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X-Ray Images Processing to Detect Packaging Defects in Canned Food Industry Using Fuzzy Logic

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ABSTRACT

Taking into account the importance of packaging in the food industry and the need to maintain the health of the materials in the packaging, and with the help of the experiences obtained from previous research with their strengths and weaknesses, we propose a method for the detection of defects in canned packaging, through the use of X-ray radiography, image processing and feature extraction methods, based on fuzzy logic functions for them.

KEY WORDS: radiography, image processing, fuzzy logic, image segmentation, feature extraction

Procesamiento de imágenes de rayos X para detectar defectos en empaques de la industria de alimentos enlatados utilizando la lógica difusa

RESUMEN

Teniendo en cuenta la importancia de los envases en la industria alimentaria y la necesidad de mantener la salud de los materiales en los envases, y con la ayuda de las experiencias obtenidas de investigaciones anteriores con sus fortalezas y debilidades, proponemos un método para la detección de defectos en los envases enlatados, mediante la utilización de radiografía de rayos X, procesamiento de imágenes y métodos de extracción de características, partiendo para ello de funciones de lógica difusa.

PALABRAS CLAVE: radiografía, procesamiento de imágenes, lógica difusa, segmentación de imágenes, extracción de características.

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Introduction

One of the major problems encountered in industrial parts is the defects in welding joints. Failure to timely identify these damages and defects will result in economic and environmental damage. Therefore, accurate and timely diagnosis of welding defects is very important. Industrial radiography is one of the methods of non-destructive tests used to diagnose welding areas (Amza and Cicic, 2015; Namdeo and Vishwakarma, 2013). Non-destructive tests perform the test without any damage to the tested item. Non-destructive testing is an integral part and most important component of any quality assurance program in any industry. The goals of the programs are quality assurance, safety and auditing, reliability and project economics. The qualitative properties of the welds (having defects such as cracking, slag mixing, porosity, incomplete melting, and welded-side sinking) as well as their alloy content can be assessed by non-destructive tests (Pascu, et al., 2014; Namdeo and Vishwakarma, 2013). An industrial radiography test which is one of the methods of non-destructive testing on the principle that X-rays and gamma rays are short wavelength electromagnetic radiation that can penetrate materials. These radiations are absorbed or passed through the material depending on the thickness, density, and atomic number of the material. This absorption phenomenon is used to interpret the information recorded on a photographic film. At this point, there is a need for processing to interpret the imaging information, in order to accurately identify the type of damage to the segment in question, which requires different algorithms or methods for accurate detection. Therefore, in this study, we process X-ray images to detect packaging defects in canned food industry using fuzzy logic.

1. Review of the related literature

Izadbakhsh et al (2017), in their research designing an image processing-based expert system to control the quality of copper wires, concluded that quality control plays a key role in today's industrial environments and whenever necessary take appropriate measures to ensure that products and services manufactured meet quality standards. In this study, they designed an expert system for quality control automatically. In this input expert system, there are images of the product being manufactured. Image processing techniques have been used for this purpose. First, since the images may be noisy, they are pre-processed and then processed using a fuzzy system. In this fuzzy system, according to the images, certain rules are written to extract the specific properties needed. After the required feature is extracted, the chart is used to classify the product in terms of quality. The proposed approach has been used for copper wires. Rastegari et al. (2017), in their research reviewing the basic concepts of image and image processing, came to the conclusion that with the advancement of the convergence technologies of computer science, electricity and electronics, the application of image processing is becoming increasingly widespread. So digital image processing is a valuable and indispensable area for human life to continue. It has quickly become one of the most widely used sciences in all fields. Image processing has penetrated all sciences and has many applications in a variety of fields. Image processing is the best tool for feature extraction and position analysis and ultimately decision making.

The purpose of image processing is to implement human performance against data and to perform specific processes to extract the features needed to achieve a predetermined goal. The purpose of this article is to introduce the basic concepts for image and digital image processing for further research. Fardin Far (1936), in his study of fuzzy logic based image processing flame detection methods, concluded that image processing based flame detection is now a novel method with significant potential for development. In addition, it can replace conventional photodiode infrared sensors and is more reliable in preventing tunnel accidents or chemical accidents. This article presents a two-step algorithm for detecting flammability to obtain this valuable information. The first step is to identify pixels with color and dynamics similar to real flames. The next step evaluates the instantaneous spreading of the desired pixels using a specific spatial expansion parameter SEP. In parallel, the oscillatory changes in the number of pixels detected over time are transferred to the frequency domain. Frequency spectrum analysis makes it easy to identify the fire by the usual vibration frequency. The proposed identification method uses fuzzy logic classification for each step. Therefore, no static threshold is needed and this makes more choices available to increase the flexibility of this algorithm. This algorithm is capable of distinguishing between flames and fires with high accuracy. In addition, the expansion of the identified combustion processes is little explained.

2. Statistical population and sample

The number of samples in this study is 100 cans at the end of production line and after packing. In this study, simple random sampling was used. Sampling was done three times during the fall season in the year 2017 in September and October of the factory output. Each item was sampled at three different hours and sent to the laboratory for testing. The following notes are required at the time of sampling:

- Air temperature (in shade)
- Atmospheric conditions of the sampling site
- Location and storage of samples

The specifications of each sample must be clearly specified. This is done by following:

- Storage name
- Sampling location
- Sampler name
- Date and time of sampling

3. Research Method

The present study investigates the processing of X-ray images to detect packaging defects in canned food industry using fuzzy logic. The research method is library and field study and sampling and analysis of samples is from factory output. To conduct this research, the first stage of field survey of the production line and sampling from the storage and the end of the production line (packaging) is performed to explain the performance. After this step, we perform sampling to measure and process X-ray images. The images are specified to eliminate the distortions that occur during the image gathering process, and then image processing, which is an operation that prioritizes a range of applications. For x-ray images of cracks containing 80 kV voltage generator, 4 mA current, and 3 minutes irradiation time and 400 KODAK AA film irradiation time was used. The images were digitized in TIFF format and stored on the computer. MATLAB R2012b software was used for subsequent processing of these images (Huang and Wu, 2008). A ScanMaker 1000-XL Microtek film scanner is used to convert X-ray film to digital image format, capable of scanning A3 documents with maximum spatial resolution 6400 (dpi) (micron) and it has the highest 4 optical density films and its sensitive element is CCD. For calibration and scanner control, Agfa's standard IT8.7 / 1 calibration film as well as BAM and X-rite calibration step films were used. Radiographic films have to be converted to digital images in order to process them and a scanner is used to achieve this. Since most X-ray films are very dark and high density, so using a conventional scanner cannot produce a good resolution and quality image. After scanning the x-ray film, digital images is acquired, which are stored in JPG format on the computer, so the stored images are now ready for computer processing on them.

