# Multiscale Texture Feature Variability Analysis in Images During Laparoscopy Under Different Viewing Positions

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**Abstract**

In this study we investigate variability of texture features for laparoscopy images of tissue captured under different viewing conditions. In order to perform this test we captured the following sets of images: ten images, where the camera was at a small distance from the tissue (panoramic, 5cm distance), ten images where the camera was close to the tissue (close up, 3cm distance) and twenty images for two consecutive angles (ten for each) with $5^0$ degrees difference. Multiscale analysis was carried out in order to examine image texture at different scales. Images were downsampled and filtered to ten scales (1x1 up to 10x10) for the different distances and six scales (1x1 up to 5x5 and 10x10) for the different angles. Regions of Interest (ROIs) were selected from each image and the following texture features were extracted: the Statistical Features (SF) and the Spatial Gray Level Dependence Matrices (SGLDM). Results indicate that there is significant variability between the panoramic and close up views for multiscale texture features. However, there is some variance (within reasonable bounds) between the multiscale texture features of consecutive angles. It is hoped that the results of this study will prove useful in computer aided diagnosis in laparoscopy imaging. However, more experiments have to be carried out and more images have to be analyzed to support this further.

## 1. Introduction

Laparoscopy has become the preferred method for diagnosis and treatment of the majority in gynaecological problems. Laparoscopy is minimally invasive technique due to the very small incisions used [1]. The eye piece of a 10mm in diameter telescope is connected to a camera and a monitor. The physician guides the telescope tip inside the abdominal cavity in order to investigate suspicious areas and to establish the diagnosis [2]. Many times the diagnosis is difficult and histopathological examination of a biopsy in necessary for conclusive results. Laparoscopic computer based image processing is a difficult task but we investigate the possibility of having an additional information of the suspected regions observed during laparoscopy before biopsy results. The main objective of this study is to investigate the differences of texture features of laparoscopy images under different viewing conditions using multiscale analysis.

To the best of our knowledge no similar study was performed for laparoscopy imaging. Similar work was presented only for colonoscopy images [3]-[4] for the detection of tumours in colonoscopic video where the performance in the detection rate of abnormal colonic regions corresponding to adenomatous polyps was very high. In previous work by our group we studied images from three different organs (endometrium, cervix and ovary) trying to compare normal and abnormal regions of interest. Only texture features were extracted and the results were very promising [5].

However, in order to investigate further the differences of laparoscopy imaging features when computed under different viewing conditions we decided to carry out this study using multiscale analysis in chicken.

## 2. Methodology

In order to capture the images the CIRCON IP4.1 endoscopic camera was used. The analog output signal of the camera (PAL 475 horizontal lines) was digitised using the Matrox Meteor II frame grabber which was installed in a PC. Through this system the physician is able to select and freeze RGB images with a resolution of 720x576 pixels x24 bits (tiff format) and transform them to gray scale format in order to carry out the analysis. The following images were captured from the experimental tissue (chicken): i) ten panoramic images, at 5cm distance as illustrated in Fig. 1a, ii) ten close up images, at 3cm distance as illustrated in Fig. 1b, and iii) twenty images for two consecutive angles of 5 degrees difference. The physician manually selected Regions of Interest (ROI) as illustrated in Fig 1 on all images. Multiscale analysis and texture features were computed for the evaluation of the different capturing conditions.

### 2.1 Multiscale Analysis

The goal of multiscale image analysis is to reveal image characteristics at different image resolutions [6]. For example, small objects affect texture features at low resolution levels (with little or no downsampling involved), while larger objects affect texture features at higher resolution levels. Thus, if there is a particular range of scales, where we have objects of diagnostic interest, it is preferable to use this range for feature extraction in computer aided diagnostic systems. Within a single image scale, there is a number of different frequency bands that can be used for texture feature analysis. In this study, we used only the low-frequency band, where most of the image energy is nearly-always concentrated. This was implemented by first applying a low-pass filter, followed by downsampling by a factor of two to ten in each direction. Multiscale analysis was applied to all captured images using a scale from 1x1 to 10x10 in close up and panoramic views and 1x1 to 5x5 and 10x10 range to different angles views. Figure 2 illustrates the resampled images for panoramic and close up views for the scales 2x2 to 5x5. Texture features were then computed for the ROIs of the downsampled images.

