01 Apr 1991

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Abstract

This project focuses its attention on the detection and quantification of Atrophic Rhinitis (A.R.), a disease prevalent in pigs. A.R. causes some of the bony structure in a pig's snout to atrophy, which exposes the animal to other diseases that may effect its growth. It is studied by examining a cross section of the pig's snout. By comparing areas and perimeters of the nasal cavity to bony structures, or turbinates in the snout, one can determine the severity of the atrophy. Currently, the veterinarian's diagnosis is based on a subjective analysis of the snout. The problem with this method is that it varies among veterinarians. One would like to automate this procedure so that the system analyzes the same criteria (i.e. areas, perimeters) for all snouts. Semi-automated methods of manual planimetry are too slow and cumbersome to be of much use. The goal of this project is to develop a PC based system which could be installed in the slaughterhouse and could quickly determine the severity of Atrophic Rhinitis. This report describes the procedure and summarizes the results of software which has been developed to automate the task of determining the severity of A.R. Software has been developed to define the area of interest within the snout, create a histogram of the image, automatically threshold the gray level image, and compute areas and perimeters from the binary image.

Introduction

These automated methods will be used to compute known measurements for diagnosis of Atrophic Rhinitis. The measurements include the morphometric index (M.I.)[1], the turbinate area ratio (T.A.R.), and the turbinate perimeter ratio (T.P.R.)[2].

The core of this report is divided into four sections. The Materials section describes the systems and languages used to code the software. The Methods section discusses the various graphics and image processing techniques implemented. The Discussion section outlines the procedure taken to obtain measurements of atrophy. Lastly, the Results section tabulates the measurements taken and the correlation between the software and the subjective analysis.

I. Materials

This software was developed on an IBM XT model personal computer with 512kb of resident RAM. To display the snout images an image display board by HRH Electronics was used. This 8-bit, internally installed card, is capable of storing a 256 by 256 gray level image. Since each pixel is represented by an 8-bit number, each pixel value ranges from 0 (black) to 255 (white) and the total image occupies 65536 bytes of memory. These pixel values are set and modified by directly accessing memory which begins at a user set memory address. With the configuration used in this project, the 64kb block begins at $E000. The output of the image board is then connected to a monochrome composite monitor for the display of the image. The software for the investigation of Atrophic Rhinitis was developed in Borland's TURBOPascal version 5.0.

II. Methods

In the process of writing this software, many interactive graphic and image processing techniques were obtained from various sources. The computer graphics methods provided the backbone of the software. Bresenham's line drawing algorithm and flood filling[3] were used to construct polygons to confine the area of interest and to mask unwanted regions of the image. For reasons outlined later, flood filling was also used to count pixels in order to measure areas. Among the digital image processing methods used are automatic thresholding[4] to create a binary image and edge tracking[5] which was used to approximate perimeters.

III. Discussion

The following discussion describes the general procedure taken to obtain measurements of A.R. For a detailed outline of the software commands and source code listing, refer to (Mussman, 1990).

Upon displaying the snout image, it is obvious that there is much unwanted information. The snout should be located roughly in the center of the screen with the rest of the image being irrelevant. Thus it is necessary to remove this so as to focus all subsequent processing to the turbinates and nasal cavities, which are defined as the area of interest. This is accomplished by constructing a polygon around the area of interest and masking the outside region with a specific gray level, 255 in this case. This will serve as a mask, so the computer knows not to process this area. The masking is done by choosing a starting point in the region to be masked and then flood filling the region. When this is complete, the image should contain the snout in the center, surrounded by white pixels.

In order to compute areas or perimeters of any object, it is usually best to start with a binary image. The reason being that it is trivial to determine boundaries between the object and the background when one of two possible gray levels defines each region. Therefore, we must threshold this gray level image. To do this, a histogram of the image must first be created. The histogram contains the gray level intensity and number of pixels on the x and y axis respectively[6]. The histogram does not contain information on the location of the pixels but does contain information on the number of pixels in each gray level. Due to the nature of these images, the histogram has been normalized for ease of analysis.

In the case of pig snouts, the histogram has been assumed to be bimodal. Thus the histogram should contain a large number of pixels near or at gray level 0 and a large group near or at gray level 255. The threshold value is then chosen as the valley between the two peaks. Since the histogram is not very smooth in this case, it is divided up into sixteen bins of sixteen gray levels each. The peak and valley bins are then located by comparing each bin with the two bins next to it. Once the valley bin is located, the gray level with the fewest pixels is chosen as the threshold value. All pixels with a gray level at or below this threshold value are turned black and all pixels above are turned white. The snout is now a binary image with the darker nasal cavities black and the lighter turbinates white.