Before performing any processing on the radiographic images, first at this stage, a special window around the area suspected of having a defect or the entire welding area is considered (Sargunar and Sukanesh, 2010). Most radiographic images are of poor quality, so in order to improve the quality of the images, special pre-processing of the images is required. In other words, image preprocessing is used to modify the pixel values of digital images to a sufficient extent for subsequent processing (Gonzalez et al., 2004). Techniques used to pre-process images include:

- Histogram Equalization
- Location filtering using the Median Filter
- Gray Levels Slicing Image

4. Research findings

4.1. Proposed Algorithm

In this paper, product failures are diagnosed in two stages, but before the feature extraction, the image is segmented by a neural network. In the first phase, the geometrical properties of the objects in the segmented image are examined and analyzed. The four properties are extracted from the objects in the binary image. These features are listed below:

- Area: The number of pixels in the image
- Perimeter: The number of pixels on the edge of the image
- Shape: Compression measures the shape and results from dividing the perimeter by area
- Roundness: If an area has a lot of circles it is a circle and if there are oval and other shapes it has a little circle

These criteria are defined using trapezoidal fuzzy sets. If an object has a malfunction, it is geometrically high and has a low shape criterion and has a large environment and its rotation is low. All this is valid when it has a small area. Otherwise it belongs to the background. Therefore, the fuzzy inputs for the cases stated above are expressed as follows (Table 1).

Table 1: First phase fuzzy inputs

Area	Suitable	Notsuitable
Perimeter	Long	Short
Shape	Irregular	Smooth
Roundness	High	Low

And fuzzy outputs include background failures. These are analyzed by the Mamdani fuzzy system. In the second phase the inputs are as follows:

- The average intensity between an object and a rectangular area that surrounds it: DIFFERENCE
- Average intensity for the area of interest and pixels in its neighborhood: TOGETHERNESS

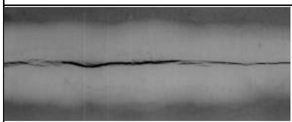
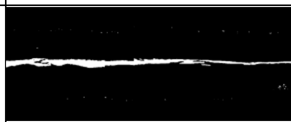
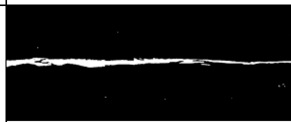
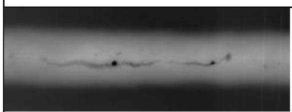
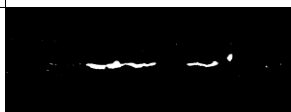
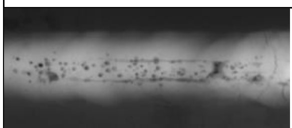
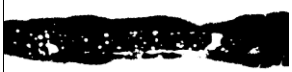
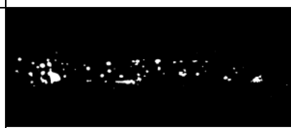
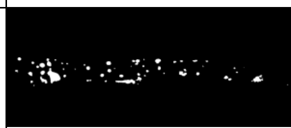
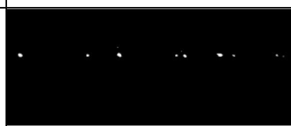
The inputs of these fuzzy sets are expressed as follows (Table 2).

Table 2: Secondary phase fuzzy inputs

Difference	Small	Large
Togetherness	Close	Loose

To detect failures we need to look for objects that have more DIFFERENCE and TOGETHERNESS. Therefore, by considering these fuzzy sets, we identify the failures. The results of the above method are as follows (table 3).

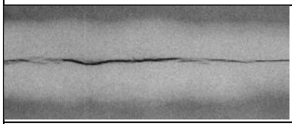
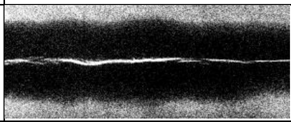
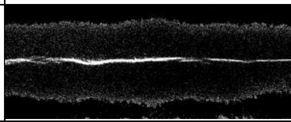
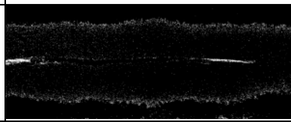
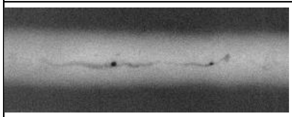
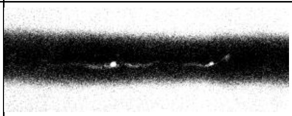
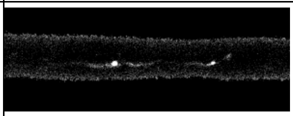
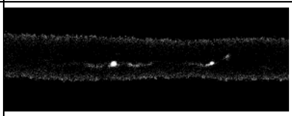
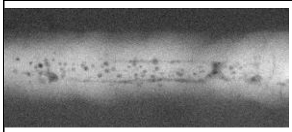
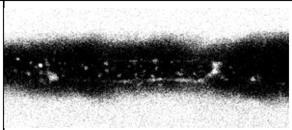
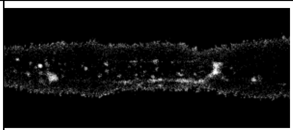
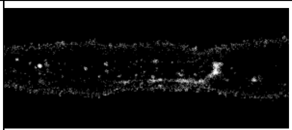
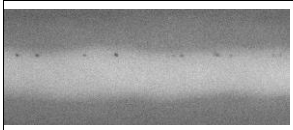
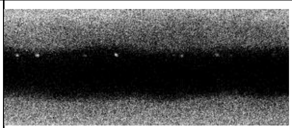
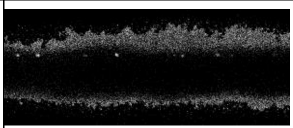
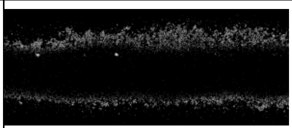
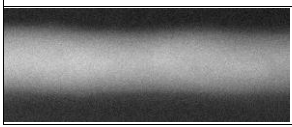
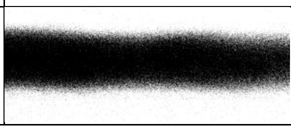
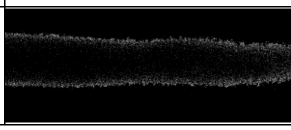
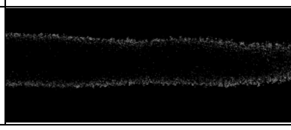
Table 3: Fuzzy outputs of the first and second steps