### 2.2 Feature Extraction

Texture features were extracted from the ROIs using the following feature sets:

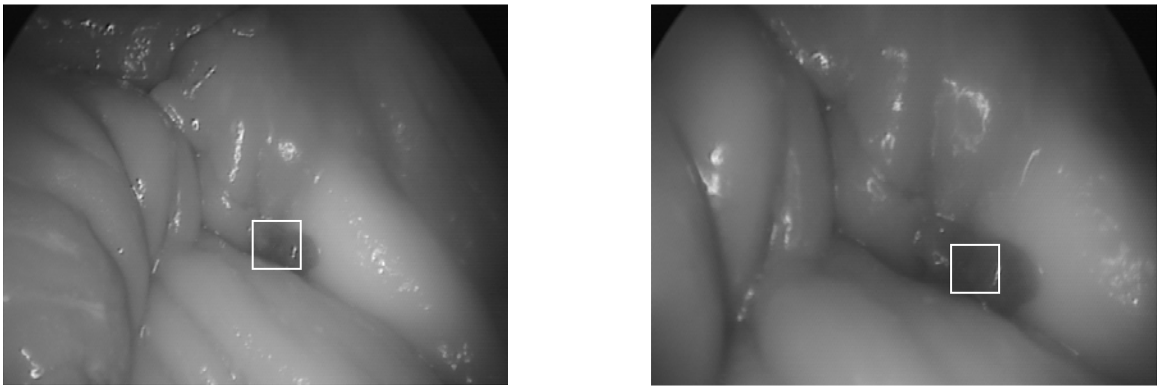
**A. Statistical Features (SF):** SF features describe the gray level histogram distribution without considering spatial independence. The following texture features were computed: 1) Mean value, 2) Variance, 3) Median value, 4) Skewness, 5) Kurtosis, 6) Energy, 7) Entropy and 8) Mode.

**B. Spatial Gray Level Dependence Matrices (SGLDM):** The spatial gray level dependence matrices as proposed by Haralick et al. [7] are based on the estimation of the second-order joint conditional probability density functions that two pixels $(k,l)$ and $(m,n)$ with distance $d$ in direction specified by the angle $\theta$, have intensities of gray level $i$ and gray level $j$. Based on the probability density functions the following texture measures were computed: 1) Angular second moment, 2) Contrast, 3) Correlation, 4) Sum of squares: variance, 5) Inverse difference moment, 6) Sum average, 7) Sum variance, 8) Sum entropy, 9) Entropy, 10) Difference variance, 11) Difference entropy, 12) Homogeneity, and 13) Information measures of correlation. For a chosen distance $d$ (in this work $d=1$ was used) and for angles $\theta = 0^o, 45^o, 90^o$ and $135^o$ we computed four values for each of the above texture measures. The above features were calculated for displacements δ=(0,1), (1,1), (1,0), (1,-1), where δ≡(Δx,Δy), and their mean values were taken.

## 3. Results

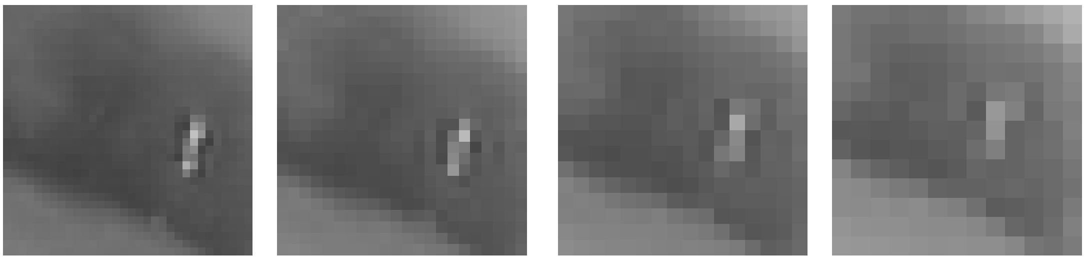
The multiscale texture features ASM, contrast, variance and homogeneity for panoramic vs. close up views are tabulated in Table I for scales 1x1 to 10x10. As shown in Table I, for scale 3x3 all four features have significant difference between close up and panoramic views, whereas for scale 6x6 and 9x9 all four features have no significant difference. In the other scales, certain features have significant difference whereas others have not.

Figures 3 to 5 illustrate the multiscale analysis results for the first experiment (panoramic vs. close up view) for the texture features homogeneity, entropy, and correlation respectively.

