduce the rework, cost, and time [1]. In late 19th century, with increasing in demand for mostly use product, the mass production become necessary. Due to mass production, the quality of product became poor and some of the products came back for rework and so that inspection term become active. In early days, an inspection was done manually by human operator with specific skill set [2]. As the manual process was too slow, time consuming, and it was not 100% accurate all the time, also cannot perform precise, repetitive inspection for very small and dedicated devices or products. Machine tools was [1] invented to improve the assembly line with high speed and it was 1st used by Henry ford for production line [3].

As all manufacturing and production process become more assembled with high speed, it become more complicated for human to inspect the product or raw material [4]. The solution for this problem is Machine Vision, which provides innovative solution toward the industrial automation. Automatic inspection of the product or raw material is the most important area and there is a great diversity of applications [5] among others, delicate electronics component manufacturing, quality textile production, metal product finishing, glass manufacturing [6], machine parts, printing products and granite quality inspection. integrated circuits (IC) manufacturing and many others such as measurement of dimensions, counting of good or bad product, bar-code reading and so on. Quality is an integral part of the process of design, manufacture and assembly which is defined as the degree of excellence or fitness for use or purpose by considering

the most economical level [7]. The quality can be maintained by having different procedures and controls by inspection at various stages, which is the most useful for quality control and to reduce the scrap and reworks. Rework and scraps are the Major Industrial problems in United States. Any Industrial sector involve in manufacturing and later on assembling them always find loses when the ratio of rework and scrap rates go high.

For an industrial automation with automatic inspection of products there are some factors which we have to consider for choosing the inspection systems. There are lots of technique present now a days such as machine vision, computer vision, light beam, laser beam, optic sensors for the quality inspection and before you select inspection system consider the main three factors, cost, resolution and speed. In this paper we proposed a cost effective solution with high resolution and variable speed of inspection. The machine is built in PLC Lab, University Of Bridgeport and tested in real world application for detecting the good and bad part for different application. This machine can be used at any stage of manufacturing or production or assembling industries and ready to inspect any type of products or raw material with any size.

System Design

Today's advances in hardware technologies in addition with the development of standard processing platforms have made the production and maintenance of industrial automation system feasible at relatively low cost which needs such environments that are developed in short time and are adjusted to modifications of the manufacturing process must be simple to operate and maintain [4]. There has been lots of application vision system in industries for the inspection of products or raw materials. The main purpose or the goal of an industrial quality inspection and control is to monitor the industrial production processes and guarantee the good quality outcomes from it [8]. While all the industrial production and manufacturing processes are very high speed, mostly repetitive, dangerous and boring for the human operators. To solution for this problem is an automated quality control system which allows an accurate, often non invasive and standardized quality control. Figure 1 shows the layout of the proposed system in which the main components are Cognex vision system, Programmable logic controller, ROBO actuator, Human Machine interface and sensors.

The machine we designed is very compact and flexible so that it can be installed or implemented at any step of the production line or manufacturing processes as well in assembly industries too and can inspect any type of product of any size and any type by using Cognex vision system in real time. There has been lots of vision system and image inspection systems are available in the markets, also lots of paper has been published on the images processing inspection systems and machine vision but they are all lack in classifying the techniques [9, 10]. Also all those techniques are more time consuming and more costly than the Cognex vision system. Programmable logic controller (PLC) is act as a brain of the system and it controls all activities of the system, while Human machine interface (HMI) is used to monitor all the inputs and outputs in real time. Also through HMI operator can change the job selection and see the count of good parts and bad parts on it.

