Distributed Inspection System: The Next Level in Packaging Line Inspection Automation

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ABSTRACT

Brewers are renowned for constantly striving to ensure the quality of their packaged products all the while steadily increasing operating efficiencies and reducing the costs incurred by poor quality. To this end, new quality verification solutions and advancements are regularly being tested and integrated into the existing inspection strategies. These in turn provide greater amounts of information from which to effect process improvements. Unfortunately these advancements may result in the addition of new inspection stations, and their related hardware, onto crowded packaging lines and, as these systems are usually not harmonized with the brewery’s process control environment, they represent added demands on the Operation staff to setup and monitor.

The Distributed Inspection System (DIS) is our vision of how quality inspection equipment can best help brewers meet this challenge. It is comprised of:

• Smart, vision based, multi-point inspection stations,
• Universal access to quality, alarm and event information as well as system parameters through industry standard communication protocols and tools,
• An open-door environment allowing the brewery to take advantage of best-of-class third party software and hardware tools.

This technical paper describes the efforts undertaken and to be taken in completing the DIS. It is hoped that others will adopt this philosophy and open up their systems so that simplicity can be achieved through the use of industry standard communication protocols and software tools.

This vision derives from experiences acquired in the process control, networking machine vision and intelligent software fields and represents not so much a single product as it does a technology alignment with these.

Keywords: inspection, multi-point inspection, communication, quality, networking, information, machine vision

INTRODUCTION

It is believed that the Distributed Inspection System (DIS) is the next level in packaging line inspection automation due primarily to its open environment and adherence to globally accepted standards. Nevertheless the question of utmost importance to brewers is: “How will this approach help keep costs down and ensure high quality?” The following pages describe how the DIS methodology can help simplify line layouts, and the associated costs, reduce manpower requirements, increase
access to quality information for a more efficient process, provide integration to best-of-class tools and help brewers become independent.

This program started with a simple concept: Make the inspection environment (communicate like) a Programmable Logic Controller (PLC). That is, provide the ability to connect to the Instrumentation Bus using industry standard PLC communication protocols, creating not only a data stream but also access to the configuration, limits, set point and alarm parameters. As with PLCs, the brewer can then select a third party tool of his/her choice to: gather, archive, massage and present the information as well as adjust the parameters to current product and process requirements.

Additionally, it was felt that Ethernet based Transmission Control Protocol / Internet Protocol (TCP/IP) connectivity was necessary as it provides ready access to information via Enterprise Wide Networks and Intranets.

The concept was further refined with ideas borrowed from Distributed Control Systems (DCS) whereby the individual inspection stations are rendered as capable as possible with the use of advanced software. Also, a multi-point vision based inspection strategy is used to help simplify line layouts and provide inspection strategy adaptation capability through the addition of software and/or hardware modules.

This technical paper describes the program’s mandate, touches briefly on current practices and technologies and goes into details on the development stages.

**DIS PROGRAM’S MANDATE**

The program’s mandate is comprised of five key objectives:

Provide access to best-of-class tools:

- Create an open-door environment to help brewers take advantage of third party best-of-class tools.

Facilitate process optimization efforts:

- Integrate real-time quality information into the bottling line’s control environment providing the operator and the control platform more information from which to optimize the process.
- Use vision-based multi-point inspection stations to increase the amount of quality information available from a given location, helping the Operator identify and correct process anomalies early.
- Provide the operator a global view of the packaging line’s quality performance to assist proactive quality practices.

Reduce manpower costs:

- Centralize access and control of the inspection stations reducing the demand on the operation staff to manually setup and monitor these stations individually.
- Normalize access and control of the inspection stations with a brewery’s process control platform removing the constant need for specialists when working with these stations.
- Use industry standard tools and procedures so that support services can be available from a number of sources. This will encourage brewery independence and the need for premium labor.