Main image	Segmentation	Fuzzy first stage	Fuzzy second stage
			
			
			
			
			

4.2. Results for Gaussian Noise

System performance was evaluated in the presence of Gaussian noise. This noise has an average value of 0.1 and a variance of 0.01. The Gaussian noise results are shown in table 4. The method is not noise resistant and also because the number of objects in the shape increases. In the second phase, the computational speed of the system is very slow, because noise causes interconnected objects to be separated.

Table 4: Fuzzy output of the first and second phase with Gaussian noise

Image of Gaussian noise	Segmentation	Fuzzy first stage	Fuzzy second stage
			
			
			
			
			

MATLAB code

Here, the image is read and resized, and if the image is colored, it would turn black and white otherwise it would not change (Figure 1).

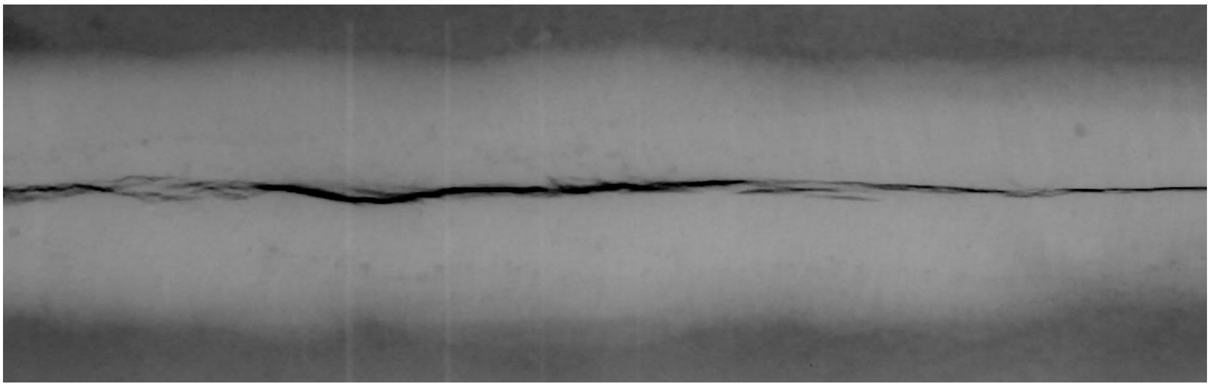


Figure 1: Input image to the system

The image needs to be entered into the neural network for segmentation, for this purpose the image is reshaped to the vector. It should also turn black and white if the image is colored. The post-propagation neural network was used to segment the newff function (Fig. 2). These images instruct the grid to convert each pixel to one or zero of different intensities depending on the corresponding pixel.

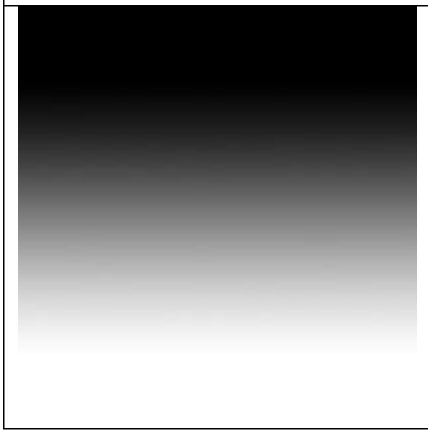
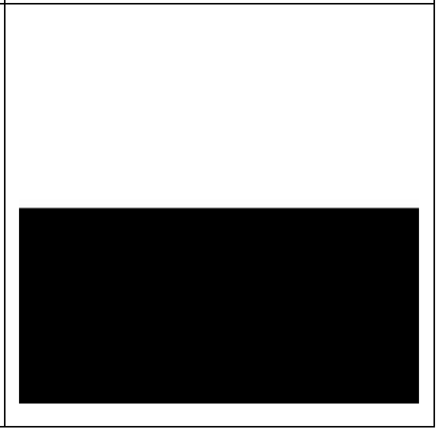
Input	Target
	

Figure 2: Images for neural network training

Figure 3: Segmentation output stage

This image does not include failures and parts of the background have also been detected. In the later stages, these additional objects can be eliminated (Figure 3).

4.3. Fuzzy system first stage

The fis file is created first. Appropriate inputs and outputs are selected as follows. In each image, the fuzzy sets of inputs and outputs are shown separately.