Figure 2 shows the system setup, signals from all sensors, actuator and air cylinders are connected to Inputs and Outputs of PLC. The advantage of having HMI is that, operator can also control and monitor the process at remote location by using LAN or Wireless network. By considering following factors we have proposed and

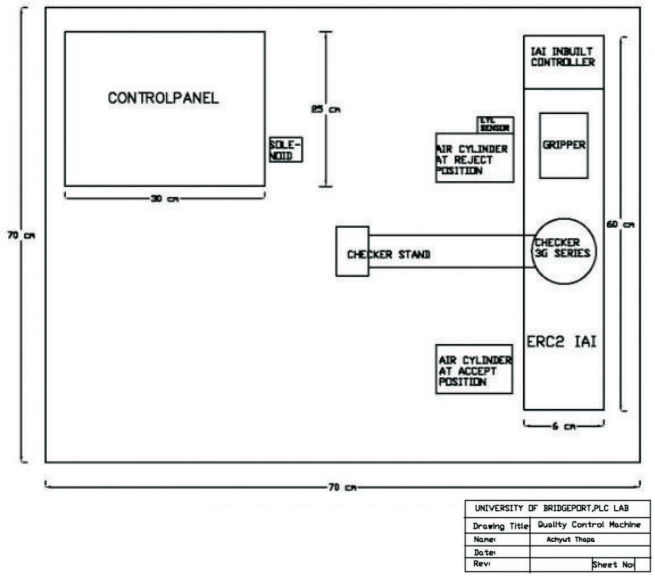

Figure 1. System Layout

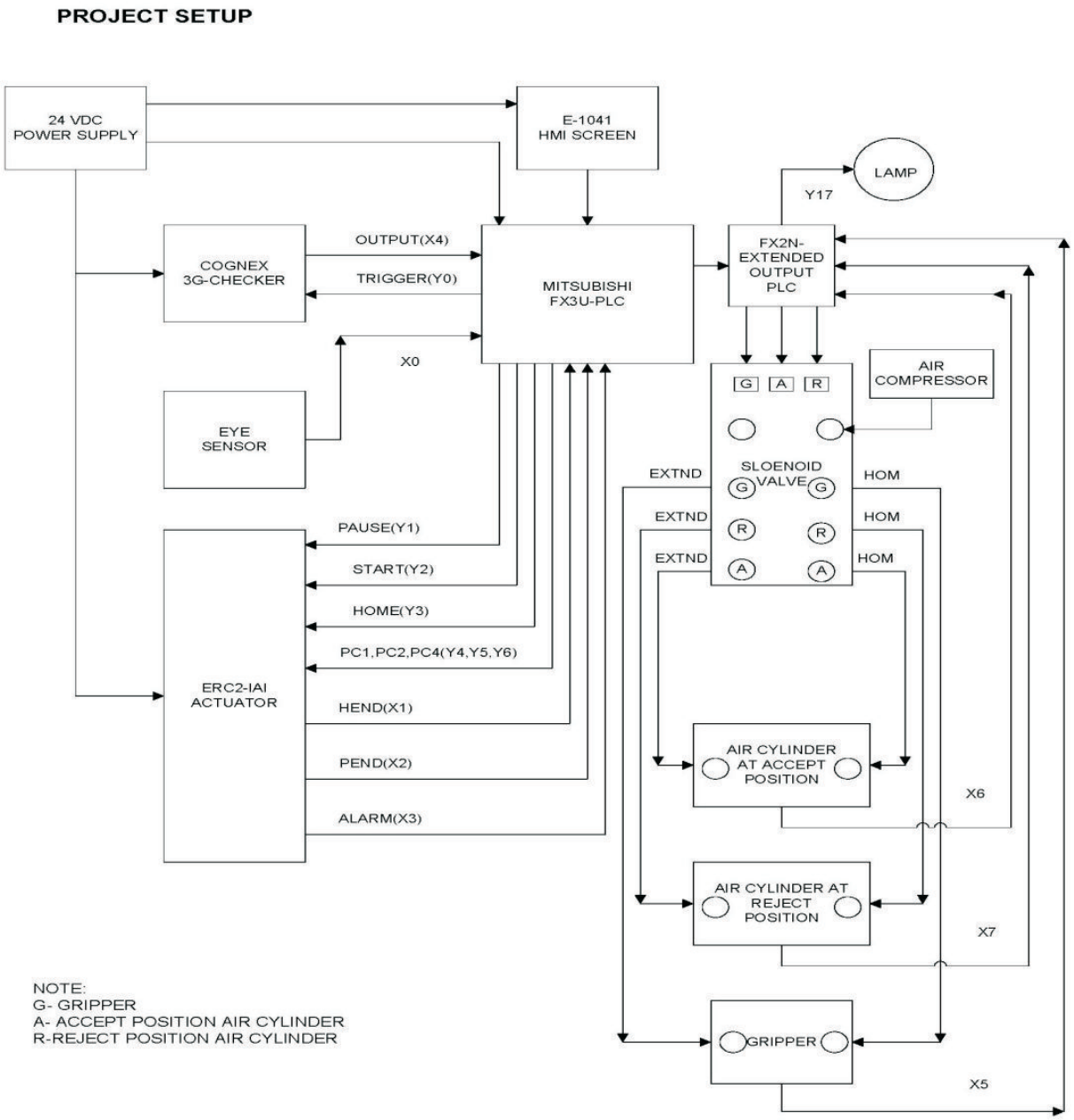

Figure 2. System Setup

designed the universal quality and inspection machine, which is very cost effective, robust and reliable as compared to the present image processing machines and machine vision systems.

- Acquisition of data (signals and images) from sensors and camera,
- Extraction or selection of a good or bad product from Cognex vision system,
- Decision making by the PLC as to move product or object to respective area,
- Classification of the situation defined by the designer or production of a measure or an index of quality.

The hardware consist 5 main components as follows

- Sensors and Actuator
- programmable Logic Controller
- Cognex Vision system
- RoBo Intelligent Actuator

- Human Machine Interface

In the following section each component is described in detail with their specification. In this machine, when any product or object is detected by eye sensor at loading station, then PLC will give signal to gripper for close. After that the ROBO actuator will start moving and will go under Cognex Camera for inspection, depending on the inspection result the actuator will go for respective area such as rejection or acceptance area. Air cylinders at rejection and acceptance area will unload the object or product from gripper as soon as they get the signal from PLC.

Sensors and Actuators

Photoelectric Sensor is used to detect presence of part at loading position, if it detects any part at loading position it will send high signal to plc.

Limit Switches makes ease to determine the position of gripper arms and air cylinder's piston. It helps to figure out whether air cylinder is at home position or at extended position, similarly for gripper it helps to determine whether gripper is closed or open.

Air cylinders are used for the purpose of pushing products outside from gripper at accept and reject position. We are using two air cylinders one at accept position and other at reject position each air cylinders have one limit switch at home position.