Simplify packaging lines and the future addition of inspection functions:

- Use multi-point inspection stations to minimize the number of inspection units (and their associated hardware and conveyor runs) present on the line, simplifying line layouts and reducing:
  - The number of components which can fail.
  - The overall cost of station installation and maintenance.
  - Production floor space requirements.
- Design the multi-point inspection stations in such a way as to facilitate the easy expansion of inspection functions through the addition of software and/or hardware modules.

Simplify packaging line operations:

- Use a centralized monitoring and management window to simplify startups as well as brand and container changes. This will reduce changeover time and manpower requirements.
- Operator screens must be configurable by the brewery’s personnel so that information and access can be provided where and how it is needed without recourse to external services.

**REVIEW OF CURRENT PRACTICES**

Generally speaking, brewers are just beginning to link quality inspection information into their networks, while inspection station adjustments, such as inspection head positioning and limit settings to adapt to brand or container changes, are done at the station. At the same time, inspection equipment suppliers have made strides to provide, if not access to the system parameters, at least access to the data. Also, Supervisory Control and Data Acquisition (SCADA) and Statistical Process Control (SPC) environments are evolving rapidly as are other plant management tools. The DIS Program’s goal is the harmonization of the online quality inspection systems to these management tools by adopting the connectivity strategies used by the process control world to transfer data and manage the inspection stations.

**TECHNOLOGIES USED**

**REAL TIME DISTRIBUTED OPERATING SYSTEM**

A real time kernel was selected as the Operating System (OS) since it offers:

- Real time control of the Input and Output (I/O) points;
- Memory protection for all processes;
- Mission-critical control;
- Robustness;
- Hot fail-over;
- Sockets-based TCP/IP connectivity;
- Scalability and resource sharing.

**MACHINE VISION**

Definition - The use of devices for optical non-contact sensing to automatically receive and interpret an image of a real scene, in order to obtain information and/or control machines or processes.
In this application, machine vision is further evolved with post processing of the images to improve image resolution as well as complete the visual patterns and eliminate distortion.

**TEMPORAL REASONING**

Temporal reasoning is the drawing of inferences or conclusions from known facts that are limited by time.

In this application, temporal reasoning is used to adapt to process and product variations in a continual self-tuning mode.

**HEURISTIC RULE PROGRAMMING**

A heuristic rule is an assembly of the knowledge that a human would use to understand, formulate, solve problems or make decisions in a particular domain. These are the rules that direct the use of knowledge and handle the complex relationship between facts.

**FUZZY LOGIC**

Fuzzy Logic is precise reasoning about imprecise concepts. For example, this allows one to define a concept, such as percent reject, as a set point, or objective, with the system dynamically adjusting itself to try to meet the objective while making quality assessments despite it.

**MATHEMATICAL AND STATISTICAL MODELS AND ALGORITHMS**

These are computer representations of the interrelationship between variables and/or parameters. Mathematical models employ individual data points while statistical models use data direction and tendencies.

**DEVELOPMENT PHASES**

**DESIGN SUMMARY**

The DIS is being developed in phases starting with a full function inspection platform from which derives traditional inspection stations with vision-based multiple point inspection capabilities. The inspection platform facilitates the creation of additional multi-point inspection stations as well as eventual virtual inspection stations.

The next phase encompasses the design and development of the Supervision and Distribution Functions. These are the functions involved in Instrumentation Bus, Wide Area Network (WAN), Local Area Network (LAN) and Intranet communication as well as data management and information presentation.

**INSPECTION STATIONS**

**INSPECTION PLATFORM**

The first step was to develop a rugged platform that would be the basis for specific, practical inspection stations. The platform had to be modular enough to allow future evolution of the solutions and include the advanced tools and connectivity necessary for the next phases.

**PLATFORM ARCHITECTURE**

The platform is a compilation of advanced hardware and software modules described in the following groups:
Platform Topography

The following sketch highlights the platform’s topography and its components. At the heart of the platform is the real time distributed Operator System (OS). Also, the platform’s communication structure provides the ability to link multiple inspection stations together, add remote inspection heads and a file server as well as communicate with an Enterprise Wide Network via a TCP/IP protocol.

