A Vision System for Automatic Inspection of Meat Quality

M.Barni, V.Cappellini, A.Mecocci

Dipartimento di Ingegneria Elettronica, Università di Firenze
via S.Marta n.3, 50139 Firenze, Italy

An Intelligent Perception System (IPS) is presented which makes full-rate automated inspection of chicken meat feasible. It analyzes RGB images representing the chickens after they have been washed and plucked and detects defects such as burns, hematomas and blisters, together with other relevant features. First the chicken is extracted from the background and it is segmented into its anatomic parts. Then, defective areas are identified by means of morphological reconstruction. Finally, defects are classified by comparing their features against the defect description contained in a reference database.

1 Introduction

Nowadays, quality control of alimentary products is mainly performed by means of manual inspection; however, in many cases inspector's capabilities can not meet the high-speed production rates achieved by means of the modern manufacturing facilities. The introduction of *machine vision* tools can allow a full-rate automated inspection of alimentary products. In this paper an *Intelligent Perception System* (IPS) devoted to *on line* quality control of chicken meat before packing is presented[1]. The IPS analyzes images representing chickens after they have been washed and plucked. Its aim is to detect chicken defects, along with other relevant features such as the chicken size or some parameters related to the chicken global shape. Hematoma, burns and blisters are examples of defects the IPS should detect. Information collected by the IPS is used to address the further product processing.

The IPS overall architecture is reported in figure 1. Images are gathered directly on the production line by means of an RGB CCD camera, providing 760x562 red, green and blue images, with eight bits of intensity per image. The camera is equipped with an electronic shutter, so that images are *frozen* and blurring effects due to the motion of the conveyor belt (about 70 cm/s) are avoided. The Image Vision System is devoted to image analysis; it extracts the chicken from the background, segments it into subparts, i.e. neck, legs, wings and breast, and recognizes any existing defect. Besides, the IVS measures some general features of the sample product under in-

[1] The system has been developed in connection with ALINSPEC: a project partially supported by EEC under contract number BRE2-CT92-0132.

spection (e.g. the global color of the chicken skin and the chicken size). The information extracted by the IVS is fed to the Expert System (ES) whose aim is to decide the actions to be performed on the chicken. According to the defects revealed by the IVS, the ES can decide to reject the item, or to use it for a suitable application. The IVS and the ES are interfaced to the user via the Man Machine Interface (MMI). The ES controls the Manipulation Unit, which is responsible for physically performing the actions the ES decides to undertake.

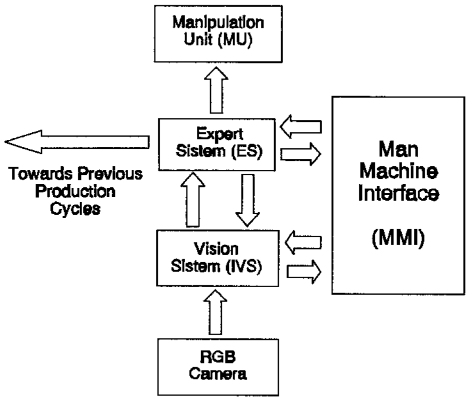

Fig. 1. Overall IPS Architecture.

2 IVS Architecture

The main tasks of the IVS are background removal, chicken segmentation and defect detection. Among them, defect detection is the most complex one, since it is affected by the great variety of defects to be revealed and by the lack of a suitable definition of them. Other requests which increase the IVS complexity are the real-time-functionality as well as the algorithm robustness. In addition to pure defect detection, the IVS also provides information for the global characterization of the hicken. These information (e.g.: the mean skin colour) are used by the Expert System to perform a full quality monitoring of the production.

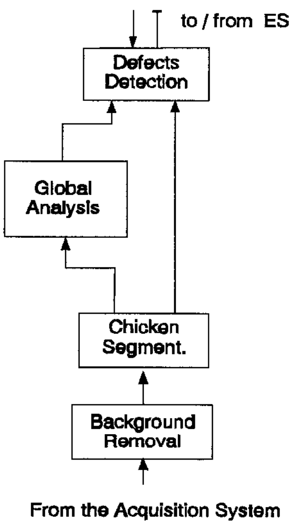

Fig. 2. Image Vision System outline.

