COMPUTER VISION IN THE MEAT INDUSTRY : CONTROL OF AUTOMATIC CUTTING OF PIG CARCASSES

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SUMMARY

The objective of our researches is to achieve a visual feedback control which would be part of an automated process for the cutting of carcasses. In order to execute this control, we have to be able to extract from images of the carcass geometric patterns which are discriminating of the cutting paths. In this paper we describe methods of image processing through which the necessary visual information can be obtained.

Introduction

Computer vision has become quite commonly used in the industry during the last few years. It is mainly utilized : first for the quality control of manufactured products and second as a sensor contributing to the control system of robots. However, it is still rarely implemented in the meat industry, as automation is not yet very developed there, especially for slaughtering and cutting operations. Nevertheless, two kinds of application can be mentioned : i) the estimation of the fat content of meat cuts (Chen and al., 1992) or of comminuted meats (Newman, 1992) and the grading of carcasses (O'Grady, 1989 ; Jones and al., 1992 ; Van der Stuyft and al., 1992) ; ii) the automation of cutting or deboning (Purnell and al., 1990 ; Salé, 1991 ; Anon., 1994).

The automation of slaughter and cutting operations is a real challenge for the meat industry : a significant decrease of the microbiological contamination of carcasses and cuts, as well as the elimination of toilsome or dangerous tasks and thus the reduction of the number of accidents at work or more generally the decrease of absenteeism depend on it.

Our own work dealt with primal cutting of pig carcasses. More precisely we studied three cutting paths with simple geometry : first, the separation between loin and belly ; second, the cutting of the leg ; third the cutting of the trotter. We do not use computer vision in order to measure the half-carcass neither to compare it with a model. We use it to determine directly the precise location of cutting paths, in reference to anatomic elements which are identified in images taken by one camera. Thus we may think of doing a visual feedback control : indeed in such a control system, the camera and the operating tool are interdependent, their movement being slave to the location of a pattern in the image (Chaumette, 1990). Then the deformations or shifting of the carcass occurring during cutting can be taken into account in the control procedure.

In this paper, we describe the methods of image processing which were used to determine the three cutting paths that we studied and to locate the corresponding areas of interest within a view of the whole half-carcass. Then we present potential ways of integration of these results in the design of an automated cutting device.

Materials and methods

Determination of the paths

The aim was to find patterns discriminating the three paths that are studied. Therefore images of various anatomic parts of the carcasses were used.

Several pig sides were filmed at the experimental cutting facilities of the Meat Institute Development Association (A.D.I.V.). The obtained data are grey level images coming from a CCD camera and registered with a PCcomputer. Four images of each half-carcass are taken : the first one shows the whole half-carcass, the second one shows the trotter, the third one gives a view of the leg, the last one shows the loin and the belly.

In view of executing a visual feedback control, one has to use quite simple patterns : points, straight lines, circles... Two kinds of algorithms have been developed in order to obtain these patterns : first an edges segmentation of the images, second an areas segmentation.

Edges segmentation

An extraction of edges is effective to perform the recognition of the backbone and of the joint of the trotter, which are the anatomic references utilized to locate respectively the first and the third cutting paths. Indeed the shapes which are sought in the image offer a strong difference of grey levels with the surrounding objects.

In order to obtain a binary image of the contours, a gradient filter is applied to the image of grey levels, the modulus of the gradient is computed for every point. Only the points which have a gradient modulus higher than a chosen threshold are kept.

In the image showing the loin and the belly, the backbone, as well as the edges of the half-carcass can be approximated to straight lines. In order to find such patterns, a HOUGH transform is applied to the image of edges (Besanson, 1988). This transform allows to detect straight lines in a set of points. In the present case, the search is restricted to vertical straight lines, given the direction of the carcass in the image. The HOUGH transform gives all the vertical straight lines, so it must be filtered to keep only those which are the result of the alignment of a sufficient number of points of the edges. To perform it, the transform is thresholded. Thus, straight lines representing the backbone and the contours of the half-carcass are obtained.