Due in part to the handling of the actual snouts and the noise in the system, all of the snouts had discontinuities in the nasal cavity regions. To measure the areas and perimeters efficiently, these areas must be connected. The software does allow for image editing. The user simply constructs a polygon to approximate the connection of the two separated regions and flood fills the polygon black. This same procedure is followed if part of the turbinate has been eroded due to a high threshold value. The only difference being that the user would fill the polygon white instead of black.

Once the binary image of the snout is editing, the perimeter and area of the nasal cavity can be found. The area is computed by simply counting pixels as the area is flood filled. The perimeter is found by using an edge tracking algorithm. This procedure also counts pixels, adding a correction factor for diagonals, as it tracks the boundary of the object.

To compute the areas of the turbinates, they need to be separated from the rest of the snout. The dorsal and ventral conchae, which are the upper and lower sections of the turbinate, are separated from the snout by drawing lines roughly tangent to the nasal cavities, which cut the conchae away from the bone. Area measurements can now be taken on these enclosed regions by following the same procedure as above.

The last measurement needed is the perimeter of the entire snout, which includes the nasal cavities and the turbinates. This is found by filling all of the turbinates black, so that both halves of the snout are completely black, leaving a silhouette of the snout. Again, the perimeter of this shape can be found by using the edge tracker.

IV. Results

From the eight area and perimeter measurements, defined below, three ratios were calculated: M.I., T.A.R.,and T.P.R.

<u>Areas</u>

C_{DR} = right dorsal conchae
C_{VR} = right ventral conchae
S_R = right cavity space

C_{DL} = left dorsal conchae
C_{VL} = left ventral conchae
S_L = left cavity space

<u>Perimeters</u>

C = perimeter of entire snout

D = perimeter of cavity space

<u>Morphometric Index (M.I.)</u>

$$M.I. = ((S_L / (S_L + C_{VL})) + (S_R / (S_R + C_{VR}))) / 2$$

<u>Turbinate Area Ratio (T.A.R.)</u>

$$T.A.R. = (C_{DL} + C_{VL} + C_{DR} + C_{VR}) / (C_{DL} + C_{VL} + S_L + C_{DR} + C_{VR} + S_R)$$

<u>Turbinate Perimeter Ratio (T.P.R.)</u>

$$T.P.R. = (D - C) / C$$

The following four tables contain the data taken from the snouts. Table 1 and Table 2 contain the first and second area and perimeter measurements respectively, from the snout. However, when the data from Table 1 was recorded, the perimeter measurements had not yet been perfected, thus they are excluded. In both of these tables, samples M0-M5 are the plaster model snouts. They are labeled M#, where # is the A.R. score of the snout. In this project, the Weybridge system is used. Snouts are graded 0 (complete normality) to 5 (complete conchal atrophy)[1].

Table 3 provides a statistical analysis of the data in Tables 1 and 2 and of the subjective scores from the veterinarian(Vetscore) and pathologist (Pathscore). This data will be used to compute the correlation coefficients in Table 4, which contains the correlation coefficients between the pathologist and veterinarian as well as the individual ratios.

Some interesting results arise from Table 4. First of all, a correlation coefficient of 0.7543 between the pathologist and the veterinarian proves that subjective scoring is fairly consistent. On the other hand, coefficients below 0.5000 between the first and second M.I. and T.A.R.'s cause reason for alarm. In both cases, these two measurements should be very close. One would expect a correlation coefficient of atleast 0.7500 for both of these. This extreme error is do to the editing procedure. Apparently the edited images of the first and second runs differed enough to produce a poor correlation coefficient. Since a single user produced these results, one can only assume that two different users would produce no better results.

