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Can Seam Diagnosis from Still Image Processing

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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 fish food can 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 solution proposed, uses a machine vision system [3,4] 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 600 cans/minute (subsection 2.1)).

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

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.

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:

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

$$\%OR = 100 \cdot a / c \quad (2)$$

$$\%BHB = 100 \cdot b / c \quad (3)$$

At present, the seaming quality control used by the canneries employs a conventional routine statistical control (CRSC). This 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).

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, difficult to model in the former procedure that is absolutely wasted.

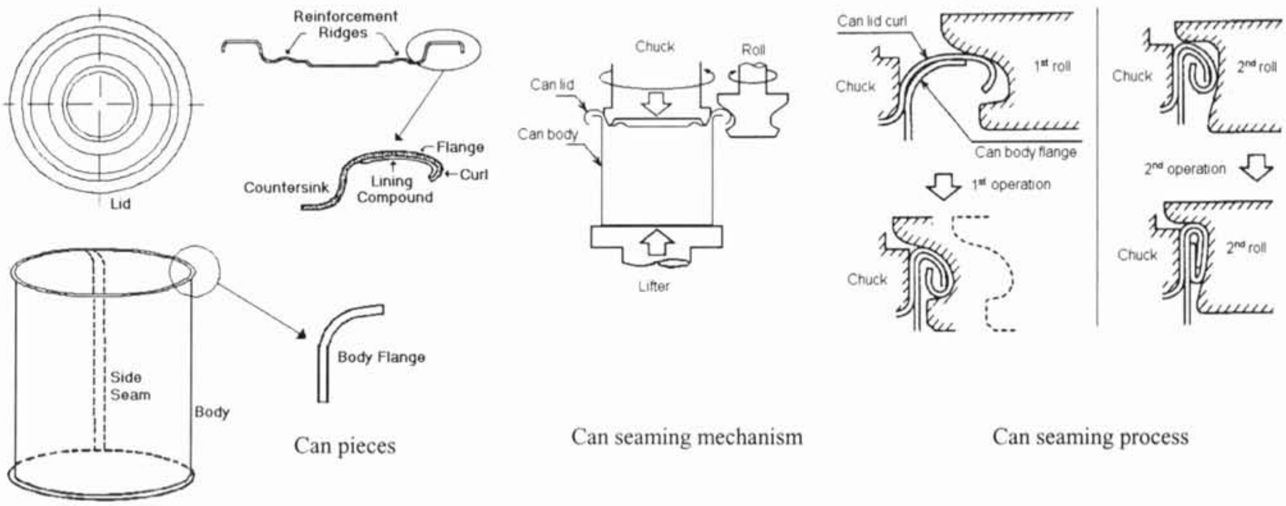

Fig. 1. Outline of can pieces, can seaming mechanism and process

Table I. Integrity factors: acceptation range

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

The developed machine vision system for inspection (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.

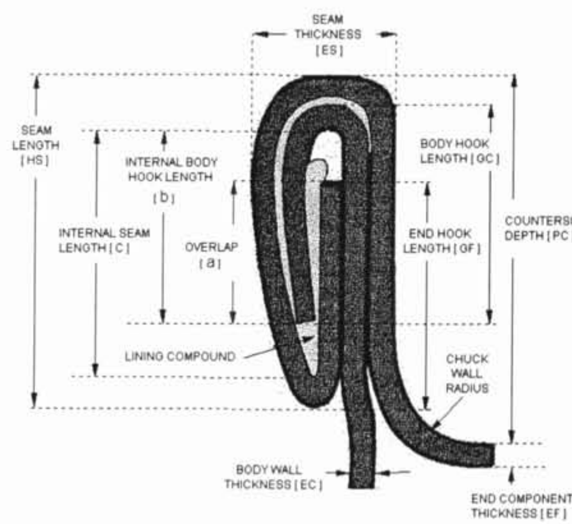

Fig. 2. Double seam dimensional terminology

2 Machine Vision System for Inspection

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) Adaptability to the variable conditions that may be encountered on different manufacturing plants, like different closing machine models, can shapes or lighting conditions, (e) And finally low costs should be considered.

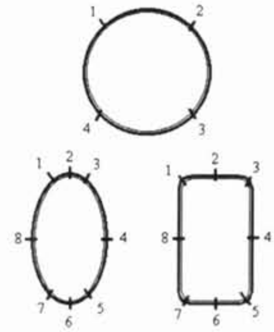

Fig. 3. Measurement points used in CRSC inspection for different can shapes

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 Eq. (1), Eq. (2), and Eq. (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.

To find such a function, data sets for these six parameters were gathered from generated I/O data sets. And after that, a neuro-fuzzy modeling was used to work out a fuzzy model [5,6,7] that did at least as well as the CRSC method.

The obtained model was a first order Takagi-Sugeno inference system [8] developed using the adaptive neuro-fuzzy inference system (ANFIS) [9] 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 the same results as the original CRSC dimensional inspection (Fig. 4), offering the same behavior for rejection purposes.

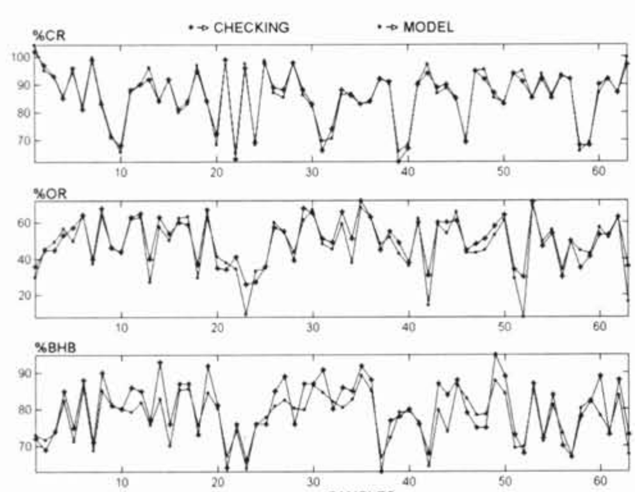

Fig. 4. Comparison of checking data with fuzzy model output

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.

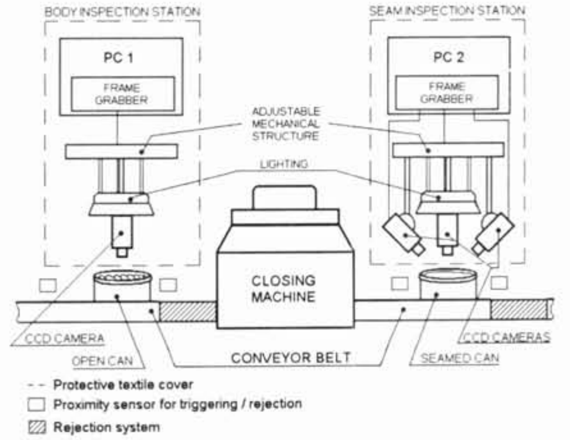

Fig. 5. VSI architecture for automated inspection of metal cans

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 120° 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.

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 75°) 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. 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

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. It estimates the three integrity factors (CR, OR, BHB) from three external double seam dimensional features (ES, HS, PC) by means of a fuzzy inference system (FIS) (subsection 2.2).

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.

3.2 Body Dimensional Inspection

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, and checking grey level differences with a pattern. 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 machine 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.
- 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.
- 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.
- 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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