The edges extracted from the image of the trotter fit to its actual edges. The first step of the treatment consists in chaining the edges points, i.e. for each point one searches a neighbouring point which is adjacent to it. Two chains are obtained, which represent the left and right contours of the trotter. These curves are filtered in order to reduce noise influence, then the maxima of the distances from each curve to the median axis of the leg are determined. They correspond to the location of the joint of the trotter.

Areas segmentation

The anatomic element used as a reference for the cutting path of the leg is the section of the hip-bone appearing in the split plane. The difference between the grey levels is not sufficient to detect it, so an areas segmentation with mathematical morphology functions (Coster and Chermant, 1989) is performed to find the muscular block of the thigh.

In a first time, an opening of the grey level image is executed to build homogenous areas. Next, a thresholding is performed, so that only areas with the lower grey level are kept. The detection of the muscular block is achieved by an operation of ultimate erosion.

Then, the major axis of the shape are computed and the position of the hip-bone is found.

Analysis of the carcass

The images allowing to find the patterns of the three paths correspond to three positions of the camera near the product. To move the sensor toward these positions, the analysis of an image of the whole side is necessary.

This processing aims to obtain from the edges of the half-carcass patterns that can be used to control the movement of the camera.

At first, an extraction of edges is performed as previously described. The external edge of the half-carcass is obtained. Then, this edge is coded in polar coordinates according to a frame with its origin at the barycentre of the edge points.

This encoding represents a signature of the shape. The maxima and minima of the signature correspond to particular points of the carcass edge. They represent, for example, sudden variations in angle of the edge. From these particular points, one gets a simplified representation of the half-carcass as a polygon.

Through this representation, the control of the sensor movement according to simple geometric patterns like straight lines or triangles is possible.

The signature of the edge also allows to differentiate between the right and left half-carcasses, as well as between the half-carcass and other objects that can be present in the scene.

Results and discussion

Results of algorithms

The algorithms that we described above have been applied to forty pig sides. The reference of the trotter cut has been successfully detected in each case (see an example on figure 1), as the one of the thigh (see figure 2).

On the other hand, for the backbone, only the images recorded while the interior of the half-carcass was lighted allowed to obtained the patterns (see figure 3). The signature of edges have been also successfully extracted for every half-carcass.

Use of patterns

The results show that we can obtain from grey level images discriminating patterns for the paths. We can use these data in a visual feedback control. To do it, the camera must be boarded on the robot which executes the cutting operations.

The patterns can be utilized as follow : an image of the pig side is grabbed, then the simplified polygon of its edges is computed. The movement which will bring the sensor to the required final position are calculated according to both this position (for example in front of the backbone) and the position of relevant points of the polygon in the image.

While the sensor is moved, other images are grabbed and the coordinates of the relevant points extracted from these images are computed. So, the trajectory of the sensor can be updated through the new visual information taking into account the trajectory of the robot and the deformation of the product. As the computation of the robot trajectory is only a function of the coordinates of the patterns in the image, there is no need to compute a three dimensional model of the robot environment. Moreover, the computed cutting paths are fitted to the considered side without any previous information about its morphology being necessary.

When the sensor has reached the required position, a new task can be executed with a new set of patterns (for example the cutting of the loin according to the straight lines symbolizing the backbone).

Conclusion

Using different techniques of image processing (HOUGH transform, morphology functions, analysis of edges chains) we succeeded in determining discriminating patterns of the three cuts studied. We also were able to find on a view of the whole half-carcass areas of interest requiring a detailed analysis by coding the edges in a signature form.

Our further work will consist in testing the validity of our patterns in a visual feedback control, in a first time by simulating the movement of the camera, then in real conditions.

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figure 1 : patterns of the trotter cut

figure 2 : patterns of the leg cut

figure 3 : patterns of the backbone