Gripper is used to grab any products at loading position after it is sensed by photoelectric eye sensors. We are using one limit switch for gripper at extended position to find whether gripper fingers are open or close. If the limit switch at extended position is ON that means gripper fingers are open if not gripper fingers are closed.

Solenoid Valve provides access to air supply for gripper and air cylinders from air compressor. It takes signal from PLC and turns switch ON and OFF according to the logic. If switch at solenoid valve is ON it access the air supply for designated actuators to which air tubes are connected. Each switch controls two air tubes one for supplying air pressure to extend actuators and other for extracting air pressure to retract actuators.

Programmable Logic Controller

In the era of advance technology, there has been lots of other devices which are used as a controller of the system among them Programmable logic controller (PLC) is the most economical, reliable and easy to operate controller. In the machine vision inspection system, PC and CCD cameras are used for inspection and controller of the process. In their machine the authors are using Mitsubishi FX-3U series plc as a controller of the system with an output extension card. The new FX3U series is the third generation of Mitsubishi Electric's successful compact PLC family. Developed for the international market, the new controllers feature a special second "adapter bus" system, which complements the existing system bus used for expansion, special function and network modules. Up to ten additional modules can be connected to this new adapter bus. The FX3U controllers also impress with their speed (0.065μs per logical instruction), a significantly larger instruction set with a total of 209 instructions and improved functions and modules, particularly for positioning tasks. Other improvements include enhanced communications capabilities with Ethernet, USB and RS-422 mini DIN connectors. The enhanced networking support has also increased the I/O capacity of the new flagship model, which can now be expanded to a maximum of 384 I/Os, including networked connections.

