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Development of Mobile Type Computer Vision System and Lean Tissue Extraction Algorithm for Beef Quality Grading

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Abstract

Major quality features of the beef carcass in most countries including Korea are size, marbling state of the lean tissue, color of the fat and lean tissue, and thickness of back fat of the 13th rib. To evaluate the beef quality, extracting loin parts from the sectional image of the 13th beef rib is crucial and is the first step. However, because of the inhomogeneous distribution and fuzzy pattern of the fat and lean tissues on the beef cut, it is difficult to extract automatically the proper contour of the lean tissue. In this paper, a prototype mobile beef quality measurement system, which can be implemented practically at the beef processing site was developed. The developed system was composed of the hand held image acquisition unit and mobile processing unit mounted with touch-pad screen. Algorithms to extract the boundary of the lean tissue and a proper tool to evaluate the marbling status have been developed using color image processing. The boundary extraction algorithm showed successful results for the beef cuts with simple and moderate patterns of the lean tissue and fat. However, it had some difficulty in eliminating complex pattern of the extraneous tissues adhered to the lean tissue in the boundary extraction. The developed algorithms were implemented to the prototype mobile processing unit.

Keywords : Lean Tissue Contour, Marbling, Beef Quality, Color Computer Vision

1. INTRODUCTION

For the past several decades, the quality and yield grades for beef have pursued to reduce the fat amount of the carcass associated with beef yield. In Korea, beef carcass value depends upon two important aspects, one is quality such as marbling and maturity, the other is composition such as total lean tissue, fat and bone, or lean with some acceptable level of fat and bone to be trimmed. Development and installation of a system for instrumental assessment of carcass value would be critical because livestock producers are not sufficiently confident in current, subjective grading systems. Recently the AGPS (animal products grading service, Korea) is very much interested in the research and development of an instrument capable of evaluating carcass lean tissue.

Automation of beef quality evaluation process requires measurement of major attributes such as color, texture, distribution and ratio of fat, and the freshness of the sectioned beef carcass. Extracting boundary of the interest, lean tissue, is essential and the first step for the quality evaluation of the beef. Through this contour information of lean tissue,

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quantification of size, color, and marbling state of lean tissue is possible. However, since the boundary of the lean tissue is sometimes very complex and obscure, it is very difficult to separate its boundary automatically.

Automatic lean tissue measurement using machine vision was reported by Chen et. al, 1995. And the algorithm for rapid and robust separation of lean tissue from its surrounding fat and other tissues in a beef carcass was developed based on the grey intensity of the cross sectioned cut image by Hwang et. al 1997. A neural network scheme was utilized to identify the boundary of the lean tissue. Though it worked in a robust way but it required a lot of work to prepare the training set for the network.

In this paper, a prototype mobile beef quality measurement system, which can be implemented practically at the beef processing site was presented. The developed system was composed of the hand held image acquisition unit and mobile processing unit mounted with touch-pad screen. Algorithms to extract the boundary of the lean tissue and a proper measurement tool to evaluate the marbling status have been developed using color image processing. And developed algorithms were implemented to the prototype mobile processing unit.

2. MATERIALS AND METHOD

2.1 Mobile Image Processing Unit

Thirty images of sample beefs were collected from the 13th rib at the "Garak (slaughter house)" agricultural fresh market in Seoul using developed mobile image acquisition and processing unit. The developed mobile unit was composed of the hand held image acquisition unit (Figure 1) and mobile computing unit (Pentium-3 700 MHz with Matrox Meteor2/MC4 frame grabber) mounted with 12" TFT touch -pad screen (Figure 2). Switch button was put on the handle. When image was ready to be captured, button was pressed. Circular shape LED lighting device and micro color progressive scan CCD camera (CV-735, JAi) were assembled as a cap shape. Figure 3 is the image obtained by the hand held image acquisition device. The measurement and analysis software was made with visual Basic.

