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Keywords: In-Line Classification, Quality Control, Non Destructive Evaluation, Machine Vision, Neuro-Fuzzy Modeling

Conference Topics: Neural Networks, Artificial Vision

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Quality Control Improvement by an Artificial Vision System

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Abstract. In this work a machine-vision system for inspection (VSI) is presented whose capabilities are able to detect seaming defects in metal cans for fishing food. Conventional method for quality inspection of seaming for cans, and their main dimensional features, are firstly shown. Then, the structure and algorithms for VSI are proposed for this application. This VSI is currently mounted over a conveyor belt for on-line/in-process inspection of metal cans, in order to assure their conformance to the given seaming requirements by detecting malfunctions of closing machines and logistic process failures.

1. Introduction

During the last years, the authors have been involved in the analysis, design, and implementation of machine vision solutions for quality control in communications and automotive industries [1,2].

In the light metal packaging industry, particularly in the steel food cans sector, the seam of recipients must be monitored to guarantee the desired life span for the target product. Today, a destructive testing based statistical supervisory control is carried out. Random samples of seamed cans are destroyed and analyzed to extract light metal packaging industry standardized parameters (subsection 1.1). Starting from these data, the acceptance/rejection decision is taken.

The growing level of production in canneries involves new challenges to seam inspection methods based on conventional routine statistical control (CRSC)[3]. It is for that reason our proposal of in-line automatic inspection based on machine vision in order to give a better response to new quality control demands.

The solution proposed, uses a machine vision system [4,5] to extract information from each seamed can and then, using an adaptive neuro-fuzzy inference system, compute the standard parameters used to reject or accept each seamed can at the closing machine rate (up to 1000 cans/minute (subsection 2.1)). One advantage is the ability to easily detect deviations from the closing machine initial working point, preventing large sequences of faulty seamed cans, and allowing a fast maintenance.

To avoid using malformed can bodies or food overflowed can bodies in seaming process, that accelerate the closing machine disarrangement process or even block closing machine, another inspection point, located before the closing machine, was developed.

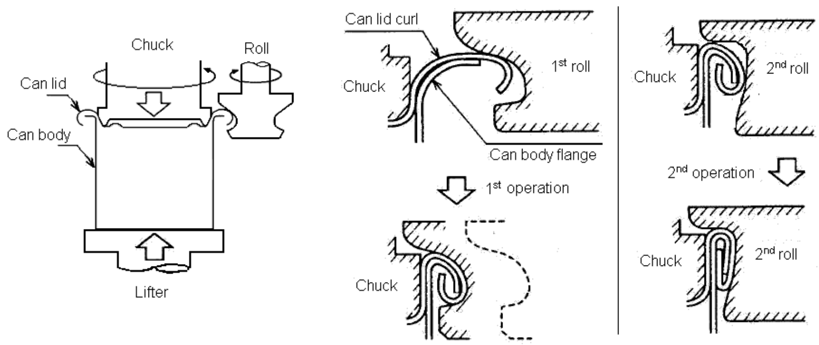
To sum up, the adopted solution is a machine vision system composed of two stations: one before the closing machine that inspects the can bodies, and another placed after the closing machine that inspects seamed cans (subsection 2.3). The first station detects: faulty can bodies, and food overflow; while the second watches for faulty seamed cans.

1.1 Can Seaming Process

Closing of three piece steel food can ends has been well supported by researchers when in 1900 the former soldering method was changed by a new double seam processing able to be made from increasingly faster and sanitary safer closing machines.

In the can seaming process (Fig. 1), a lid is mounted on the can body filled with ingredient, then body and lid are held between chuck and lifter, and then rotated before the lid is pressed against the seaming roll to carry out seaming. There are two types of seaming roll (double seaming mechanism): 1st roll and 2nd roll. The first roll approaches the can lid, and rolls up the lid curl and body flange sections of the can before retreating. Next, the second roll approaches to compress the rolled-up sections to end the seaming. In other words, the 1st roll rolls up the can lid and can body, doing mainly the bending work, while the 2nd roll compresses the rolled-up sections, and mainly does the seaming work.

