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Suggestions for Improvements in Current Computer Image Processing Methods in Detection and Quantification of the Severity of Atrophic Rhinitis in Pigs

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SUGGESTIONS FOR IMPROVEMENTS IN CURRENT COMPUTER IMAGE PROCESSING METHODS IN DETECTION AND QUANTIFICATION OF THE SEVERITY OF ATROPHIC RHINITIS IN PIGS

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Abstract.

This paper investigates several techniques to aid in the utilization of computer image processing methods to detect and quantify the severity of atrophic rhinitis in pigs. An algorithm for reducing the complexity of matrix multiplications from $O(n^3)$ to $O(n^{2.81})$ is explored. A one-pixel-wide edge detection method is also studied. These techniques are considered for improving the accuracy, repeatability, and speed of existing detection and quantification methods.

Introduction.

Atrophic rhinitis (AR) is a disease of swine involving the atrophy of bony structures (conchae) within the nose. AR rarely results in the death of a pig, but it can significantly decrease the pig's efficiency and rate of growth. Diagnosis of AR is usually confirmed after slaughter by making a transverse cross-section of the snout at the level of the second premolar teeth and by subjectively visually inspecting the nasal conchae.

The motivation for the use of computer image processing techniques to automatically detect and quantify Atrophic rhinitis stems from the conclusion [1] that a more objective measure of conchal atrophy in pigs will overcome problems associated with subjective evaluation even by trained observers. Subjective evaluations may produce accurate results, and are typically repeatable if performed by the same evaluator. However, subjective evaluations are labor intensive, expensive, and may be influenced by bias, fatigue, or training of the observer. Therefore, with an automated computer image processing system, a reliable, cost effective, and objective measure of AR might be possible.

Current methods used in the detection and quantification of AR in pigs do not yield satisfactory results. The correlations between the computer generated Morphometric Index (MI), a measure of AR, and the scores determined by pathologists are weak. Also, the speed of processing the images leaves much to be desired. Matrix multiplication, which is a fundamental operation in image processing, can create a huge burden on the computer system. To increase the speed of matrix multiplication of large matrices, an algorithm based on the divide and conquer methodology is studied. Strassen's algorithm allows the complexity of matrix multiplication to be reduced from $O(n^3)$ to $O(n^{2.81})$. While this does not seem much of an improvement, for large n (>100), the savings can be quite significant.

The problems encountered in previous works include the detection of edges of the images in order to threshold the image -- the grouping of certain ranges of gray levels into a single gray level to provide a sharper contrast. The problem lies with the line thinning process. A poor implementation would result in a totally different image than what was intended. The one-pixel-wide edge detection method by Shu [2] seems to offer a solution.

Strassen's algorithm.

The usual way to multiply two n x n matrices A and B, yielding the resultant matrix C, is as follows:

```
for i := 1 to n do
 for j := 1 to n do
 begin
   C[i,j] := 0;
   for k := 1 to n do
     C[i,j] := C[i,j] + A[i,k]*B[k,j];
 end;
```

where the three matrices A, B, and C are divided as:

$$\underset{A}{\begin{bmatrix} A11 & A12 \\ A21 & A22 \end{bmatrix}} \bullet \underset{B}{\begin{bmatrix} B11 & B12 \\ B21 & B22 \end{bmatrix}} = \underset{C}{\begin{bmatrix} C11 & C12 \\ C21 & C22 \end{bmatrix}}$$

This algorithm requires n^3 scalar multiplications (multiplications of single numbers) and n^3 scalar additions. Strassen's method [3] uses seven (n/2) x (n/2) matrix multiplications and eighteen (n/2) x (n/2) matrix additions and subtractions.

$$M_1 = (A_{12} - A_{22})(B_{21} + B_{22})$$
$$M_2 = (A_{11} + A_{22})(B_{11} + B_{22})$$
$$M_3 = (A_{11} - A_{21})(B_{11} + B_{12})$$
$$M_4 = (A_{11} + A_{12})B_{22}$$
$$M_5 = A_{11}(B_{12} - B_{22})$$
$$M_6 = A_{22}(B_{21} - B_{11})$$
$$M_7 = (A_{21} + A_{22})B_{11}$$

$$C_{11} = M_1 + M_2 - M_4 + M_6$$
$$C_{12} = M_4 + M_5$$
$$C_{21} = M_6 + M_7$$
$$C_{22} = M_2 - M_3 + M_5 - M_7$$

where M_i denotes the matrices and A_{rc}, B_{rc}, and C_{rc} are the values at the locations given by row, column (rc).