Multi-Point Inspection Stations

The inspection heads were designed in such a way as to facilitate their being positioned at the optimal keypoint locations on the line. This necessitated a small headspace, non-contact functionality and a combination of sensors to track containers and ensure that desired actions occur. Also, vision technology was adopted as it allows the possibility of concurrent multiple measurements. This increases the amount of quality information

FIGURE 3
Platform Topography
possible at any given location, reducing line disruptions and allowing for future expansion of the system with the addition of proprietary software components and/or inspection head(s) onto the base units.

To ensure reliability, the station incorporates maintenance and calibration functions, quality performance alarms and system auto-checks. All of these are accessible, via the DIS communication structure, by the centralized operator interfaces.

Also, provisions have been made for future additions of functions such as auto sampling and automated inspection head positioning. These will be accessible by the centralized operator interfaces.

Intelligent tools complete the solution by adding accuracy, adaptability to process and product variations and reasoning capability.

The following sketch is of the generic Multi-Point Inspection Station. Each station can be equipped with multiple inspection heads (comprised of cameras and light sources), a central processing unit, a touch screen operator interface, a multiple ejector controller, an Ethernet connection and a modem. The latter items are used for centralizing data, linking inspection stations together and remote troubleshooting.

Location of the current and anticipated key-point inspection stations are based on the generic design. These are currently rated at 1200 bottles per minute without loss of accuracy.

FIGURE 4
Generic Inspection Station

FIGURE 5
Inspection Stations Located on the Packaging Line
Pre-Filler Inspection Station (in development)

This station will have the ability to link to an existing EBI for bottle ejection. Inspection functions:
- Scuffing
- Bottle sorting

Post-Crowner Inspection Station (Some functions are in development)

This station can identify filler and crowner head sequence. Inspection functions:
- Filler valve monitoring: bottle breakage, auto flush and head sequence with trend and fault identification (in development)
- Foreign crown identification (available)
- Analog fill height with foam compensation (available)
- Damaged crown (available)
- Gross foreign matter (in development)
- O₂ content through visible air and foam analysis (to be evaluated)
- Missing cap (available)

Pre-Labeller Inspection Station (currently available)

This station analyzes foam characteristics to determine the presence of foreign matter such as organic matter and glass inclusions. Inspection functions:
- Foreign matter
- Foreign crown identification
- Analog fill height with foam compensation
- Damaged crown
- Missing cap

Virtual Inspection Stations

Eventually, efforts will be focused on using advanced software tools, such as expert systems and neural networks, to draw conclusions from various sources linked to the networks and provide the brewer with a software generated data point which can be used to optimize the process or indicate process anomalies. These virtual stations will be based on the platform.

SUPERVISION AND DISTRIBUTION FUNCTIONS

Communication

For the past few years the process control world has standardized on a select number of communication protocols such as Modbus and DeviceNet. These protocols normalize the way systems are accessed and are the vehicle with which most plants configure and adjust their control equipment as well as communicate between the control systems, Programmable Logic Controls (PLC), Supervisory Control and Data Acquisition (SCADA) and Statistical Process Control (SPC) systems. Due to the wide acceptance of these devices and communication formats, these protocols were added to the DIS so that the inspection stations can be fully accessed by the plant’s SCADA system without the need for software patches or translation programs. As well, Sockets-based TCP/IP connectivity was expanded to provide a greater link to the brewery’s Enterprise Wide Network as well as the company’s internet and Intranet networks.

The following sketch highlights the communication bus structure:

![Diagram of communication networks]

FIGURE 6
Communication Networks
Internal Network

The Internal Network uses a deterministic real time operating system and provides connectivity between the inspection stations offering mission-critical control of the central processing unit (CPU) resources as well as distributed resource sharing. It is Ethernet based.

The network is also accessible via a telephone modem following a callback procedure that maintains network security requirements.