The can seam obtained, double seam (Fig. 2), consist of five thickness of plate interlocked or folded and pressed firmly together, plus a thin layer of sealing compound.



Can seaming mechanism　　　　Can seaming process

Fig. 1. Outline of can pieces, can seaming mechanism and process

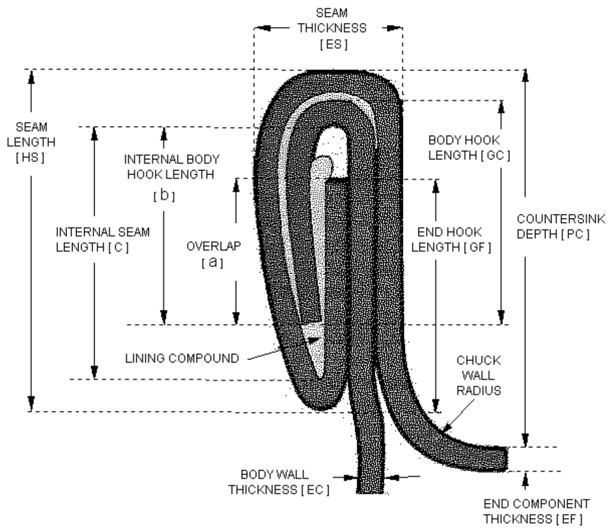


Fig. 2. Double seam dimensional terminology

The seaming integrity is achieved by a combination of the following two elements:

- The sound mechanical interlocking of the can body and can end.
- The presence of sealing compound, which effectively blocks potential leakage paths.

The parameters used to assess the seaming integrity are: Compactness Rating (CR), Overlap Rating (OR), and Body Hook Butting (BHB). They are named integrity factors and are computed, from the double seam dimensional features (Fig. 2), using the following ratios:

$$\%CR = 100 \cdot (3 \cdot EF + 2 \cdot EC) / ES \tag{1}$$

$$\%OR = 100 \cdot a / c \tag{2}$$

$$\%BHB = 100 \cdot b / c \tag{3}$$

There are international and national entities involved in the regulation of quality control procedures for fish cannery industries. Some of them, like FDA [6] (Food & Drug Administration, USA), Department of Fisheries and Oceans [7] (Canada), SEFEL [8] (EU), and SOIVRE (Spain), use a similar definition for double seam dimensional features, and integrity factors. These entities have defined a quality control based on a conventional routine statistical control (CRSC) used by the canneries.

The seaming control in CRSC method is based on seaming integrity. The three integrity factors are computed over defined points for a given can shape (Fig. 3), in order to check if the whole seam is valid, that is to say, the three computed integrity factors of each selected point provide a set of simultaneous acceptable values, otherwise the can is rejected (Table I).

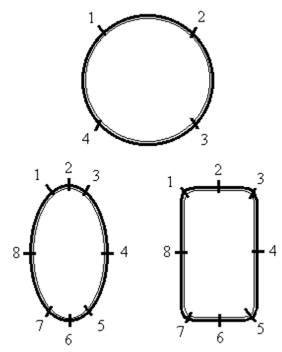


Fig. 3. Measurement points used in CRSC inspection for different can shapes

Table 1. Integrity factors: acceptation range

Integrity factor	Range
%CR	[75,95]
%OR	[45,90]
%BHB	[70,95]

The CRSC inspection involves the following off-line actions:

- A visual inspection, carried out at fixed, predefined time intervals (normally about 15 minutes).
- A detailed examination, where the seam is pulled apart and the three integrity factors are computed, carried out at the beginning of a shift, at least every four production hours and after machine adjustments.

The major drawback of this procedure is the large time it takes to gather the statistics from a small sample of cans. Once available, the offered information gets late to prevent defective seams due to a failure in the closing machine, increasing the cost. Moreover, closing machine operators do have extra information (section 3), difficult to model in the former procedure that is absolutely wasted.