Performing this method recursively the seven (n/2) x (n/2) matrix multiplications gives the recurrence equations used for solving the complexity of the algorithm:

$T(1) = 1$	single item array
$T(n) = 7\ T(n/2)$	sum of the 7 matrix multiplications each of $T(n/2)$ for $n \geq 2$

Solving the recurrence equation to derive the closed form expression of T(n) using repeated substitution will provide a preferable expression. For the case $n = 2^k$ ($k = \log_2 7$):

$T(2^k) = 7^1\ T(2^{k-1})$	substituting for n
$= 7^2\ T(2^{k-2})$	unraveling the recurrence formula
$= \ldots$	
$= 7^i\ T(2^{k-i})$	generalizing for any i
$= \ldots$	
$= 7^k\ T(1)$	terminating condition ($k = i$)
$= 7^k * 1$	
$= 7^k$	$\log_2 n = k\log_2 2 = k$
$= 7^{\log_2 n}$	

Therefore, by applying the identity $a^{\log_b c} = c^{\log_b a}$, the complexity is found to be $T(n) = n^{\log_2 7} = n^{2.81}$. The number of scalar additions performed is also $O(n^{2.81})$. This shows clearly that Strassen's algorithm is asymptotically more efficient than the standard algorithm. However, the additional overhead of managing the many small matrices imposed by Strassen's algorithm makes it feasible only for large n.

One-Pixel-Wide Edge Detection.

The goal of this method is the detection of spatially accurate one-pixel-wide edges within a gray-scale input image. This method first uses existing edge detectors such as the Sobel or Robert edge detectors as shown in Figure 1 to detect multi-pixel-wide edges. The Sobel and Robert edge detectors are commonly used edge detector operators in image processing. The detected edges are then thinned by a thinning edge operation.

-1	-2	-1
0	0	0
1	2	1

(a)

-1	0	1
-2	0	2
-1	0	1

(b)

-1	0
0	1

(c)

0	-1
1	0

(d)

Figure 1. [2] Edge detection operators, (a), (b) Sobel edge detectors, (c), (d) Robert edge detectors.

The mathematical expressions for this operation are as follows [3]:

$$E_e(i,j) = \text{Input image for the thinning edge operation} \quad (1)$$

$$E_x(i,j) = \begin{cases} E_e(i-1,j) + E_e(i,j) + E_e(i+1,j); & \text{if } E_e(i,j) \geq E_e(i-1,j) \text{ and } E_e(i,j) \geq E_e(i+1,j) \\ 0; & \text{otherwise} \end{cases} \quad (2)$$

$$E_y(i,j) = \begin{cases} E_e(i,j-1) + E_e(i,j) + E_e(i,j+1); & \text{if } E_e(i,j) \geq E_e(i,j-1) \text{ and } E_e(i,j) \geq E_e(i,j+1) \\ 0; & \text{otherwise} \end{cases} \quad (3)$$

$$E_n(i,j) = \text{Output thinned edge image} \quad (4)$$

$$= \sqrt{E_x^2 + E_y^2}.$$

The values of $E_x(i,j)$, $E_y(i,j)$, and $E_n(i,j)$ lie in the range from 0 - 255 inclusive with any calculated value greater than 255 clipped into 255.

