AUTOMATION OF DEBONNING OF CURED HAM

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INTRODUCTION

In the meat industry, the automation of cutting operations, resulting in reduction, and even suppression of manual and relatively hard tasks, is a way to obtain an improvement of the hygienic quality of meat products, a lowering of the number of work accidents and also, according to its evolution stage, a gain of productivity. It is the case for our application which deals with the automation of debonning of cured ham. Such an automation implies to obtain, by sensors, a set of information on the location of the main anatomic parts (muscles, bones). Artificial vision is the tool studied to obtain the desired information, which serve as a reference for cutting paths. A number of research projects aiming to the automation of the cutting and debonning operations, including the development of vision systems, have been carried out during the last ten years [1] [2] [3] [4] [5] [6]. In this paper will be presented operations of the new process of debonning studied, the different works achieved about the ham modeling, and the methods used to obtain the automation of the presented process.

THE OPERATIONS OF THE DEBONNING PROCESS

The debonning process can be decomposed in three main tasks : ham gripping, cutting operations of the muscular masses and traction on the muscular masses.

Ham gripping

The ham is caught by two anatomic points (figures 1 and 2) : the back of the knee and the head of the femur bone. These two characteristic points are automatically detected with artificial vision.

Cutting of the muscular masses

The cutting operations are achieved in the medial and cranial face of the ham as represented in figures 3 and 4. The ischium bone extraction is realized before these operations. The cutting trajectories are obtained automatically, using a mathematics model of the ham which has been built and which will be presented later.

Traction on the muscular masses

Two traction operations are realized on both sides of the cutting lines achieved previously. They are accompanied, if necessary, by cutting operations of the links between the muscles and the bones to separate completely the meat from the bones. The positions of the traction clamps are presented figure 5.

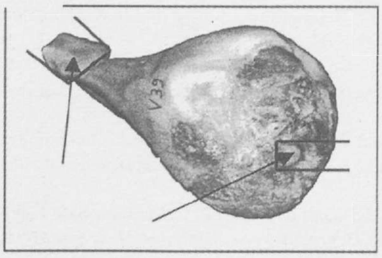

Figure 1 – Gripping points for medial face

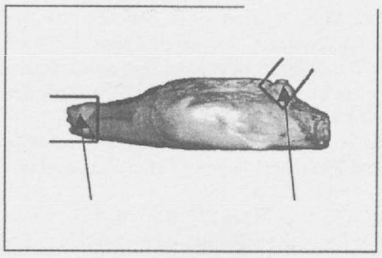

Figure 2 – Gripping points for cranial face

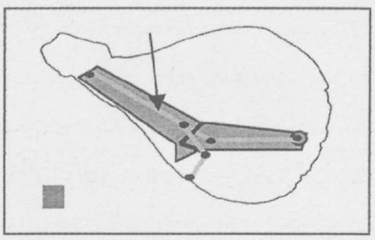

Figure 3 – Cutting lines for medial face

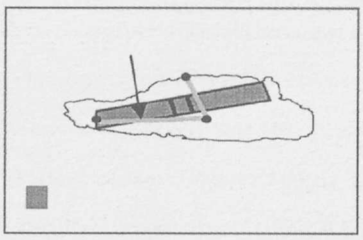

Figure 4 – Cutting lines for cranial face

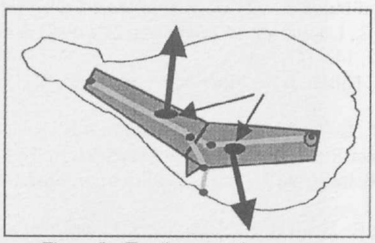

Figure 5 – Traction operations

FINAL STATE : - The bones (back of the knee, tibia, femur, patella, fibula) stay hooked to the gripping system.
- The meat is retrieved on a conveyor belt. It is destined to the next posts : removal of the rind and others parts not edibles, seaming, stamping operations.

HAM MODELING

The modeling works of the ham have been achieved on one hand to determine the geometric variability of the main characteristic sizes of the external surface of the ham and of the different bones for the mechanization of the process, and on the other hand to find relations, correlation between the different elements for the automation.

We have constituted a sample of 90 hams left and right representing different classes of weight and time of drying. We had for every ham two video images representing the medial and cranial face (figures 1 and 2) to have information about the external surface of the ham, one radiography (figure 6) of the medial face and all the bones (figure 7) for the internal information.

Geometric modeling

Geometric models representing the external surface of the ham and the bones have been constituted. To obtain these polygonal models, we have selected different points from the video and radiography images, easy to detect for all the hams of the sample (figures 8, 9 and 10).