Table 1: First run-Area data from snout samples

	left areas			right areas				
snout	SL	CDL	CVL	SR	CDR	CVR	M.I.1	T.A.R.1
1	did not record indiv			dual			0.5029	0.4970
2	measurements for						0.5291	0.4580
3	samples 1-3						0.5779	0.4220
4	1158	476	2697	1450	409	2497	0.3335	0.6990
5	2403	712	3106	2995	807	3764	0.4390	0.6090
6	3372	620	3003	3857	625	3216	0.5370	0.5080
7	3148	563	2470	3081	344	1984	0.5750	0.4630
8	3237	611	2515	3478	650	3080	0.5450	0.5050
9	2061	500	3209	1841	478	3198	0.3775	0.6540
10	2393	573	3217	2864	661	3199	0.4495	0.5930
11	1713	287	1594	1758	542	2286	0.4765	0.5760
12	2076	678	2865	2147	614	2985	0.4190	0.6280
13	2260	885	2442	2156	817	2615	0.4660	0.6050
14	1645	530	2281	1776	514	2291	0.4280	0.6210
15	2687	548	3412	2761	522	3201	0.4520	0.5850
16	3755	755	2896	2120	613	2481	0.5130	0.5340
17	2431	1228	3127	2506	801	3014	0.4460	0.6230
18	2194	700	2073	2508	769	1972	0.5370	0.5390
19	3162	828	3639	3505	552	2952	0.5040	0.5450
20-27	were not analyzed be			cause of distortion present				
28	2337	661	3661	2245	361	3603	0.3870	0.6440
29	1925	388	2928	1279	345	3369	0.3360	0.6870
30	2157	512	3877	1951	299	4277	0.3350	0.6860
31	2453	287	3023	3530	654	3848	0.4630	0.5660
32	2303	655	3798	2231	683	4163	0.3630	0.6720
33	2392	278	2683	2418	341	2876	0.4635	0.5620
34	3278	505	4245	3327	423	4463	0.4315	0.5930
35	1714	521	3933	1332	457	3952	0.2780	0.7440
36	1361	921	4957	2079	632	4338	0.2695	0.7790
37	1885	521	3543	2207	731	3722	0.3595	0.6750
38	1125	278	3472	1308	421	3501	0.2585	0.7590
39	4166	446	1901	5203	800	1245	0.7470	0.3190
40	2880	618	3372	2799	555	3040	0.4700	0.5720
41	2792	846	3542	2943	482	3065	0.4655	0.5800
42	1513	382	3288	1573	482	2775	0.3385	0.6920
M0	4484	641	3796	5020	893	3888	0.5530	0.4920
M1	5719	601	3099	5289	934	3600	0.6220	0.4280
M2	4187	874	3225	4190	1050	3529	0.5540	0.5090
M3	5492	641	2792	8181	730	3532	0.6810	0.3600
M4	4394	331	1659	5243	693	2008	0.7245	0.3250
M5	6153	0	0	5418	0	0	1.0000	0.0000

Table 2: Second run-Area and perimeter data from snout samples

	left areas			right areas			perimeters				
snout	SL	CDL	CVL	SR	CDR	CVR	C	D	M.I.2	T.A.R.2	T.P.R.
1	2641	840	2921	2790	713	3715	1005	2781	0.4519	0.6012	1.767
2	2747	642	2885	2216	630	2820	889	2070	0.4652	0.5833	1.328
3	2413	585	1415	2520	676	2035	880	1572	0.5918	0.4885	0.7864
4	1448	615	2448	1448	590	2524	855	1885	0.3681	0.6808	1.205
5	2098	814	2838	2651	1018	3929	922	2632	0.4140	0.6442	1.855
6	2119	974	3600	3220	947	3928	1003	2474	0.4105	0.6390	1.467
7	3176	599	2468	2972	472	2053	932	1797	0.5771	0.4763	0.9281
8	3142	641	2669	3484	753	3194	993	2255	0.5312	0.5227	1.271
9	2565	631	3041	1989	699	3172	954	2331	0.4215	0.6235	1.443
10	2628	710	3147	2645	813	3453	921	2210	0.4444	0.6064	1.340
11	1642	441	1614	1699	754	2406	800	1793	0.4591	0.6100	1.241
12	2117	940	2875	2204	829	2869	937	2477	0.4292	0.6349	1.644
13	2208	942	2592	2239	931	2747	899	2074	0.4550	0.6186	1.307
14	1806	598	2216	2099	564	2191	858	2256	0.4692	0.5878	1.629
15	2913	678	3145	2687	609	3213	907	2626	0.4681	0.5772	1.895
16	4151	753	2770	2278	622	2357	974	2357	0.5456	0.5028	1.420
17	2507	1278	3037	2464	751	3067	959	2450	0.4488	0.6207	1.555
18	2379	645	2046	2608	740	2006	887	2148	0.5514	0.5216	1.422
19	2931	843	3848	3138	563	3219	991	2865	0.4630	0.5827	1.891
20-27	were not analyzed because of distortion present										
28	3022	553	3542	2712	443	3423	888	3026	0.4512	0.5813	2.408
29	2391	421	2831	2333	388	2733	838	2513	0.4592	0.5743	2.000
30	2961	325	3616	3982	345	3305	898	3067	0.4623	0.5609	2.413
31	2427	247	2970	3266	601	4046	948	3437	0.4482	0.5800	2.626
32	3130	488	3458	2612	620	3904	997	2940	0.4380	0.5960	1.949
33	2606	272	2662	2454	324	2892	800	2482	0.4769	0.5486	2.103
34	3980	399	4003	3822	676	4148	993	3494	0.4891	0.5418	2.519
35	3284	561	2915	2662	614	3099	923	2855	0.4960	0.5473	2.093
36	3113	898	3988	3124	663	3724	1016	3200	0.4473	0.5979	2.150
37	2824	459	3022	3343	483	2461	948	2712	0.5295	0.5102	1.861
38	2158	377	3080	2802	530	2790	878	2603	0.4565	0.5774	1.965
39	3275	434	2922	3653	554	2943	970	3046	0.5412	0.4973	2.140
40	3423	448	2595	3375	415	2600	943	2697	0.5506	0.4858	1.860
41	3485	906	3127	3314	504	2935	919	2641	0.5287	0.5236	1.874
42	2429	292	2536	2150	396	2537	790	2221	0.4740	0.5572	1.811
M0	4581	595	3738	5171	886	3949	1144	2972	0.5588	0.4846	1.598
M1	5728	626	3109	5327	983	3556	1137	2782	0.6240	0.4281	1.447
M2	4207	852	3193	4257	1028	3508	1076	2502	0.5584	0.5034	1.325
M3	5872	584	2734	8717	656	3202	1191	2997	0.7068	0.3297	1.516
M4	4395	357	1667	5268	688	1970	1016	2074	0.7264	0.3264	1.041
M5	6174	156	483	5442	159	390	958	1098	0.9303	0.0928	0.1461