2.2 Lean Tissue Segmentation

Since colors of the lean tissue and fat are different from each carcass depending on its quality, lean tissue segmentation via threshold scheme is not simple process. In order to solve the difficulties of the segmentation caused by the color variation of the lean tissue, brightness of the red channel image at the pre-specified area of beef carcass was inspected. The pre-specified area was roughly determined to include the lean tissue portion of the beef carcass. First, images (640 pixels along x axis and 480 pixels along y axis with 8 bit intensity levels) of the beef-cut surface were cap-

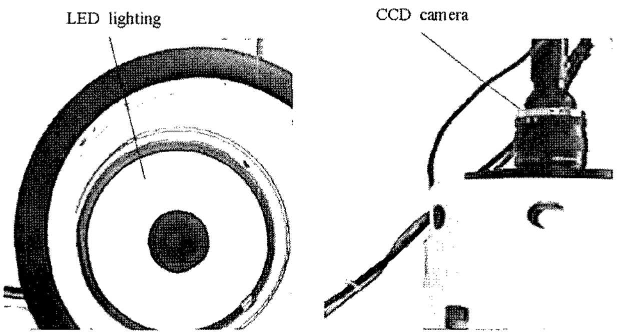


Fig. 1 Hand held image acquisition device.

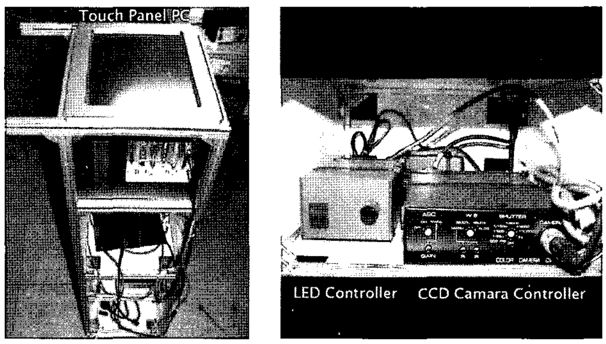


Fig. 2 Mobile frame with touch panel PC and controllers of lighting and camera.

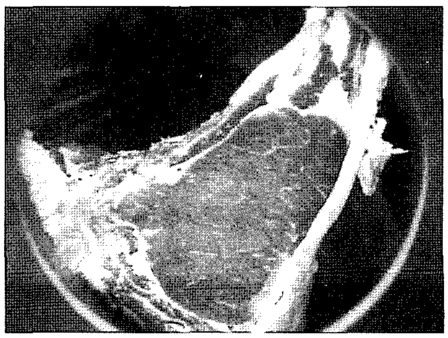


Fig. 3 Image obtained by the hand held image acquisition device.

tured from red, green, and blue channel. By inspecting brightness range of pixels of the pre-specified rectangular sub-image area such as $x \in [220,320]$ $y \in [240,340]$ in the red frame image of the beef-cut surface, threshold values for green and blue frame images were selected.

Then, the beef-cut surface images from red, green, and blue channels were divided into two parts. One part was the rectangular sub-area specified by $x \in [300,430]$ and $y \in [170, 370]$. And the other part was outside area of the specified rectangular sub-area. Images of the red, green, and blue frames of each part was segmented using selected threshold values and logical AND operation was performed with the resulting images.

The segmentation process was summarized as following.

1) Check the intensity range of red frame image in the sub-area, $x \in [220,320]$ $y \in [240,340]$.
2) Count the pixels in the intensity ranges $40 \leq R(x, y) < 90$, $90 \leq R(x, y) < 98$, $98 \leq R(x, y) < 130$, and set each value as R1, R2, and R3 respectively.
3) Perform segmentation in the sub-area, $x \in [300,430]$ $y \in [170,370]$.
   Set $G_{TH}=115$, $B_{TH}=125$, $R_{TH1}=50$
   If R1 or R2 is max., $R_{TH2}=125$
   If R3 is max., $R_{TH2}=150$
   Perform threshold process.
   $R(x, y)=255$ if $R_{TH1}<R(x, y)<R_{TH2}$
   0 otherwise
   $G(x, y)=255$ if $G(x, y)<G_{TH}$
   0 otherwise
   $B(x, y)=255$ if $B(x, y)<B_{TH}$
   0 otherwise
   Do logical AND with resulting three images.
4) Perform segmentation in the outside of the sub-area, $x \in [300,430]$ $y \in [170,370]$.
   Set $R_{TH1}=50$
   If R1 is max., $G_{TH}=80$, $B_{TH}=80$, $R_{TH2}=108$
   If R2 is max., $G_{TH}=80$, $B_{TH}=76$, $R_{TH2}=114$
   If R3 is max., $G_{TH}=100$, $B_{TH}=100$, $R_{TH2}=115$
   Do logical AND with resulting three images.

And then labeling was performed using 8-connectivity to segment the loin parts of the beef. The blob which had maximum pixel area was identified as loin tissue.