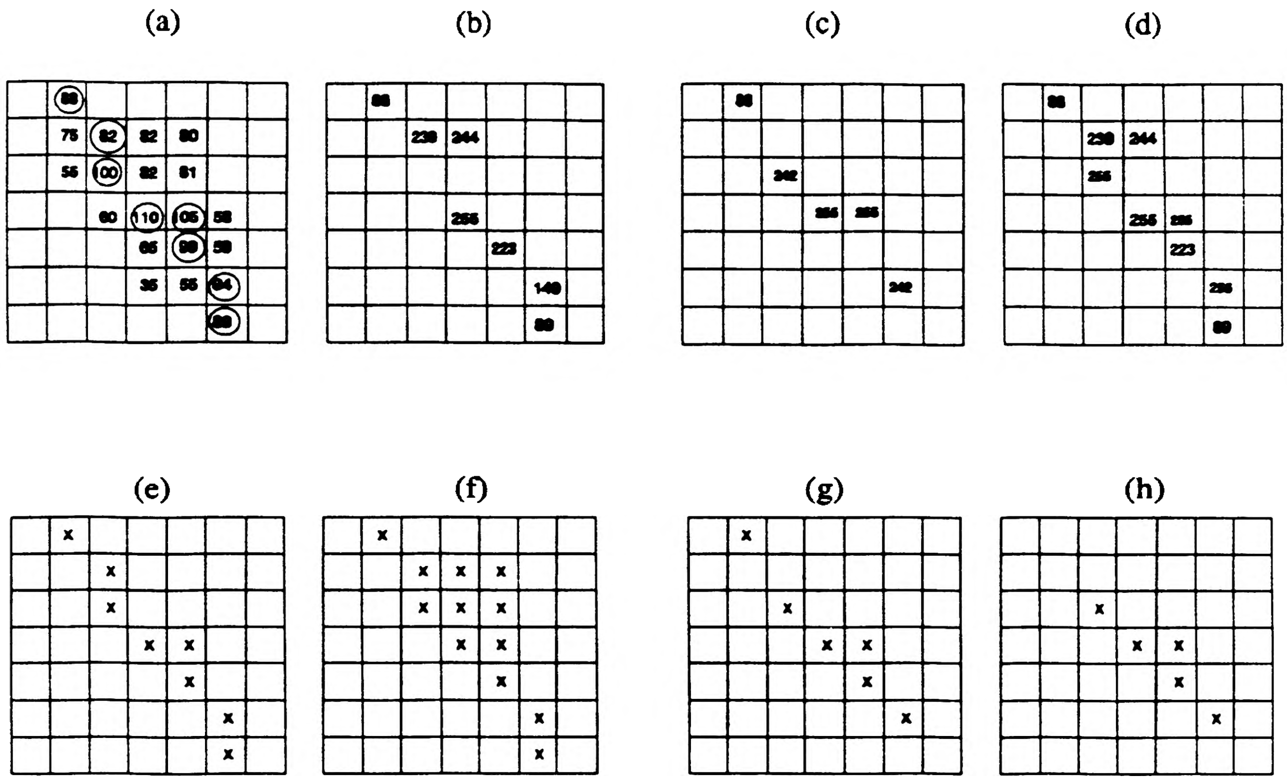

Figure 2. [2] Thinning edge processing example, (a) raw edge array $E_e(i,j)$, (b) after horizontal thinning edge operation, (c) after vertical thinning edge operation, (d) thinned edge array $E_n(i,j)$, (e) detected edge streaks by the heuristic search, (f) detected edge by thresholding Fig. 2(a) at 80, (g) detected edge by thresholding Fig. 2(a) at 85, (h) detected edge by thresholding Fig. 2(a) at 90.

Figure 2 [2] illustrates how the 2-dimensional edge thinning operation (expressed by equations (2)-(4)) processes the multi-pixel-wide edge array to reduce the edge widths. In Figure 2(a), the circled pixels in this raw edge intensity array indicate the desirable one-pixel-wide edge streak based on the human visual perception. Figure 2(b) shows the result of applying the vertical thinning edge operation (equation (2)) on the raw edge array in Figure 2(a). Figure 2(c) shows the results of the horizontal thinning edge operation (equation (3)) on Figure 2(a). Figure 2(d) shows the gray scale edges with reduced edge widths resulting from the thinning edge processing (equation (4)). After applying the heuristic search algorithm of Figure 3 which extracts optimal edge streaks whose width are exactly one-pixel wide, the detected one-pixel-wide edges of Figure 2(e) result. In Figures 2(f), (g), and (h), the detected edges by the direct thresholding of raw edges of Figure 2(a) at threshold value equal to 80, 85, and 90 respectively are shown. In these detected edges in Figures 2(e), (f), (g), and (h), the edge thinning operation followed by the heuristic search produces the best result.