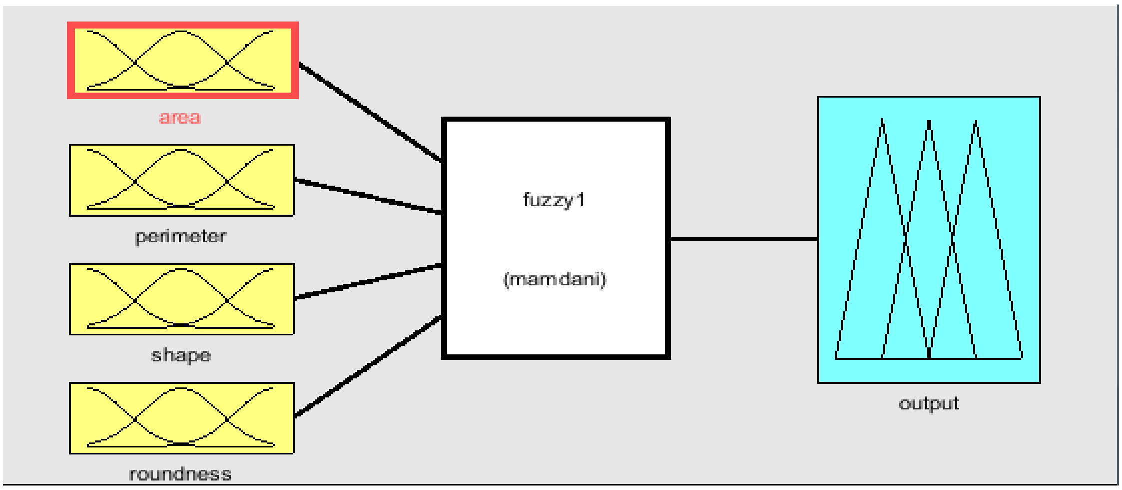


Figure 4: The fis output of the first stage

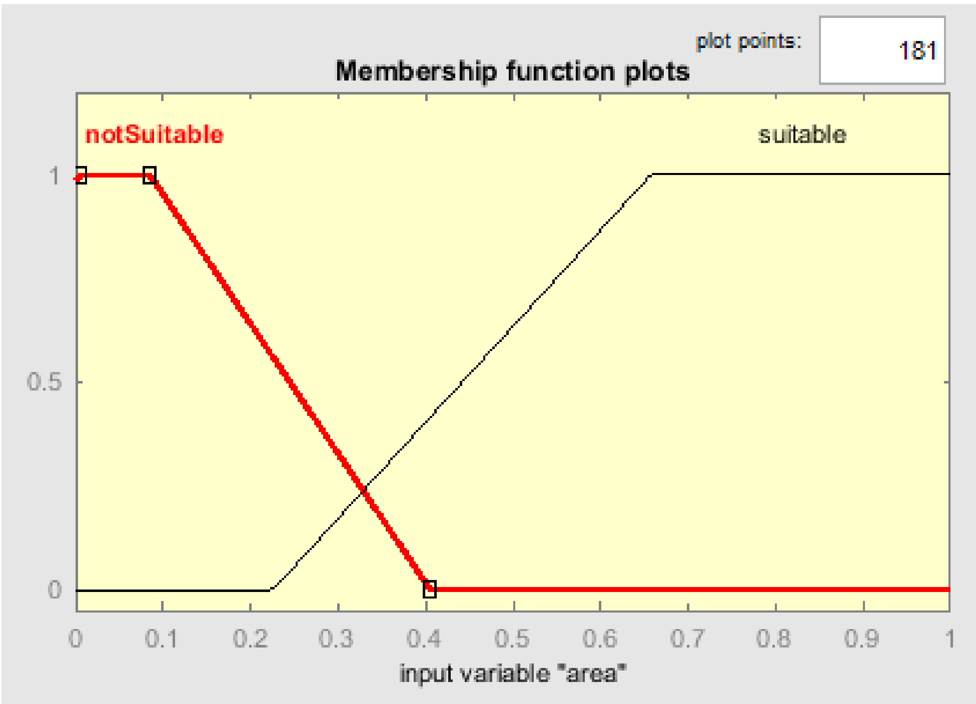


Figure 5: Diagram of area variable membership function.

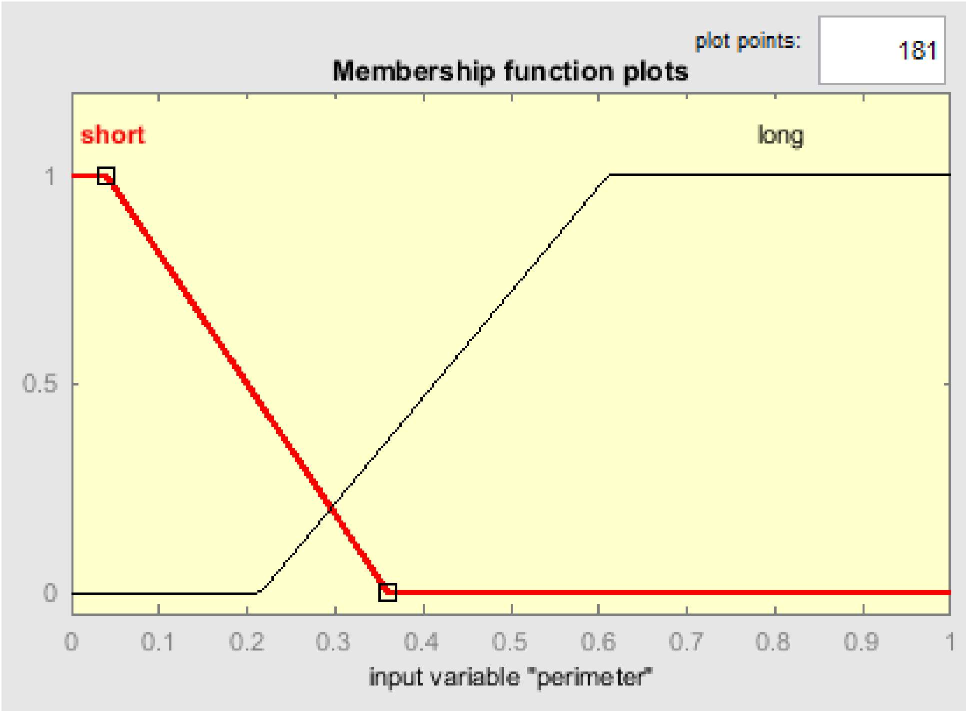


Figure 6: Scheme of variable membership function of perimeter.