To simplify the boundary of the lean tissue and to remove the small blobs of the inner muscular fat of the lean tissue, filling after morphological dilation were performed. Dilation was performed two times with 5×5 rectangular mask to soften the severe prominence and depression of the boundary and to fill the small size holes in the lean tissue parts. Filling was performed via eliminating rather large blobs within the lean tissue which were not filled with dilation operation. For filling operation, the dilated binary image was reversed such that white (loin part) to black and black (parts of fat and background) to white. After labeling the reversed image again, the small blobs (white parts) are converted to black. Then the resulting image was reversed back.

To reduce the exaggerated effect of the dilation, the erosion with 5×5 rectangular mask was performed one time. Boundary was extracted for the eroded image using line tracing based on the 8-directional chain coding.

2.3 Evaluation of marbling state

To determine the status of marbling, co-occurrence matrix was obtained from the segmented lean tissue image. Using the red channel frame image, the inside area of the extracted boundary of the lean tissue was binarized with intensity value of $R_{TH}=135$ as following.

$R(x, y)=255$ if $R(x, y)<R_{TH}$: Lean tissue
0 otherwise : Fat

The horizontal path mask was chosen among four possible paths to obtain the co-occurrence matrix as shown in Figure 4.

Four different texture indexes such as element difference moment, entropy, uniformity, and area ratio were used. Each index is described as following. Five visually recognizable different marbling samples as shown in Figure 5 were

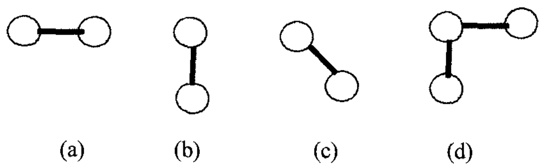


Fig. 4 Four different path masks.

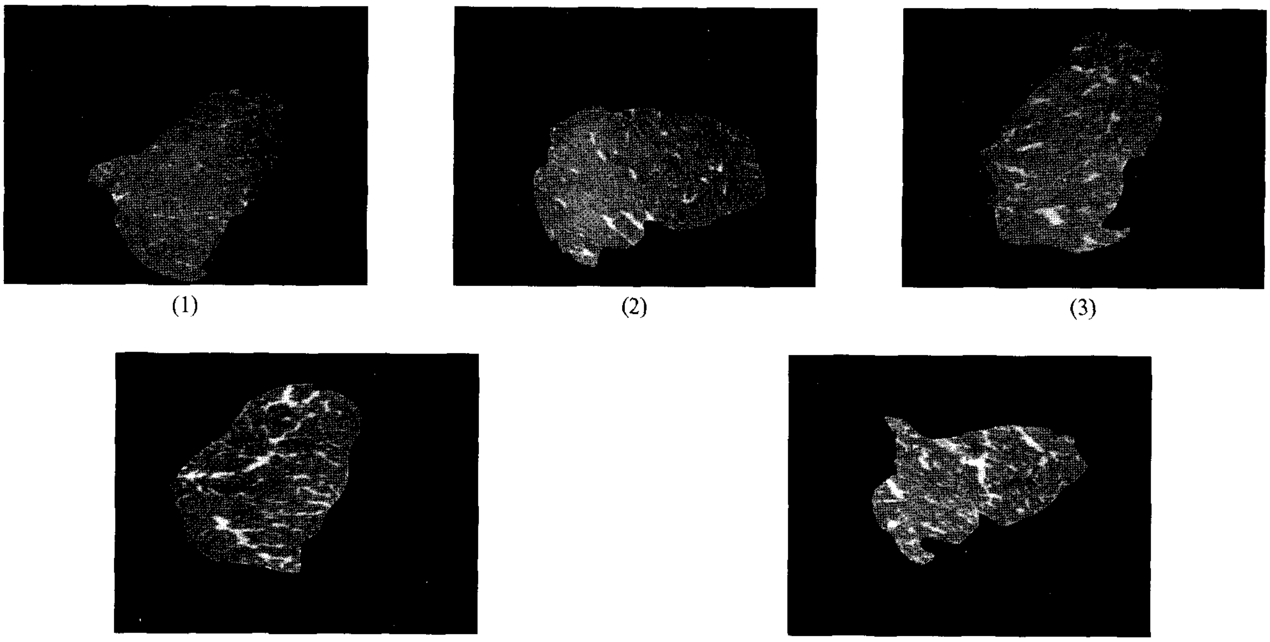


Fig. 5 Five samples of beef with visually recognizable different marbling states (marbling state 5>4>3>2>1).

used to investigate the correlations of four different indexes to the state of marbling.