Advantages of the FX3U at a glance

Safe investment : Fully compatible with the existing MELSEC FX series; IEC 61131-3 standard programming; plenty of reserves for later updates

Tailored configurations : Choose from a comprehensive range of products for positioning, analog signal processing and communications

Powerful positioning control: Internal high-speed counters and pulse outputs (100kHz) in all base units, new counter and pulse output adapters (200 kHz), bus-capable servo system for controlling up to 16 axes with data transfer speeds of up to 50Mbps

Fast installation and configuration : 209 ready-to-use instructions

Integrated automation : Modules, functions and instructions are all precisely geared to Mitsubishi automation technology

Outstanding value for money : The performance of a medium-scale PLC system for the price of a micro PLC

Specifications For FX3U-16M PLC

Power supply: 24 V DC / 100-240V AC

Integrated inputs: 8

Integrated outputs: 8

Input / Output response: Approx 10 ms

Output type: Relay / Transistor (source type)

Program Cycle Period: 0.55-1 us

Power consumption: 25 W / 30 VA

Weight: 0.6 LB

Dimensions in mm (WxHxD): 130x90x86

Memory: 32K steps EEPROM.

Software: GX Developer.

USB port and Ethernet Connection

Cognex Vision System

Vision systems play an important role in inspection of products or objects, although in the market or in industrial lots of inspection systems are available. Visual inspection of products and parts or raw material by the naked eye is more time consuming, tiring, inaccurate, and they are more costly [11]. from last two decades machine vision has been applied in manufacturing and production processes to improve the quality and productivity by using cameras and pc's which improves in precise, fast, efficient and objective inspection [12]. However high speed, high quality and high resolution application requires innovative, customized solution is outside of the scope of standard percentage of shelf system [13]. In this survey paper lots of inspection techniques has been discussed for different application, but some of the technique required pc for inspection and some of them required image processing modules which increases the cost of system. Cognex vision system on the other hand is very easy to use and no need of any extra modules as it comes with checker sensor with built in camera, processor, lighting, optics and I/O capable of detecting and inspecting up to 6,000 parts per minute. These checker sensors help to reduce the production costs and optimize quality [14]. The new 3G Checker series of vision sensors from Cognex provides the easiest and most affordable way to verify the products you manufacture. Checker vision sensors offer extremely reliable part detection and inspection unattainable with photoelectric sensors. Following are the major benefits that industries can own from this idea implementation.

- Reducing downtime and maintenance and scrap ratio.
- Providing easy setup and maintenance by factory personnel
- Simplifying the overall system design
- Displaying and recording images
- Eliminating the need for costly fixture
- Eliminating PLC programming
- Replacing multiple photo electric sensors with fewer industrial sensors

Hardware Specifications

Table 1 shows the hardware specification of Cognex Vision camera, The vision sensor will be auto-handshaking with PC by USB port. A user can find the sensor on the connection list and create a new job. It can change the brightness and direction of parts travel.It also can change the speed and trigger input delay. The basic idea is setup a image and decides it as a part at first. The sensor receives a part then compare the shape or length with preset image or scale. The vision sensor need installation with angle to get better result. The old tradition system didn't have these features to verify the object is correct and then inspect it for further

Cable	24AWG, 5 m, M12 connector (power and I/O)
Power Requirements	Voltage: +24 VDC (22-26 VDC) Current: 250 mA max
Discrete Inputs	Input ON: > 10 VDC (> 6 mA) Input OFF: < 2 VDC (< 1.5 mA) Protection: Opto-isolated, polarity-independent
Discrete Outputs	Output: Solid state switch Rating: 100 mA, 24 VDC Max Max voltage drop: 3.5 VDC @ 100 mA Max load: 100 mA Protection: Opto-isolated, protected from short circuit, over current and reverse polarity.
24V Power Fuse	500 mA, 60 V rated resetable fuse that will recover after an overload is removed. Protects against over voltage , reverse polarity
Output Fuse	200 mA, 30 V rated resetable fuse that will recover after an overload is removed. Protects each output from over current.
Weight	3.5 oz. (100g)

Table 1. Hardware Specification

more levels to make sure that it is not defected. But now Cognex has all these features to take care. The electrical connection or wiring diagram of Cognex vision camera is as show in Figure 3.