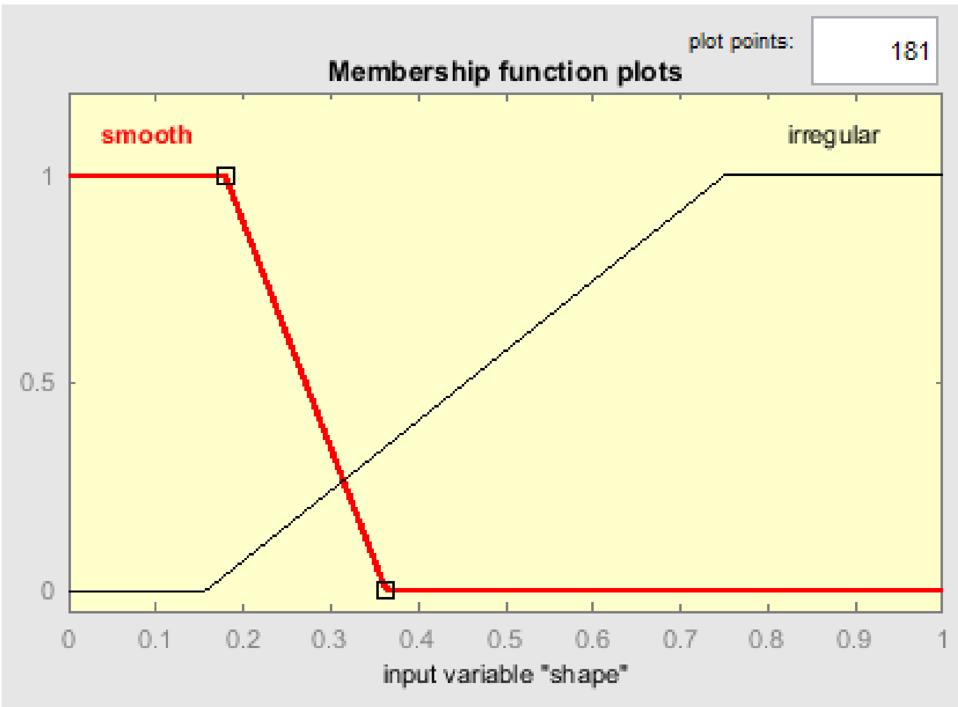


Figure 7: Variable membership function shape.

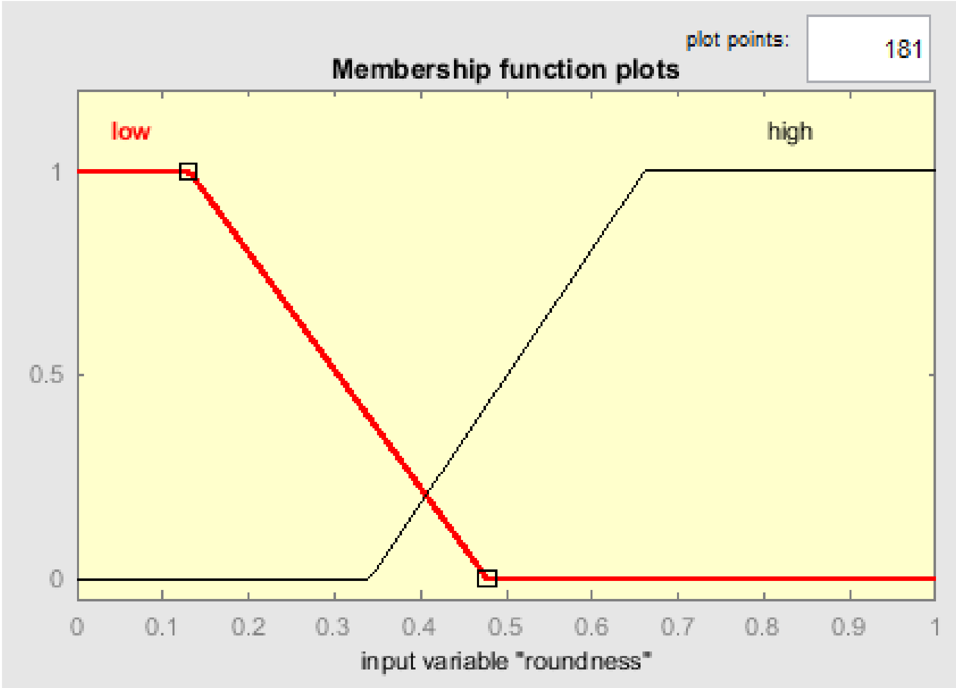


Figure 8: Graph of the variable roundness membership function.