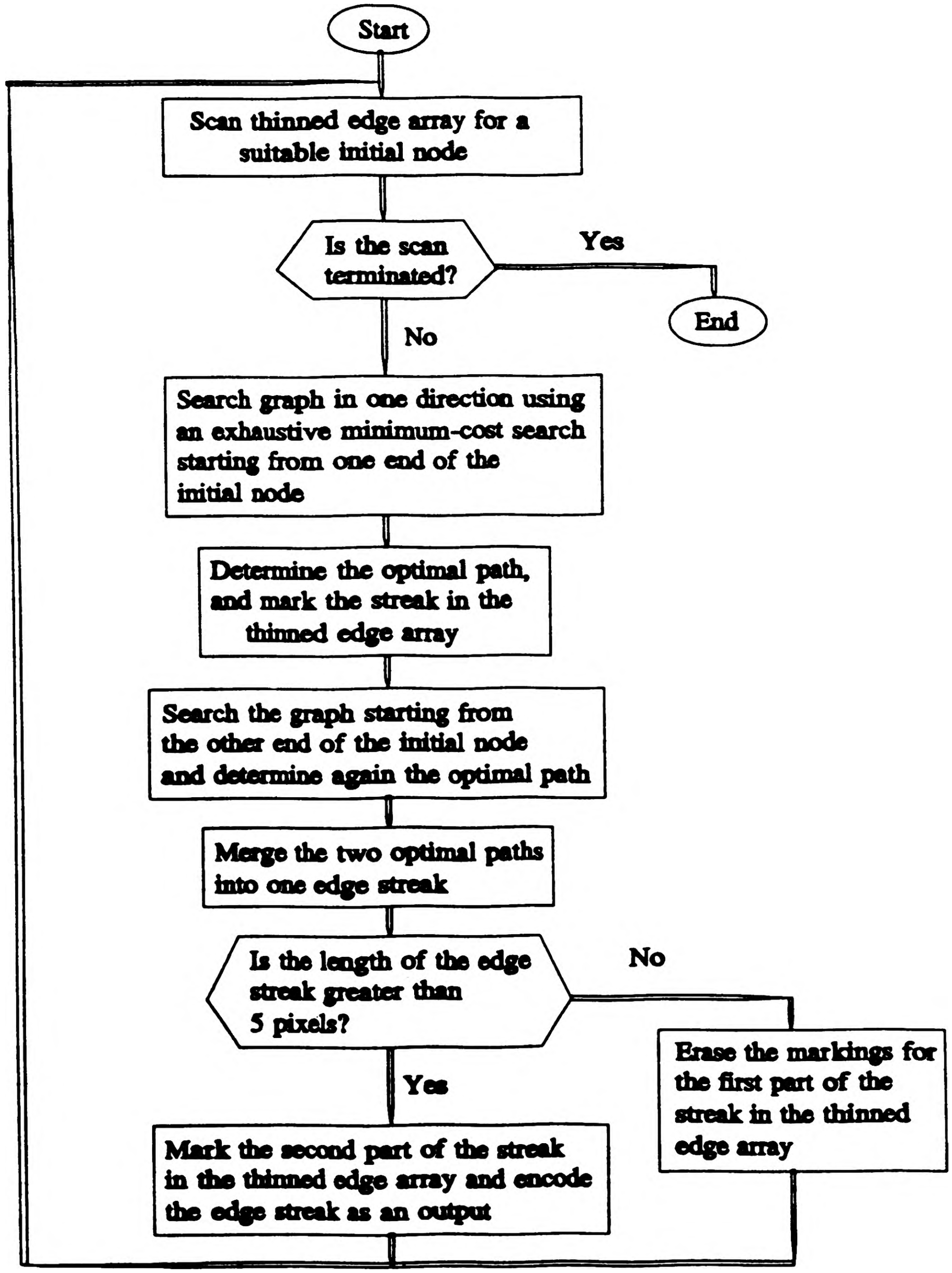

Figure 3. [2] Flow chart of the heuristic search algorithm.

Conclusions.

The utilization of computer image processing techniques in the study of atrophic rhinitis in pigs promises rewarding results. Improving upon previous techniques in the detection and quantification of images is the primary goal of this project. The major problems encountered with the old analysis system are speed, accuracy, and repeatability. The techniques described in this paper provide a new direction for further development in this area.

Strassen's algorithm provided for a faster multiplication of large matrices which is useful in the area of image processing since the images are commonly represented by matrices. It was shown that Strassen's algorithm allows the complexity of the matrix multiplication to be reduced from $O(n^3)$ to $O(n^{2.81})$. Shu's one-pixel-wide edge detection method clearly produces spatially accurate edges exactly one pixel wide. With these algorithms, the problems of speed, accuracy, and repeatability in the digital image processing system are addressed. However, due to time considerations, the implementation of these techniques was not performed.

References.

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