Statistical modeling

From the points in the geometric model, the main length, width and thickness of the external surface of the ham, and of the bones have been selected. Statistical calculations of the distances and of the positions in the space of the different points, have been realized (average, standard deviation, minimum, maximum) for the sample of hams. Also, correlation between the data have been computed in order to have relations between them.

Mathematical modeling

In figures 11 and 12 some data are obtained by artificial vision automatically : (J, J1, J2, J3, J4, C, ϕ, Fm and Fc) The others in fine line representing the position of the main bones (tibia, femur and patella) are extracted using a mathematical model of the ham which lies twice data, by linear equations. For example, the angle α between tibia and femur bones is obtained from ϕ, which is the angle between axis back of the knee – femur (JFm) and the ham direction (J2C), with a linear equation.

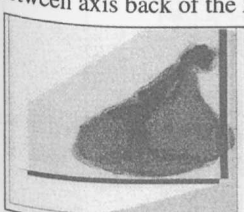

Figure 6 – radiography

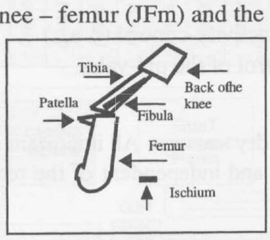

Figure 7 – The bones

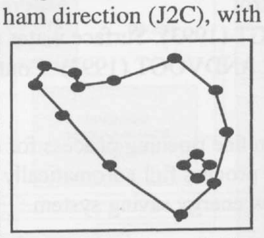

Figure 8 – Points for medial face

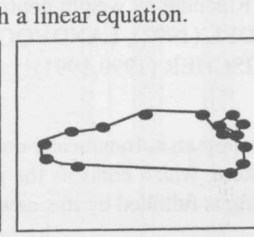

Figure 9 – Points for cranial face

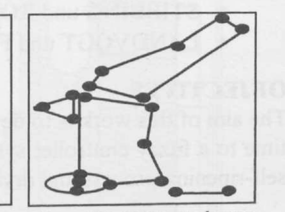

Figure 10 – Points for bones

DETECTION OF THE MODEL ELEMENTS BY VISION

For the back of the knee, we consider the medial face and we sweep a straight line (AB) parallel to the inertial axis IX (figure 13) up to reach twice points J1 and J2 using a distance criterion between twice points. J3 and J4 are obtained by stereovision from J1 and J2. J is the middle of points J1, J2, J3 and J4.

The line segment J2C corresponds to the direction of the ham on the medial face, in the cranial side.

The head of the femur bone is obtained using a correlation method (figure 14). We have established a model of this anatomic element (figure 14 lower-left) and we sweep the medial face computing the correlation coefficient between the model and all the windows (size x,y) of the image. The maximum value correspond to the femur detection Fm. The point Fc in the cranial face is obtained from Fm by stereovision.

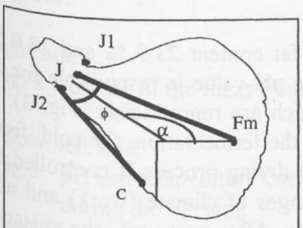

Figure 11 – Model for medial face

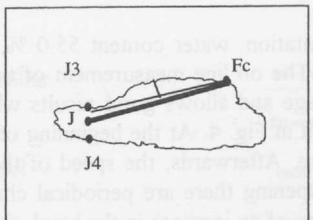

Figure 12 – Model for cranial face

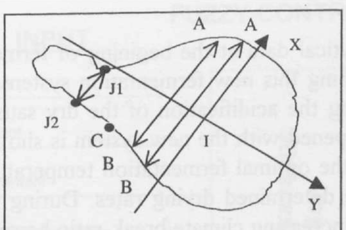

Figure 13 – Detection of J1, J2 and C

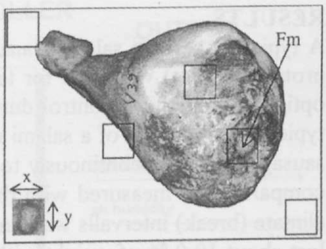

Figure 14 – Detection of the femur bone

Once the elements of the external surface of the model are detected we apply the mathematical model to obtain the position of the different bones, necessary for the automation of ham gripping, cutting operations and traction.

CONCLUSION

This debonning process studied can present different levels of automation. One can consider a system fully automated for the different operations or a partial one, in which, for example, an operator uses some data obtained by vision to make some cutting operations, difficult to automate, like for example the extraction of the ischium bone. We are working about the fusion of data coming from artificial vision and other sensors, particularly the force sensors and dielectric sensors in order to have a better accuracy in the detection of the position of the different bones.

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