In this camera, there are two personalities in the option, persence and meansurement which mean you can set an images for good part by two ways and stored them on camera memory. In presence mode a user can set up an image by mean of Contrast, Brightness or Pattern i.e. Presence Sensors: Presence Sensors evaluate part of a Checker image to determine if a feature is present or not and in Measurement mode inspection is done by length, width and diameter i.e. Measurement Sensors evaluate part of a Checker image to determine if a feature is within a specified size range. In this proposed machine we have tested Cognex vision camera on real product such as Purell Hand Sanitizer bottles for checking the presence of label, distance between two pins in Relay, diameter and presence of threads on nuts, presence of pins on USB connector, and presence of specific design and logo on greeting cards. This inspection machine or the Cognex vision system is so simple and easy to set up, even a first time user can also have it and run it in less than minute [14]. The Checker Part Finding Sensor has three important advantages

- Detects a part by locating a feature on the part, not just an edge
- Tracks parts in varying positions along the production line, overcoming imprecise part positioning

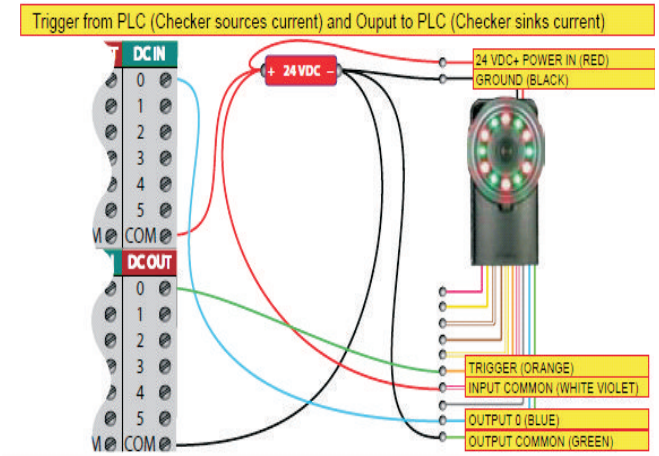

Figure 3. Cognex Wiring Connection

- Does not require additional sensors to determine if a part is present

ROBO Intelligent Actuator

ROBO Intelligent Actuators are the electrical actuator, electromechanical alternative to the Pneumatic actuator. These cylinders are more flexible than the Pneumatic actuators, intelligent in nature and also economical. As lots of process and manufacturing industries uses conveyor belt for moving of the product from one station to another station, but the problem with that conveyor line is to control it and its high cost as well as to stop them at exact position is not possible. mention the Hough transform methods used to position and area selection for inspection which requires the matlab software and pc to control the process, the cost of this setup is more than the ROBO cylinder. used the Micro-gripper robot for inspection of small sized product, but in practice an accuracy of the Piezo actuators is limited by the measurement noise of the control system and calibration of the sensors. In our proposed machine, the ROBO actuator has a gripper which can be able to hold the product of any size, any shapes. This actuator has the following characteristics over the pneumatic actuators,

- Uses low power consumption
- Used for multiple positioning with precise movements
- $\pm$ 0.02 mm repeatability
- Easy programmable velocity control
- Also programmable acceleration and deceleration
- Also present with push torque function control mode
- With wide range of Stroke length – 50mm to 1000mm
- With different speed depend upon the different model
- Serial input/output linking up to 16 different axes

These actuators are available with wide types of configuration to fit your application. We are using ERC2 type of actuator for this application. The actuator has build-in controller with servo motor for position, torque and speed control mode. The build-in controller reduces the wiring to connect with PLC as well as reduces the panel board size i.e. no need to be install the controller separately.

Specifications

- Controller (PIO type-NPN specification)

- Simple control type pulse motor
- Maximum Positioning Points: 16
- Input Power Supply and Capacity: 24 VDC ± 10% (2 A max)
- Lead: 6 mm
- Maximum load Capacity (Horizontal): 12 kg
- Maximum load Capacity (Horizontal): 3 kg (appx.)
- Load Type: Four tapped holes
- Stroke: 50-600 mm
- Drive Method: Ball screw 10mm, rolled C10
- Positioning Repeatability: ±0.05mm
- Backlash: 0.1mm or less
- Ambient Operating Temp/Humidity: 0-40 °C, 85% RH or below (non-condensing)
- When the stroke increases, the maximum speed will drop to prevent the ball screw from reaching a critical speed.
- The ERC2 series uses a pulse motor, so the load capacity will decrease as the speed increases.
- The load capacity is based on operation at an acceleration of 0.3G. This is the maximum acceleration.