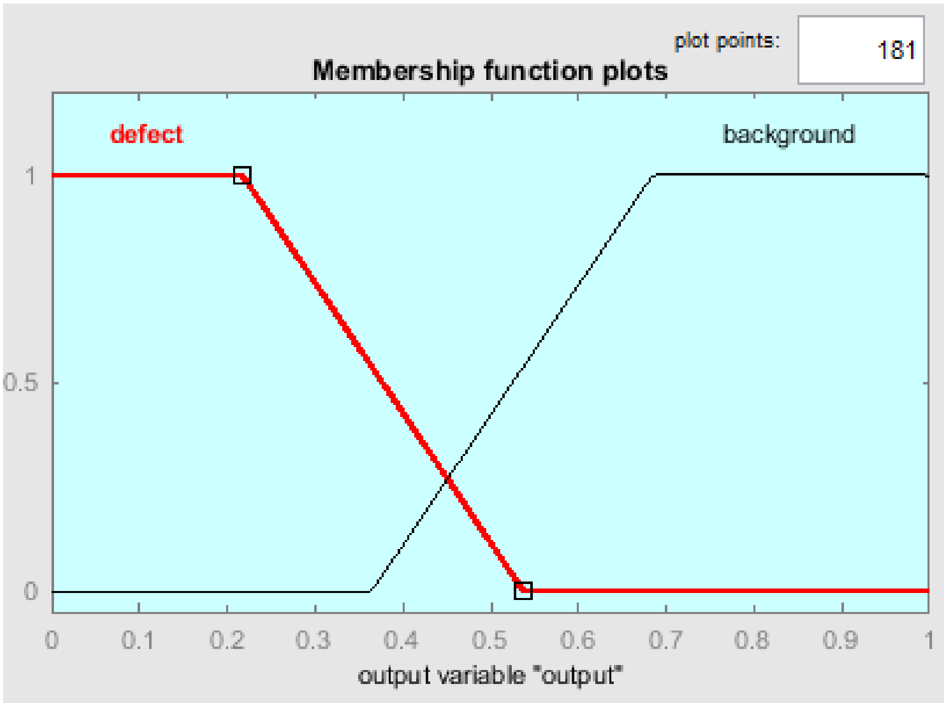


Figure 9: The membership function diagram of the output value.

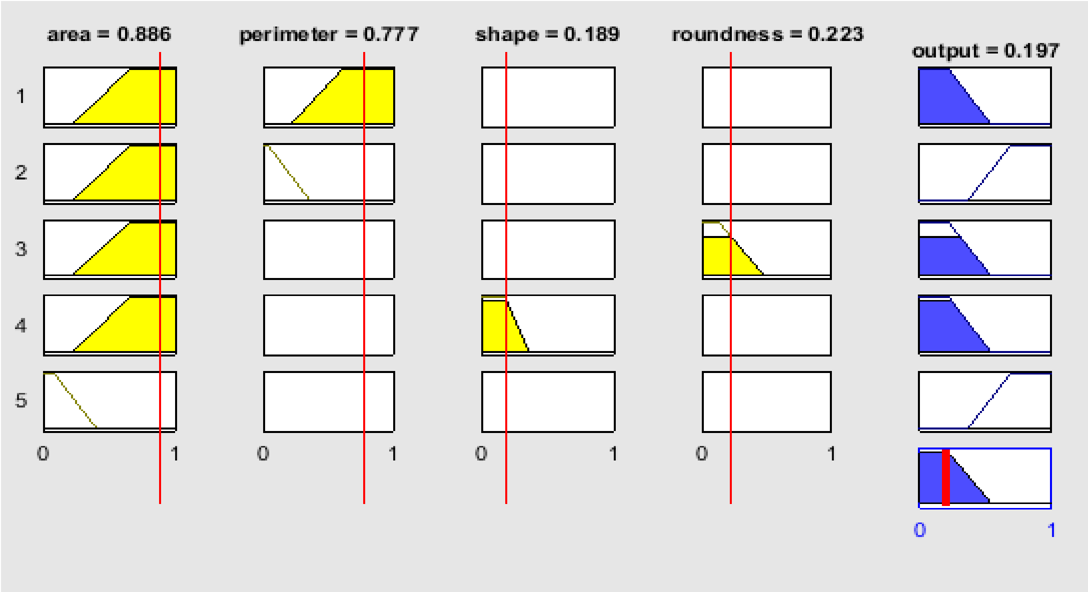


Figure 10: Fuzzy output of the first step of the proposed method for one of the tested samples.

In this section, we first find the interconnected objects in the image with bwconncomp, and then use the regionprops function to obtain the four properties that must be entered into the fuzzy system for each object. At this point, the generated fis file is introduced to the algorithm and placed in ourfis variable. It is then calculated using for loop output based on all the objects in the binary image (Fig. 11).

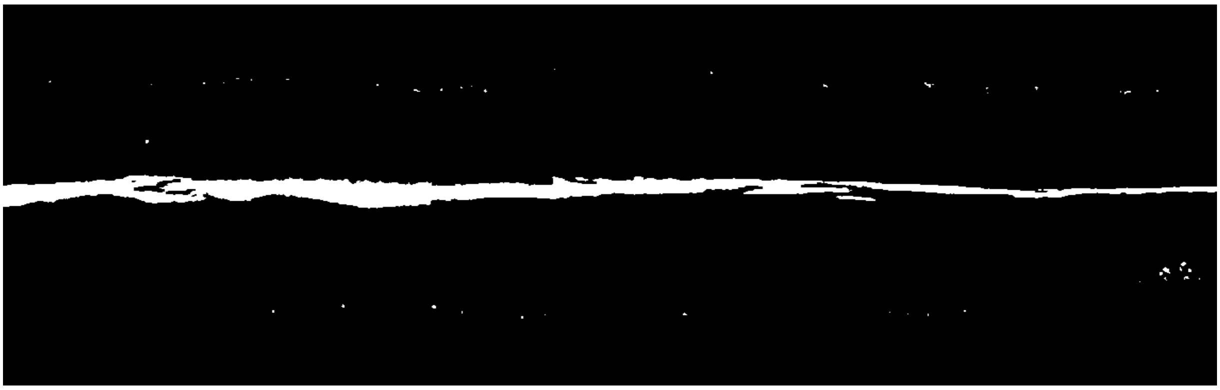


Figure 11: Fuzzy first stage output

4.4. Fuzzy Second Stage

At this point, the fis file is first created based on what the article says. Appropriate inputs and outputs were selected as follows. In each image, the fuzzy sets of inputs and outputs are shown separately.