Instrumentation Bus

Modern instrumentation buses handle the communication between the controllers, PLC, SCADA, DCS and sometimes SPC environments. These quite often use industry standard process control communication protocols such as Modbus and Device Net. They in turn normalize the information transfer following very clear guidelines providing an easy and reliable communication environment from which to control the plant and adapt the network topography to future needs and technologies.

Enterprise Wide Network and Intranet

These environments are usually Ethernet based and TCP/IP is common for both.

**Information Presentation and Data Management**

With open-door communication, the DIS can rely, to an extent, on third party environments such as SCADA (Supervisory Control and Data Acquisition) and SPC (Statistical Process Control) for the information presentation and archiving functions. These best-of-class tools, combined with specific proprietary interfaces and a flexible database, provide the utmost in versatility and brewery independence.

**SCADA**

This is where much of the work described in the previous sections will start to bear fruit as the normalized data, event information and system parameters will become accessible from third party SCADA (Supervisory Control and Data Acquisition) systems. From this vantage point the quality inspection data will be integrated seamlessly into the process control, optimization and management environments in a continuous, real time mode. This global view will provide an added dimension and should lead to easier, faster and smoother brand and container changes, startups and adjustments to process anomalies.

SCADAs are adept at:

- Providing a single window environment that standardizes the way operators interact with the process and eliminates the multiple types of display systems that proliferate today’s plants.
- Facilitating a migration path by integrating dissimilar control environments.
- Delivering a unified database that offers other information technology (IT) systems a consistent and standard environment for exchanging real-time and transactional data.

**SPC**

The DIS provides product quality information, in real-time, normalized to the instrumentation bus and enterprise wide network formats, facilitating the implementation of an effective Statistical Process Control (SPC) strategy.

In the broadest sense, SPC is a statistical technique that helps brewers decide when to take action to keep the process in control, on target or within certain boundaries. The software tools used for SPC gather and present statistical information about the process in order to identify variables, characteristics or attributes from which to affect the control strategy or the process flow. They include report functions that provide analysis results and charts. SPC software tools may require manual inputs or may be linked directly to the instrumentation bus, the SCADA or the Enterprise Wide Network.

The SPC analysis strategy is based upon available data, with more accurate and trustworthy strategies possible with access to more data as well as access to real-time data. Real-time information access is at the heart of the DIS and is intended to lead to better control and optimization of the process.

**Proprietary Interfaces**

The SCADA and SPC do not, however, preclude the need to develop proprietary operator interfaces, as certain functions, such as calibration and maintenance, require local access. However, these can be kept much more generic as brewery specific windows will be generated, on the SCADA and SPC, by the brewery’s own personnel.

**Data Management**

The data structure is being evolved to provide an easy adaptation to large numbers of data sources and data points as well as the ability to record data sequence and tendencies. This will also include access to quality performance information, system and process alarm management and defect prioritization capabilities. This latter will be managed by the SCADA.
CONCLUSION

This development program has generated intense interest among our advisors in the brewing community, both locally and internationally, and should be completed within the next few months.

The move from a secular to an open-door environment, with industry standard communication protocols, will facilitate the selection of best-of-class tools for operating and optimizing the packaging lines. It will help integrate quality, in a seamless and continuous mode, into the plant’s control strategies and operating practices optimizing the process and reducing manpower requirements. It will also assist proactive quality practices by providing the operator with a global view of the packaging line’s quality performance. Also, the concentration of quality information derived from vision based multi-point inspection stations will minimize the number of inspection stations located on the packaging lines simplifying line layouts. This in turn will reduce the number of components to purchase and maintain as well as the production floor space required to house these. Furthermore, it will increase the amount of real-time information available for process optimization and facilitate future add-ons. Finally, the DIS will help breweries become more independent as access to the inspection environment will be available using industry standard tools, configured and maintained by their own personnel, on their environment of choice. After all, access to information cannot be compromised, as it is an essential element in brewers’ continuous drive towards the next level of operation excellence.

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