The designed machine vision inspection system (VSI) overcomes CRSC inspection, because its real-time inspection features allows checking the three integrity factors set on each seamed can when it is on-line/in-process over the conveyor belt of closing machine (subsection 2.3).

The developed VSI of double seam integrity emulates CRSC inspection. In order to overcome CRSC inspection restrictions, the VSI anticipate possible closing machine malfunctions by means of a previous filled can body inspection, giving a useful performance monitoring of canner's logistic process.

2. Machine Vision System for Inspection (VSI)

2.1 System Requirements

After developing a System Requirements Specification (SyRS, IEEE Std 1233) for the project, the critical factors affecting design decisions for the VSI were the following: (a) Double seam measures should be within a two tenth's millimeter precision, (b) The whole system speed should match or surpass that of the closing machine, imposing a serious restriction to the image processing subsystem speed, (c) Faulty cans should be detected and rejected before and after the closing machine; the first restriction prevents the closing machine heads from being misaligned when a flawed can body is inserted in the belt queue, (d) From the system life cycle point of view COTS (Commercial Off-The-Shelf) should be used with flexible software development tools [9,10,11], (e) Adaptability to the variable conditions that may be encountered on different manufacturing plants, like different closing machine models, can shapes or lighting conditions, (f) And finally low costs should be considered.

2.2 Decision Model

Can seaming quality is assessed from the seaming integrity factors (subsection 1.1): CR, OR, and BHB. As it has been seen in equations (1), (2), and (3), they depend on several external and internal dimensional parameters.

Because of the machine vision system can only measure the external parameters: ES, HS and PC (Fig. 2), these parameters are the only information to estimate the seaming integrity. Then, the validation of a decision model for detection of faulty cans must firstly be carried out.

The purpose of model is to emulate CRSC dimensional inspection taking only three external double seam dimensional features (ES, HS, PC), to compute the three integrity factors (CR, OR, BHB).

To find such a function, data sets for these six parameters were gathered from generated I/O data sets. After statistical conditioning those data sets, some mathematical modeling methods were tested. Statistical methods such as Bayesian, and Non Linear Regression gave poor results to be used by the acceptance/rejection decision model. Finally, a neuro-fuzzy modeling was used to work out a fuzzy model [12,13,14] that did at least as well as the CRSC method.

The obtained model was a first order Sugeno inference system [15] developed using the adaptive neuro-fuzzy inference system (ANFIS) [16] from the Fuzzy Logic Toolbox of Matlab® (The MathWorks Inc.). The model contains seven if-then rules with: a gaussian membership functions (MF) for each input and rule, and a first order polynomial MF for each output and rule. The defuzzification method was a weighted average.

With only seven rules, the first order Sugeno fuzzy model achieved almost the same results as the original CRSC dimensional inspection (Fig. 4). The main discrepancies arose for values that were far away from the acceptance intervals for each factor. Thus, we can consider that both models give the same results within a 5% margin of error, offering the same behavior for rejection purposes.