EDM (element difference moment) : $\sum_i \sum_j (i-j) C_{ij}$

ENT (entropy) : $\sum_i \sum_j C_{ij} \log C_{ij}$

UNF (uniformity) : $\sum_i \sum_j C_{ij}^2$

Maximum Probability (MP) : $\underset{i,j}{Max}(C_{i,j})$

3. RESULTS AND DISCUSSION

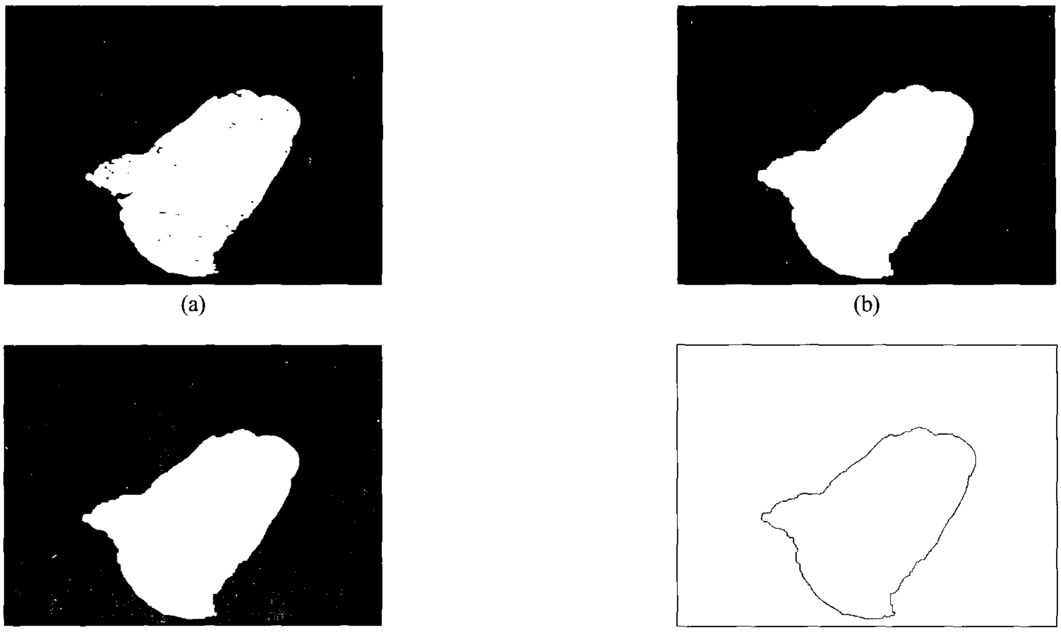
3.1 Lean Tissue Segmentation

Images of the red, green, and blue frames of each part was segmented using selected threshold values and logical AND operation was performed with the resulting images. Figure 6 shows the results of the logical AND and the labeling process.

Figure 7-(a) is the result of the two successive dilations using 5×5 rectangular mask. Severe prominence and depression of the boundary was softened resulting in the simplified boundary. Figure 7-(b) shows the image after filling the inner muscular fat after eliminating rather large blobs within the lean tissue which were not filled with dilation operation. Figure 7-(c) shows the image after applying erosion one time with 5×5 rectangular mask. The exaggerated effect caused by the dilation was reduced. Figure 7-(d) shows the extracted boundary for the eroded image

(a) (b)

Fig. 6 Image after logical AND of three threshold images for red, blue, and green frames (a) and image after labeling process using 8-connectivity (b).



(a) (b) (c) (d)