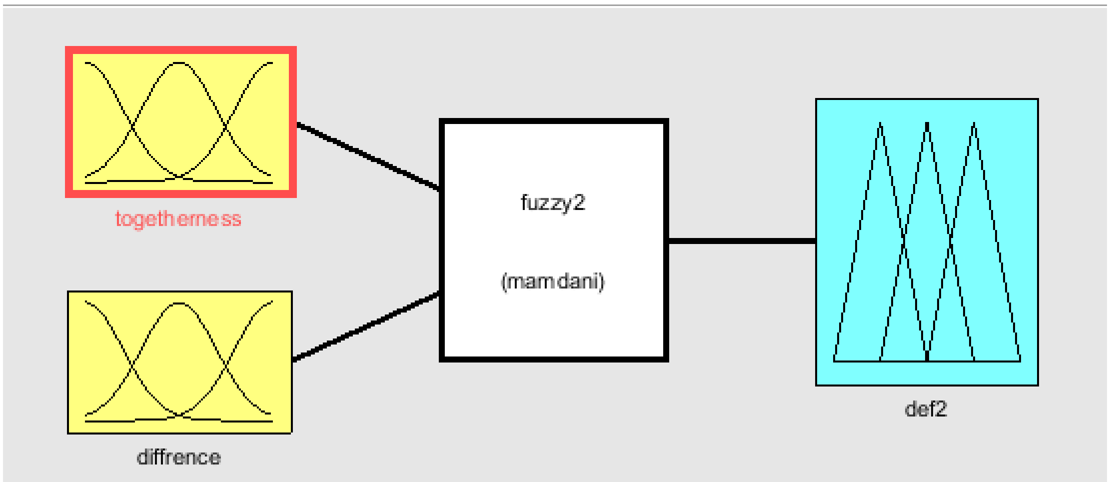


Figure 12: second stage fuzzy output.

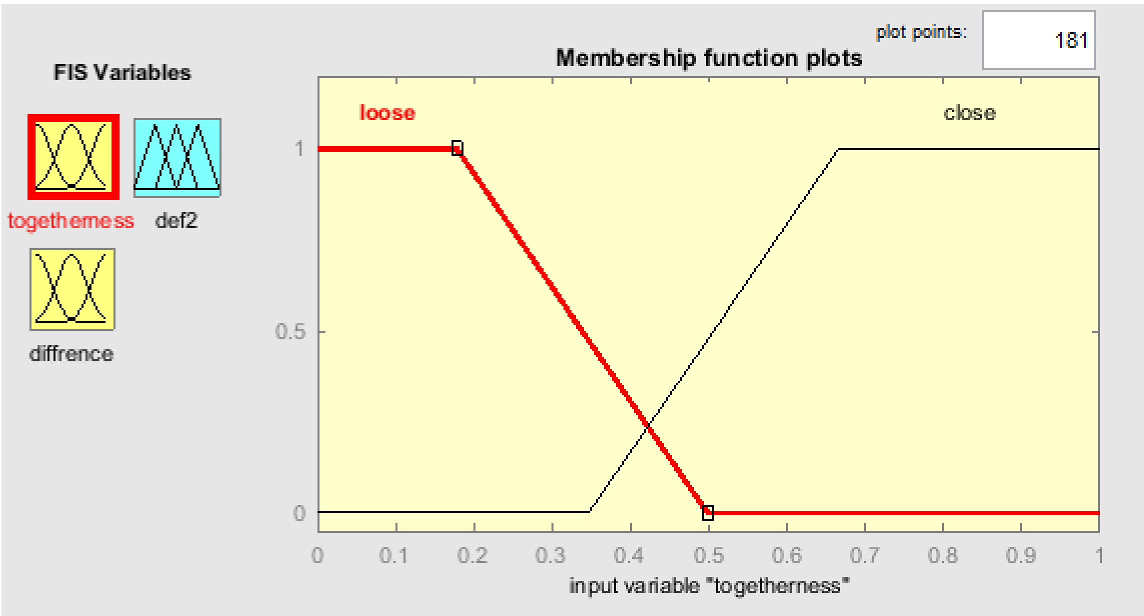


Figure 13: Graph of the correlation variable membership function.

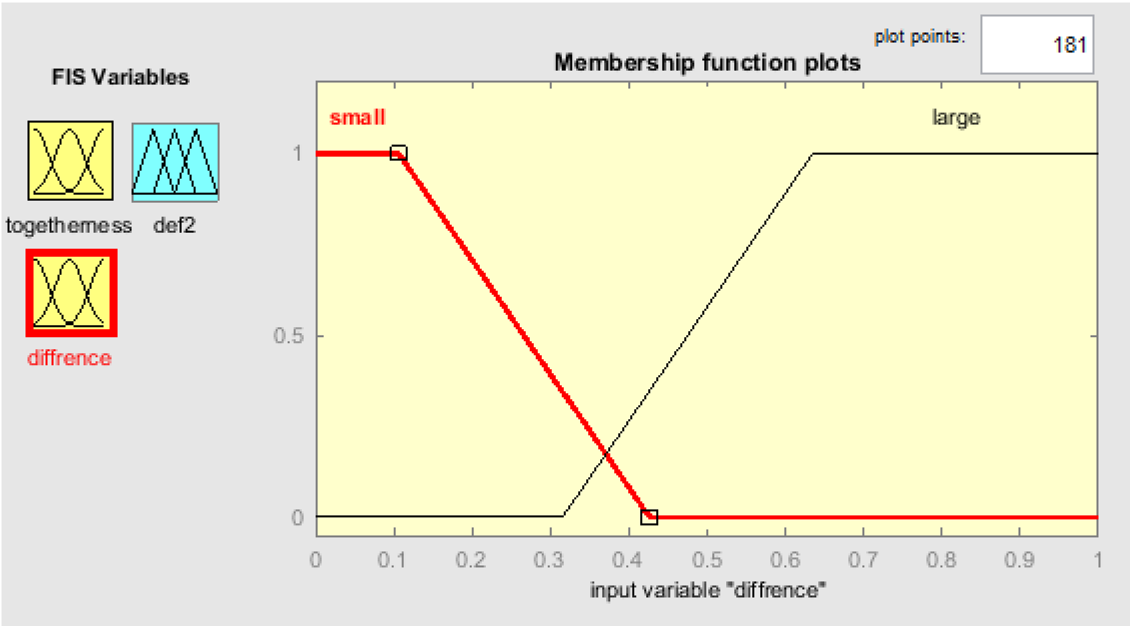


Figure 14: Diagram of the difference membership function.