The IVS architecture is shown in figure 2. The first action to be performed is background removal. To make such a task easier, chickens are framed against a blue rear panel which is clearly distinguishable from the chicken body. Then the chicken is segmented into its anatomic parts. On the segmented image a global analysis is performed, whose task consists of extracting some features characterizing the chicken in its entirety. These features are used by subsequent modules to adapt their behaviour to the sample currently being analyzed. The global analysis gives useful results also for the tracking of the production quality. In many cases, in fact, global features can be regarded themselves as defects, for example, if a chicken is too little it can not be used for certain applications. The detection of defects constitutes the core of the IVS. Its goal is to identify possibly defective areas and to associate them to one of the defects contained in a given reference list.

3 Background Removal

In order to distinguish the chicken body from the background, a coordinate transformation is first performed to pass from the RGB space to a perceptual representation of colours [1,2]. In fact, it has been demonstrated [2,3] that most of the information needed to extract the chicken from the background and to detect a large class of defects is carried out by the colour hue. More specifically, a coordinate system has been adopted which is obtained by considering the same intensity of the HIS system and by using a cartesian representation for the H and S coordinates, which in the HIS space are expressed in polar form. The coordinate transformation from the RGB to the new system, is expressed by the following equations

$$I = \frac{r+g+b}{3}\ ; \quad C_1 = \frac{b}{r+g+b}\ ; \quad C_2 = \frac{1}{2}\frac{2r+b}{r+g+b}$$

By considering only the two chrominance features (C_1, C_2) and by plotting the scattergram of the chicken images, two well separated clusters appear: a yellowish cluster corresponding to the chicken body and a bluish cluster relative to the background. The area between the clusters is filled by pixels lying on the contour of

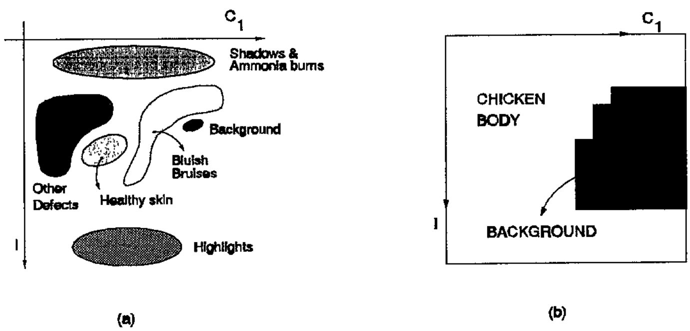

Fig. 3. a) Rough position of the various classes of pixels in the C_1-I space; b) mask used to separate the background from the chicken body.

the chicken. These pixels have intermediate colours between that of the background and those of the chicken skin. It is worthwhile noting that pixels belonging to bluish bruises and shadowy areas can belong to the sparse area between the clusters or even to the blue cluster, so they cannot be distinguished from the background on the basis of chrominance information only. Upon inspection of the scattergrams it also appears that the C_1 feature is sufficient to discriminate between the two clusters. To account for bruise and shadowy pixels, intensity information must be taken into account. In particular, the following points must be considered: pixels relative to healthy skin always belong to the yellowish cluster; pixels relative to bluish bruises belong to the sparse area between the clusters or to the blue cluster, they can be distinguished from the background since they are darker; with regard to pixels belonging to other defects, three cases are possible: they belong to the yellow cluster, they are darker than the background, they are reddish (very small C_1 values); shadowy pixels are darker than the background; pixels belonging to highlights are brighter than the background. The position of the various classes of pixels on a bidimensional feature space, is summarized in figure 3a. To segment the images into chicken and background, the mask reported in figure 3b has been built which splits the features space into two parts: pixels whose features lie inside the white area are classified as chicken pixels, while the others are labeled as background pixels. Background removal has been tested on more than 250 images, and in all the cases it succeeded in distinguishing the chicken from the background.

4 Chicken Segmentation and Global Analysis

Chicken segmentation is achieved by means of mathematical morphology [4]. In particular, an opening is performed with the structuring element chosen in such a way that wings, legs and neck are discarded and only the breast is left. In order to cut legs more sharply, a properly shaped kernel has been used instead of a classical circle. Besides, the kernel size is computed on the basis of the chicken area, thus making the system adaptive with respect to the chicken size.

With regard to global analysis the main task to be performed is the chicken classification according to skin colour. Two different kinds of chicken have been considered: white and yellow chickens. The importance of determining the colour of the chicken skin stems from the fact that skin colour affects the detection of colour-related defects, e.g. hematoma, bruises, livid areas, ammonia burns and so on. Along with white and yellow chickens a third class has been introduced to take into account abnormal skin colour. Defective chickens such as incompletely bled chickens belong to this class. Several approaches have been investigated to achieve a good classification. The best results have been obtained by means of a classical Bayesian classifier with an error probability of 5.3% which, compared to the error probability obtained by means of a manual classification (3.6%), witnesses the effectiveness of the adopted approach.