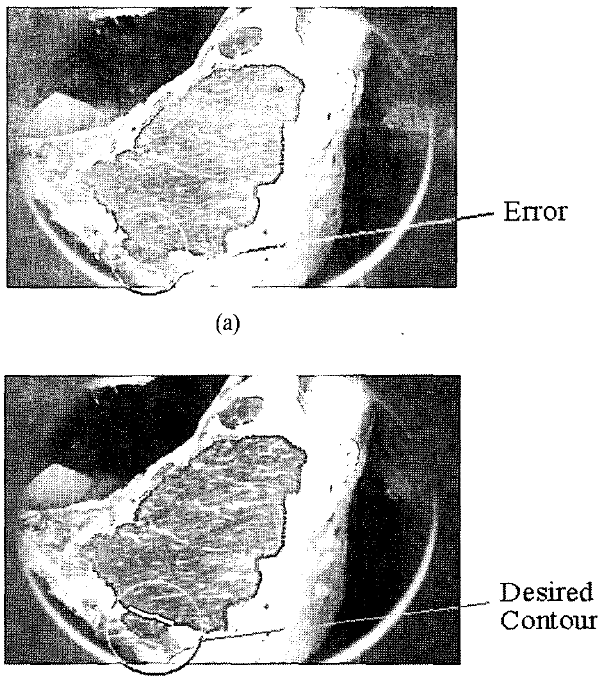
Fig. 7 Results of boundary extraction process : result after two successive dilations (a), image after filling the inner muscular fat (b) image after erosion (c) resulting image after chain coding (d).

using line tracing based on the 8-directional chain coding.

The extracted boundary was superimposed on the raw color image to validate the results of the processing as shown in Figure 8. The developed algorithm was applied for 30 beef cut samples and showed the successful results for the beef cuts with simple and moderate patterns of the lean tissue and fat. Morphological dilation and erosion cooperated with some heuristic rules based on the geometric characteristics of the lean tissue could successfully remove the simple adhered or isolated regions of the image.

The proposed algorithm, however, had some difficulty in eliminating complex pattern of the extraneous tissues adhered to the lean tissue as shown in Figure 9. Though some undesirable results were caused by the improper cutting of the beef, which resulted in the obscurity of the boundary between lean tissue and the extraneous tissue of the beef cut, further improvement of the boundary extraction

Fig. 8 Successfully extracted boundary of lean tissue superimposed on the raw color image.



(a) (b)

Fig. 9 Extracted boundary : improper contour extraction (a), desired contour (b).