Table 3: Statistical analysis of Tables 1 and 2

Variable	N	mean	std. dev	median	minimum	maximum
Vetscore	42	0.7857	0.9509	0.5000	0.000	3.000
Pathscore	42	1.476	1.018	2.000	0.000	3.000
M.I.1	35	0.4420	0.1004	0.4500	0.2590	0.7470
T.A.R.1	35	0.5943	0.0968	0.5930	0.3190	0.7790
M.I.2	34	0.4769	0.0511	0.4626	0.3681	0.5918
T.A.R.2	34	0.5706	0.0509	0.5787	0.4763	0.6808
T.P.R.	34	1.742	0.4393	1.833	0.7864	2.626

Table 4: Correlation between the variables

Spearman correlation coefficient / prob > |R| under Ho:rho=0 / number of observations

	Vetscore	Pathscore	M.I.1	T.A.R.1	M.I.2	T.A.R.2	T.P.R.
Vetscore	1.000	0.7543	0.6269	-0.6037	0.4390	-0.4117	-0.3856
	0.000	0.0001	0.0001	0.0001	0.0094	0.0155	0.0243
	42	42	35	35	34	34	34
Pathscore	0.7543	1.0000	0.3414	-0.2882	0.1559	-0.0969	-0.5944
	0.0001	0.0000	0.0447	0.0932	0.3787	0.5854	0.0002
	42	42	35	35	34	34	34
M.I.1	0.6269	0.3414	1.0000	-0.9746	0.4594	-0.3275	-0.4594
	0.0001	0.0447	0.0000	0.0001	0.0063	0.0587	0.0063
	35	35	35	35	34	34	34
T.A.R.1	-0.6037	-0.2882	-0.9746	1.0000	-0.4282	0.3204	0.3829
	0.0001	0.0932	0.0001	0.0000	0.0115	0.0647	0.0254
	35	35	35	35	34	34	34
M.I.2	0.4390	0.1159	0.4594	-0.4282	1.0000	-0.9343	-0.0738
	0.0094	0.3787	0.0063	0.0115	0.0000	0.0001	0.6783
	34	34	34	34	34	34	34
T.A.R.2	-0.4117	-0.0969	-0.3275	0.3204	-0.9343	1.0000	-0.1438
	0.0155	0.5854	0.0587	0.0647	0.0001	0.0000	0.4172
	34	34	34	34	34	34	34
T.P.R.	-0.3856	-0.5943	-0.4594	0.3829	-0.0738	-0.1438	1.0000
	0.0243	0.0002	0.0063	0.0254	0.6783	0.4172	0.0000
	34	34	34	34	34	34	34

Conclusions

This investigation of automated methods for the diagnosis of A.R. proved to be a limited success. The automatic thresholding procedure was successful for bimodal histograms, however, very few of the snout images produced a bimodal histogram. A solution to this problem would be to assume that the histogram is a combination of two guassian distributions. One could then use statistical methods to separate the two distributions to find the threshold value.

Manual editing of the images proved to be inconsistent when the same images were processed more than once. A possible solution is to have the computer approximate the connection of the two separated regions, instead of the user. The software may produce a more predictable result.

Despite these shortcomings, the software did perform what it was designed for. This procedure for diagnosing A.R. is much more automated than before. However, there is still work to be done, especially in the area of pattern recognition, if this procedure is to be fully automated.

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