As mentioned in specification, these intelligent actuators are able to move 16 different précised movements with push-pull force if required also with built in controller capability we can store the positions [17] in it. By using this actuator you can achieve positioning of up to 1,500 points and a repeatability of ±0.02mm as well as they are also capable of stopping at any point of the stroke during operation. As the demands for high quality with low cost products is increasing day by day and to achieve such thing in real world is very hard by considering its effect of environments too. IAI ROBO Intelligent actuator provided the solution for this problem by environmentally friendly, saving money in electricity and increase in production ratio. It also reduces the labor cost and they are easy to set up and maintenance.

Human Machine Interface

Human Machine Interface (HMI) provides user to control and monitor the processes at the factory floor or on remote location through LAN or WAN. An operator can interact and adjust the system without connecting to a control system or completing complicated system programming by using HMI. The HMI is designed so that it is very simple for operator to view counts, set tolerances, set different jobs or images into camera according to the requirement and adjust the camera setting for different size and shape of the products and objects. The HMI also provides log in access control to prevent unauthorized personnel from altering the system and includes detailed product counters for data collection and trend estimation. In proposed universal quality inspection and control machine, MITSHUBISHI E1040 SERIES HMI is used. Their outstanding features include: state-of-the-art processor technology for maximum data security and handling really complex applications, high-resolution TFT displays with 16 grayscales or up to 65,536 colors, new ergonomic design, comprehensive communications support and extremely easy connectivity with a full range of interfaces and ports. Key features include

- Simple ergonomic design, with Explorer type buttons for easier use
- Tough Aluminum casing - stands up to the industrial work place
- Bright TFT display with high resolution and 16 grayscales or 65,536 colors
- New high performance Intel X-scale CPU with Windows CE.NET
- USB host and device interfaces
- Compact flash slot for file transfer and data storage

Specification Of E1041 HMI

- Display Type and Size: TFT, 3.5"
- Resolution/Pixels: QVGA 320 x 240
- Colors AND Input Type: 65K TOUCH with 20/22 LED/ Function keys
- Alarm Function: 7 – 11 groups
- FLASH Memory: 12 MB
- Serial Ports: RS232 (9-pin DSUB), combined RS422/RS485 (25-pin DSUB)
- Ethernet: One 10/100 Mbit TP-port

- USB Host: One port for printer, keyboard, mouse, scanner.
- Housing / Front Material: Cast aluminum
- Power Supply: ±24 VDC (20 - 30 VDC)
- Dimensions (mm/inch): 155.8 x 119 x 6 (6.1 x 4.7 x 0.2)
- Weight (kg/lbs): 0.56 (1.23)
- Max. Current Draw Min. (Max.): 0.15A (0.35A)
- Ambient Temp V (H): 0 – 50°C (0 – 40°C

Method of Inspection

Figure 4 shows the flow chart of the inspection procedure for proposed universal quality control machine.

Initially all cylinders and actuators are at home position and Gripper will be open. User or operator will decide which product or object is going to be inspected and after that from HMI the selected job image will be loaded into Cognex Vision Camera. Once sensor detects the presence of object or product into gripper, plc will give command to gripper for closing of gripper. Once the limit sensor determines the gripper is closed, it will signal to PLC and PLC will give command to ROBO actuator to move under the Cognex Vision Camera for inspection of different attributes set by user or operator in it. The Cognex vision camera has two outputs which are connected to the PLC, according the bits or signals receives on it, if it is good product, will go to packaging or accepted area and if it is bad product or missing some attributes in it, and then it will go to rejection area for rework. And Air cylinders at accepted and rejected area will remove or unload the product out of gripper depends on the signal send by PLC.