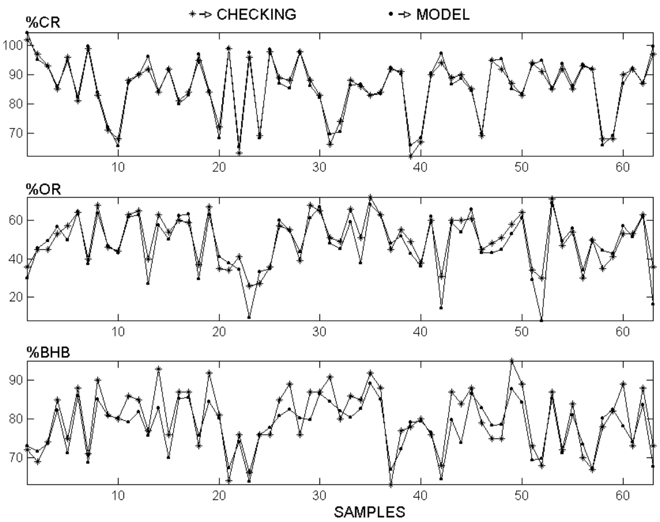


Fig. 4. Comparison of checking data with fuzzy model output

2.3 Prototype Description

There are two inspection stations (Fig. 5) composing the prototype: BIS (Body Inspection Station) and SIS (Seam Inspection Station). The first one, with a single camera, is responsible for the detection of faulty can bodies that may cause potential damage to the closing machine head, rejecting them. The second station is responsible for the extraction of the integrity factors from the image processing subsystem and for the rejection of faulty seamed cans.

BIS contains one camera whose optical axis is in the vertical over the conveyor belt. Once a can body reaches the BIS, the sensor triggers the image capture and the can body image is processed. There is another sensor, placed after the camera, that lets the system know when the can body is passing by the rejection system. The rejection system is activated in case the can body were defective.

SIS has three cameras in a horizontal plane arranged with their optical axis in symmetrical radius position so each camera observes 120º of the can seam, to measure HS; and one camera in zenithal position, to measure ES, and PC. The rest of the system operates in the same way that the BIS, this time inspecting the seam integrity.

Both kind of algorithms run within a Windows PC platform with the frame grabber cards installed inside. Sensors and actuators are connected with each station to complete the system.

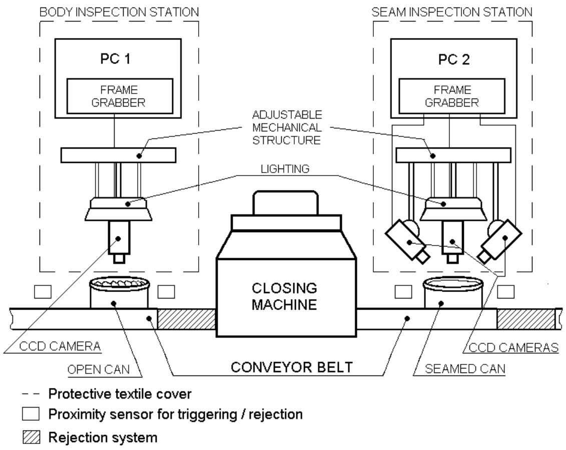


Fig. 5. VSI architecture for automated inspection of metal cans

2.4 Prototype Materials

For SIS station: four CCD cameras CV-M40 from JAI are used to read can images at 60 images per second transferred to two PC-RGB frame grabbers from Coreco-Imaging Inc., and buffered for immediate image processing using the MV Tools (libraries in C/C++) and Sherlock framework on a Pentium III with Windows NT OS. To avoid noisy images due to metal can reflections, one diffused light sources (NER Dark Field Ringlight DF-150-3 75º) with three halogen lights are employed. The need to synchronize the presence of the can with the frame grabbers capture triggering is solved with an inductive proximity sensor [17]. An electronic valve controlling the jet of compressed air combined with another sensor is used in the rejection of defective cans. For BIS station, a similar configuration was designed. In this case, one CCD camera CV-M10 from JAI with a PC-Vision frame grabber from Coreco-Imaging Inc. was chosen.

Furthermore, a Siemens' PLC Simatic S7-300 for both inspection stations to adapt signals from proximity sensors to PC's and from these to the rejection system.

3. Algorithms For Inspection

From the knowledge and experience acquired from industrial can seaming, the next remarks were noticed: (a) Once adjusted the closing machine, in a normal operation cycle, its misalignment is slow, giving a chance for real-time analysis, (b) A closing machine is easily misaligned or even entirely blocked if (body dimensional inspection): a body hook is defective, a radius flange changes (Fig. 1) or there is an overflow of canned food out of the open can, among other possible causes, (c) Each seaming head in a closing machine is under different operating conditions and its misalignment will not be identical.