5 Detection of Defects

So far, the attention has been focused on the detection of colour-related defects, i.e, bruises, ammonia burns, blisters, livid areas and incomplete bleeding. In figure 4 the main steps involved in the defect detection process are summarized. First two sets of points are built: the former comprises pixels whose probability of belonging to defective areas is very high, whereas pixels belonging to the latter set, labeled as *uncertain*, are likely to be defective only to a lesser extent. Classification of defective and uncertain pixels is achieved by carrying out a statistical analysis on the chromatic features of healthy skin. By considering only pixels representing healthy skin, I, C_1 and C_2 can be assumed to be distributed according to a multivariate normal distribution whose parameters have been determined statistically. Then, for each pixel in the images, the Mahalanobis distance from the healthy skin cluster is computed. According to such a distance, pixels are classified as defective, uncertain or healthy.

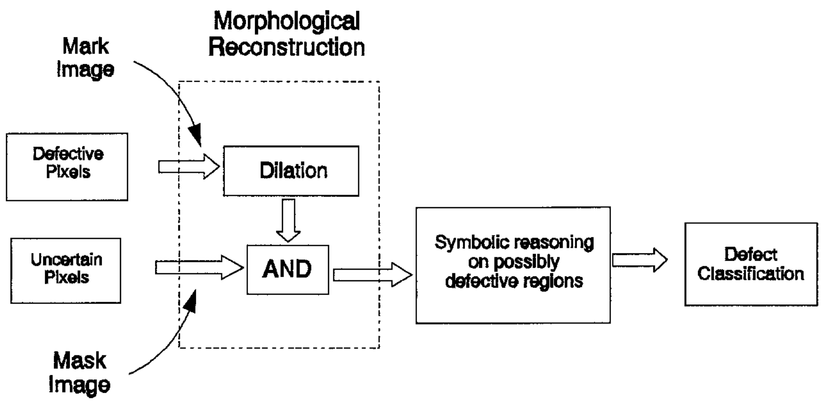

Fig. 4. Processing chain for the detection of defects.

At this point morphological image reconstruction [5] is applied to build possibly defective regions. Let I and J be two binary images, and suppose that $J \subseteq I$, i.e. $J(p) = 1 \Rightarrow I(p) = 1\ \forall p$. J is called the *marker* image, whereas I is referred to as the *mask* image. The morphological reconstruction $R_J(I)$ of mask I from marker J is defined as the union of the connected components of I which contain at least one pixel of J

$$R_J(I) = \bigcup_{J \cap I_k \neq \emptyset} I_k$$

where $I_1, I_2, ..., I_n$ are the connected components of I. In our case, the marker image contains only defective pixels, while the mask image is composed by defective and uncertain pixels. The next task to be performed is symbolic reasoning on the regions extracted so far. Symbolic reasoning is necessary to minimize the number of false alarms, since morphological reconstruction fails to extract only really defective areas. Thus, regions on chicken borders are discarded as well as regions containing too many highlight pixels or very small regions. Finally, a Bayesian classifier associates each region to a particular defect.

6 Experimental Results and Future Works

Experimental results show the effectiveness of the proposed approach. The IVS has been tested on 150 images; for each of them the background has been removed and the chicken subparts successfully extracted. Classification results are summarized in Table I. For sake of simplicity the table considers only two classes: healthy and defective chickens. In the table the confusion matrix is reported together with the average error probability and the two probabilities of either missing a defect or rising a false alarm. The values along the diagonal represent the percentage of correctly classified images for each class; values along a given row indicate how misclassified chickens are distributed among the classes. The average error probability is 10.68%, with a false alarm rate of 10%. The probability of missing a defect, i.e. to classify as healthy a defective chicken, is 11.7%. Future work includes the analysis of other classes of defects such as shape and texture-related defects. Besides, we will try to increase algorithm robustness: different approaches will be investigated, among them fuzzy techniques are likely to provide good results.

TABLE I
CONFUSION MATRIX

	Mapped Class		
True Class	Healthy	Defective	Number of test images
Healthy	90%	10%	90
Defective	11.7%	88.3%	60

$P_e = 10.68\%$
P(false alarm) = 10%
P(missing a defect) = 11.7%

7 References

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