Conclusion

If comparing to the current inspection systems, the proposed Universal Quality Inspection and Control system implemented and described along this paper can be adapted and used at any stage of the production and manufacturing processes for different types of shapes and size of product inspection with minimum effort. It is a

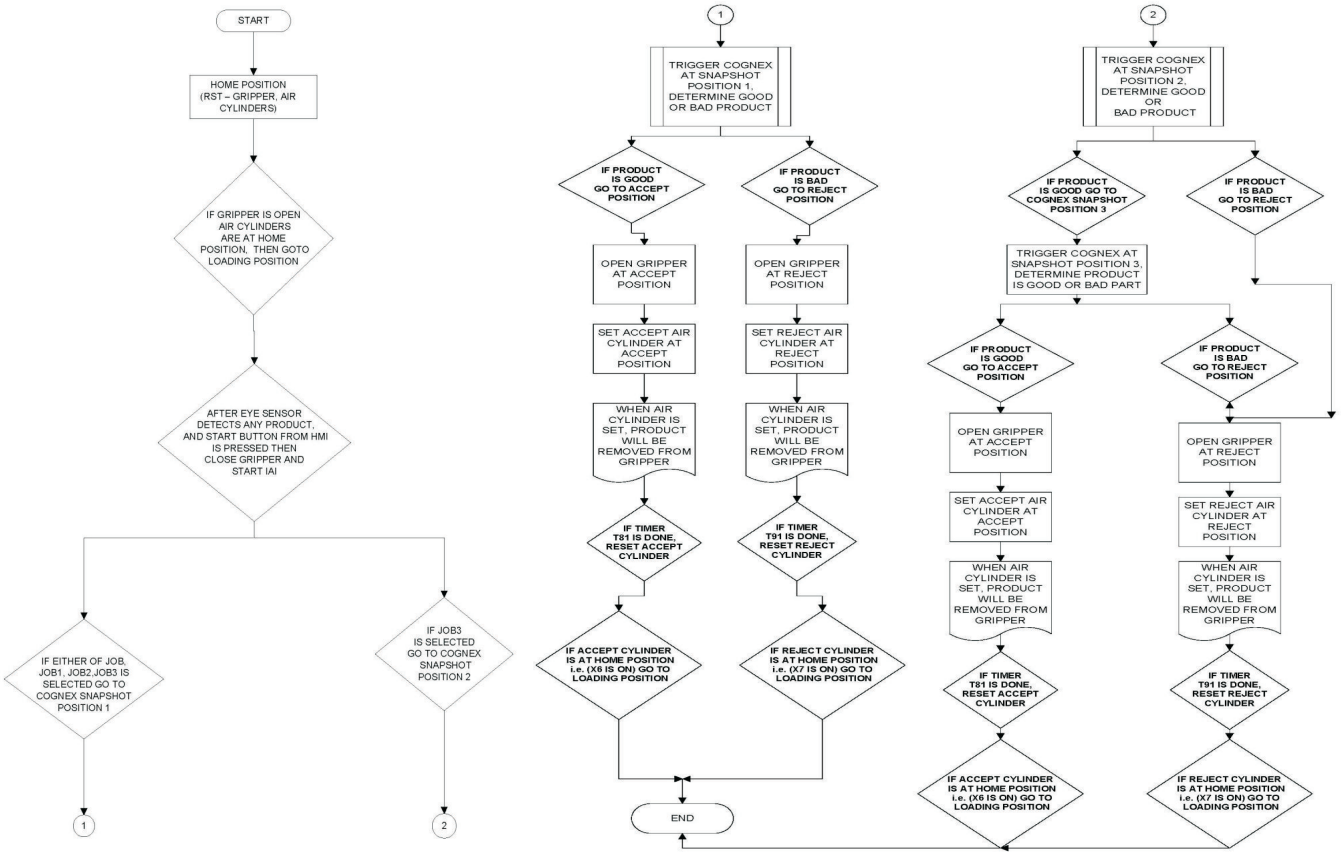

Figure 4. Process Flow Chart

robustness system, which avoid a huge number of problems associated to a malfunction with very precise movement. It has high-speed inspection rates, environmentally friendly and it is a cost-saving system, thank to the reduction of repetitive work and loss associated to this that it offers. The application of commercial industrial elements to each module of the system decreases development times and, most of all, allows and standardization of each used part.

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