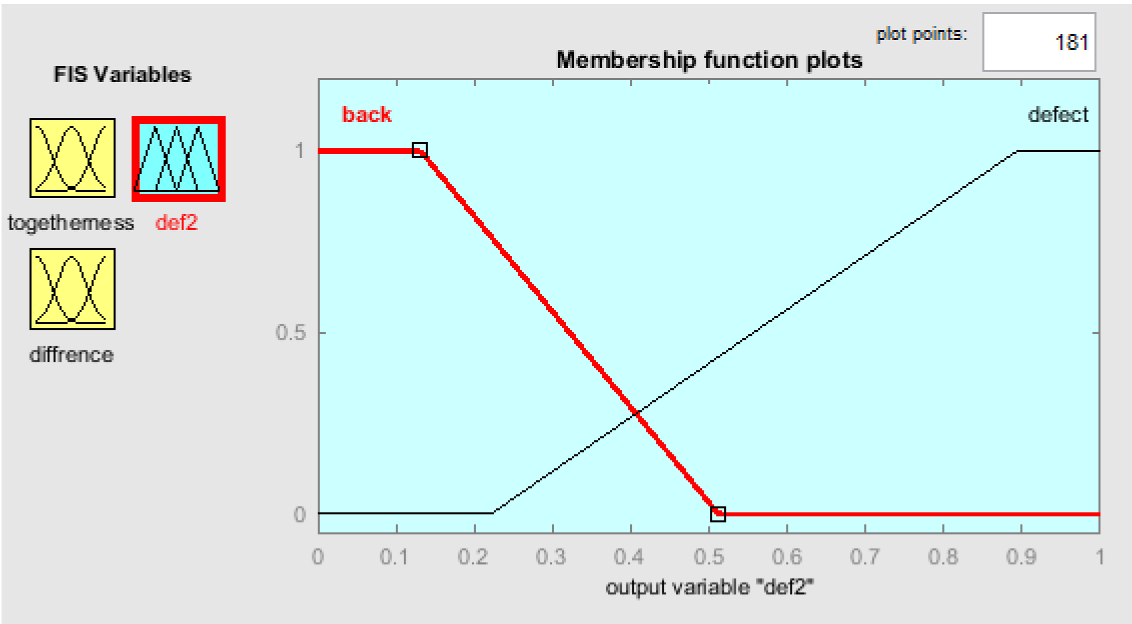


Figure 15: Graph of membership function of output value.

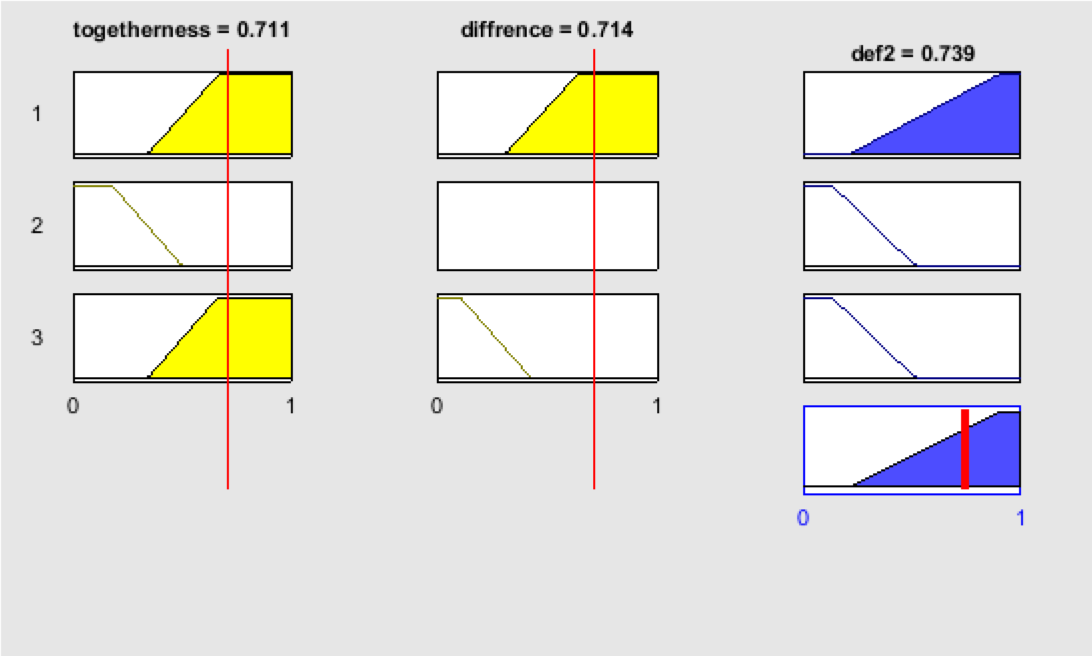


Figure 16: Fuzzy output of the second step of the proposed method for one of the tested samples

The second fis file is introduced to the system and with this output failures can be found. Values of less than 0.4 are considered to be failures. The def2 variable is the final output and represents the failures (Figure 17).

Figure 17: Neural network output

Conclusion

One of the most common tools in diagnosing welding defects is the use of welding radiographs. Due to poor quality of welding radiographic images, some welding defects such as transverse and longitudinal cracks may not be well recognized. This paper was presented to improve the quality of welding radiographic images to detect packaging defects in canned food industry using fuzzy logic. In the proposed method, the input image is first filtered by a 9 * 9 Gaussian filter with a variance of 0.2 and the mixing noise is significantly reduced due to the imaging and scanning of the image.

On the other hand, an approach for using an expert system using image processing and quality control was presented. After pre-processing on images, due to the advantages of fuzzy systems, this system was used in image processing and appropriate feature was extracted. Then, using the extracted feature, each sample was classified into two groups of healthy and damaged. Then, by filtering the image vertically and analyzing the signal by applying a matching threshold, the location of the weld image is determined and the weld image is separated from the rest of the image. In the following, a filter differentiation highlighting algorithm is constructed using a 0.25 image coefficient of amplified detail. The proposed algorithm is implemented in the MATLAB programming environment. Results show that the proposed method is effective in better and easier detection of longitudinal and transverse crack defects.

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