This information is used to develop algorithms based in real-time machine vision, given that once adjusted a closing machine for a particular kind of can and filling food, it has a slow, small, and progressive degradation around an initial working point. Such a point is fixed for each seaming head from external features measured on the can over which the last adjustment was made.

Two machine vision algorithms were developed for this VSI, one before closing machine running on BIS for can body inspection, and the other after closing machine executed on SIS for seamed can inspection (subsection 2.3*)*.

3.1 Double Seam Dimensional Inspection

The developed machine-vision system for inspection of double seam emulates CRSC inspection, taking only three external double seam dimensional features (ES, HS, PC) to compute the three integrity factors (CR, OR, BHB) through a fuzzy inference system (FIS) to check can validity (subsection 2.1).

Several populations of same formatted cans were seamed to validate the computer vision algorithm for SIS. To get simultaneous, precise values of those double seam external dimensional features at a series of points all around of can end, a vision based algorithm analyzes four images taken all under the same triggering: from three cameras arranged with their optical axis in symmetrical radius position that measure HS; and a fourth one in zenithal position that measure ES, and PC.

Then, the three integrity factors are estimated through the FIS. After that, the seamed cans were measured at four points of the perimeter by mechanical destructive procedures used in CRSC inspection, in order to compute the true three integrity factors for each can from external and internal dimensional features.

The comparison of both procedures showed that the error had slightly grown with respect to the FIS model alone (subsection 2.1). However, as the closing machine working point is at the center of the integrity factors acceptation range, the behavior for rejection purposes is the same as CRSC method.

3.2 Body Dimensional Inspection

The body dimensional inspection for the BIS vision algorithm does not require any validation, given that the previous inspection before closing machine is not standardized by international entities, on the contrary of the above mentioned double seam dimensional inspection.

Given that both flaws, whether the overflow of canned fishing food or the body dimensional faults of can (i.e.: Body mismatching, Flange width, etc.) can damage closing machine operation likewise, a part of vision algorithm for BIS must also check if there is food overflow. Therefore, the whole vision algorithm for BIS has two parts, body dimensional inspection, and food overflow testing.

The possible overflow is detected scanning frames from the open can surface, from previously taken images, with a selected window, and checking grey level differences. The can body dimensional inspection measures flange width on several points around the can body flange contour and tests if the can body shape is outside the tolerance. In this station only a vertical camera, whose optical axis is lined with the open can axis, is needed.

4. Conclusions

The computer vision system implemented by the authors for quality control inspection on fish cannery industries (VSI) has demonstrated better results than CRSC inspection, in the following topics:

- Total seaming inspection, not statistical, over the whole population of seamed cans. This enhances the reliability of quality control figures given that the whole population of cans is inspected and not only a reduced sample.
- Powerful fuzzy model algorithm designed to avoid the measurement of internal double seam features, validated through trials on canner's shop floor, using only three external features to calculate integrity factors. This allows a completely automated quality control system.
- Better inspection reliability in terms of acceptation or rejection of inspected cans (positive false or negative false), because a higher number of points are measured over the perimeter of such a can.
- Enhanced efficiency of double seam process, because poor filled or defective cans are rejected by VSI before they arrive to closing machine. This is a new contribution from implemented VSI, about monitoring of shop floor logistic process, given its capability of inspection before closing machine. Obviously closing machine increases its operating life avoiding repeated malfunctions, and seaming cycle is enlarged because there is no need for frequent head adjustments.
- Faster quality control inspection given that implemented VSI allows automatic performance in a real-time and on-line/in-process ways. This eliminates off-line complex, slow, expensive, manual destructive inspection and, restricted to a limited sample of cans, to measure external and internal double seam features in each point of can perimeter, because by means of implemented VSI, quality control is made on-line during seaming process.
- Flexible and low cost machine-vision system (VSI) able to be mounted in any SME's (Small and Medium Enterprises) of metal packaging industry, given its easy programming and existing off-the-shelf elements.

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