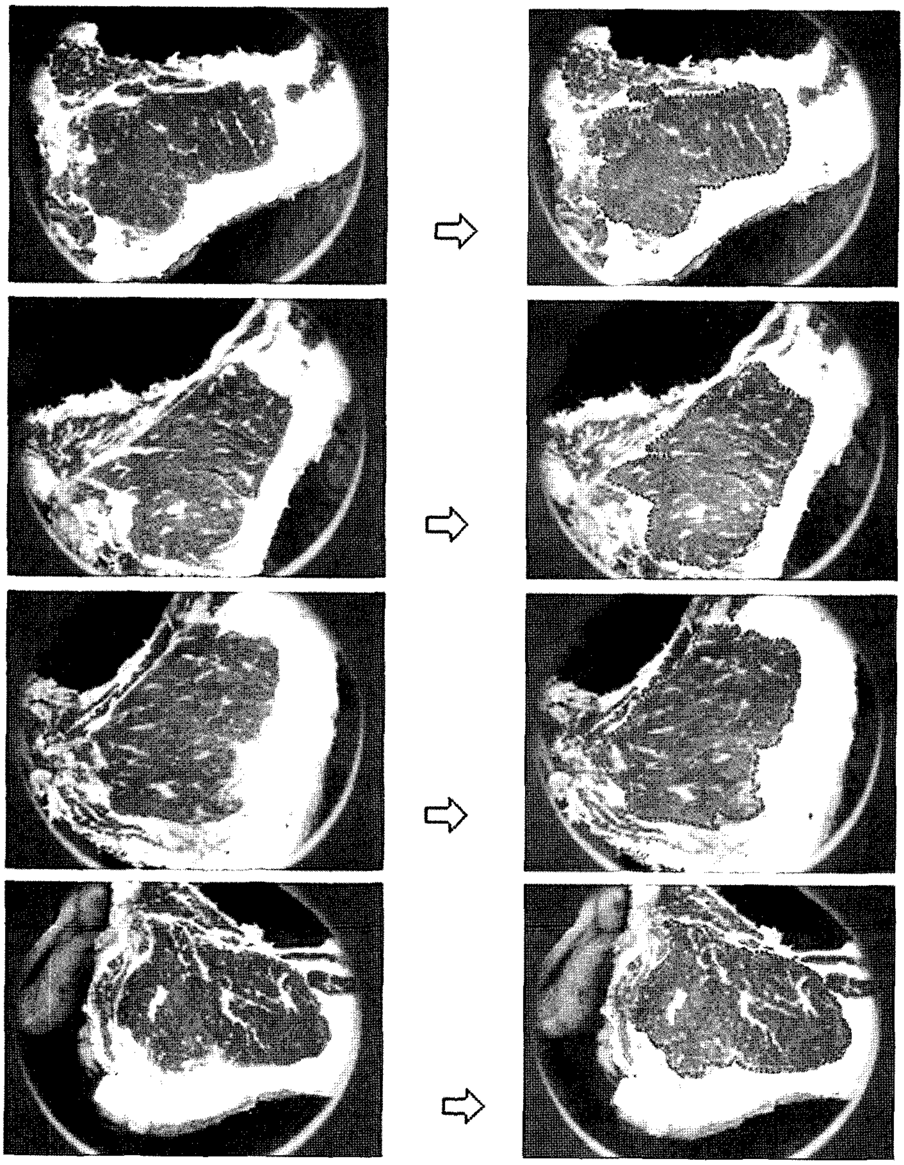


Fig. 10 Results of boundary extraction of the lean tissue from the beef cuts.

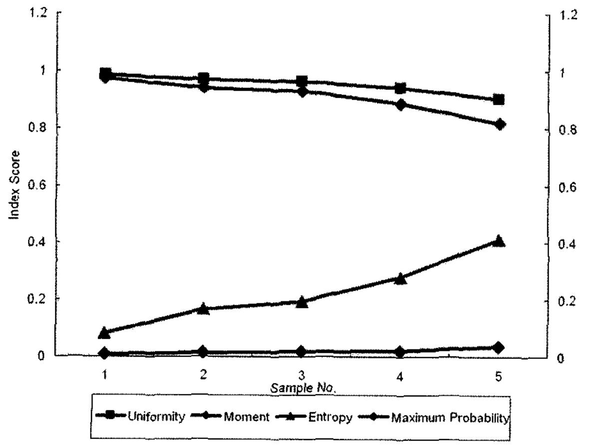


Fig. 11 Scores of texture indexes for marbling states of sample beef cuts.

algorithm was necessary to achieve human like performance in boundary extraction. Typical results of extracting boundaries of lean tissue are shown in *Figure 10*.

3.2 Measurement of Marbling State

Five beef samples with different marbling states which could be visually recognized easily were used to compare values of four texture indexes such as element difference moment, entropy, uniformity, and area ratio. Figure 11 showed the resulting scores of four different texture indexes for given samples. Correlation value for each texture index was 0.9314 for maximum probability, 0.8881 for element difference moment, 0.9515 for entropy, and 0.9224 for uniformity respectively. Entropy and maximum probability computed from the co-occurrence matrix using the horizontal path mask gave relatively better correlation among four indexes.

4. CONCLUSIONS

Contour extraction of the lean tissue is critical to automatically evaluate the beef quality. Based on this generated contour information, marbling state, and fat composition ratio are determined. In this paper, algorithms were developed to extract the boundary of the lean tissue and proposed an index tool to evaluate the marbling status using mobile hand held color image acquisition and processing unit. The developed algorithm was applied for 30 beef cut samples and showed the successful results for the beef cuts with simple and moderate patterns of the lean tissue and fat.

And for the marbling state of lean tissue quality, entropy and maximum probability indices obtained from the co-occurrence matrix gave relatively better correlations with visually recognizable marbling states. And a prototype mobile beef quality measurement system, which can be implemented practically at the beef processing site was developed. The developed system was composed of the hand held image acquisition unit and mobile processing unit mounted with touch-pad screen.

Based on the results of this research, two ways of the algorithm modification and improvement for the boundary extraction could be considered for further research. One was the introduction of the interactive human intervention to guarantee the 100% successful boundary extraction. And the other was the improvement of the boundary extraction algorithm by tracing the curvature of contour.

Based on the correlation results between the marbling states of the beef-cuts and texture indexes such as entropy and maximum probability of co-occurrence matrix, researches on quantification of marbling state and validation of the index scores for the various beef samples graded by the human expert will be performed.

REFERENCES

1. Chen, Y. R. and B. Park. 1995. An image processing algorithm for separation of fat and lean tissue on beef cut surface. ASAE Paper No. 953680. ASAE St. Joseph, MI.
2. Hwang, H., B. Park., M. Nguyen and Y. R. Chen. 1997. Hybrid image processing for robust extraction of lean tissue on beef cut surfaces. Computers and Electronics in Agriculture, 17:281-294.