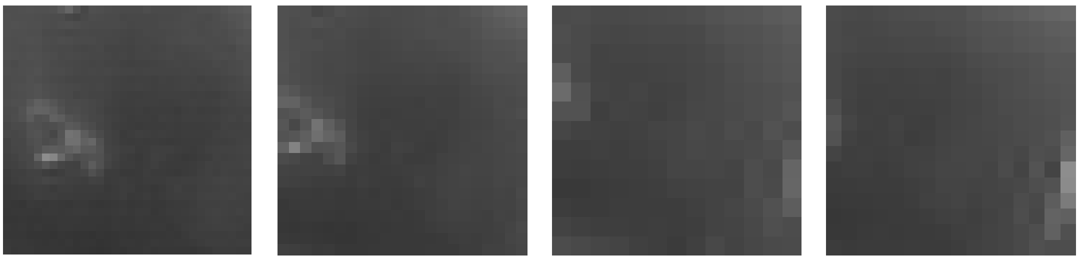


a) Panoramic view b) Close up view

**Figure 1**: Original gray scale image with ROI shown in square area with white perimeter. (a) Panoramic view and (b) Close up view.



a) 2x2 (32x32 pixels) b) 3x3 (22x22 pixels) c) 4x4 (16x16 pixels) d) 5x5 (13x13 pixels)



e) 2x2 (32x32 pixels) f) 3x3 (22x22 pixels) g) 4x4 (16x16 pixels) h) 5x5 (13x13 pixels

**Figure 2**: ROI downsampled images. (a) - (d) Panoramic views, at scales 2x2 to 5x5 and (e) – (h) Close up views at 2x2 to 5x5

As illustrated in Fig. 3, the texture feature of homogeneity has a maximum value for 2x2 downsampling scale. Also, as illustrated in Fig. 4, the entropy feature drops at the same downsample scale (i.e. 2x2) and then it varies very little. According to this we can conclude that the optimum downsampling scale is 2x2 for this example.

**TABLE I:** SGLDM TEXTURE FEATURES (CLOSE UP - PANORAMIC) FOR ALL SCALES {$Q_1$, $Q_3$, AND SIQR REPRESENT THE LOWER QUARTILE (25% PERCENTILE), UPPER QUARTILE (75% PERCENTILE) AND THE SEMI-INTER QUARTILE RANGE, RESPECTIVELY}

| Scale | $Q_1$ | Median | $Q_3$ | SIQR | $Q_1$ | Median | $Q_3$ | SIQR | H[1] |
|---|---|---|---|---|---|---|---|---|---|
| 1x1 | | Close Up | | | | Panoramic | | | |
| ASM[2] | 0,004 | 0,005 | 0,007 | 0,001 | 0,003 | 0,008 | 0,021 | 0,009 | 0 |
| Contrast | 73,754 | 82,989 | 93,377 | 9,811 | 139,955 | 180,842 | 204,211 | 32,128 | 1 |
| Variance | 124,695 | 139,706 | 184,476 | 29,891 | 166,110 | 172,599 | 182,079 | 7,984 | 1 |
| Homogeneity | 0,158 | 0,208 | 0,283 | 0,063 | 0,084 | 0,112 | 0,169 | 0,042 | 1 |
| 2x2 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,006 | 0,007 | 0,009 | 0,001 | 0,009 | 0,011 | 0,018 | 0,005 | 1 |
| Contrast | 85,074 | 136,638 | 140,856 | 27,891 | 105,684 | 136,397 | 143,832 | 19,074 | 0 |
| Variance | 125,172 | 130,199 | 136,844 | 5,836 | 87,974 | 113,140 | 125,218 | 18,622 | 1 |
| Homogeneity | 0,183 | 0,219 | 0,308 | 0,063 | 0,134 | 0,175 | 0,211 | 0,038 | 0 |
| 3x3 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,004 | 0,004 | 0,006 | 0,001 | 0,007 | 0,013 | 0,020 | 0,007 | 1 |
| Contrast | 92,940 | 109,503 | 126,276 | 16,668 | 216,033 | 398,403 | 563,231 | 173,599 | 1 |
| Correlation | 0,650 | 0,668 | 0,714 | 0,032 | -0,025 | 0,093 | 0,255 | 0,140 | 1 |
| Variance | 149,790 | 175,832 | 187,880 | 19,045 | 208,010 | 247,728 | 319,437 | 55,713 | 1 |
| Homogeneity | 0,171 | 0,192 | 0,263 | 0,046 | 0,070 | 0,099 | 0,201 | 0,065 | 1 |
| 4x4 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,004 | 0,005 | 0,005 | 0,000 | 0,003 | 0,004 | 0,008 | 0,002 | 0 |
| Contrast | 14,371 | 22,420 | 36,517 | 11,073 | 46,921 | 59,129 | 63,910 | 8,495 | 1 |
| Variance | 123,588 | 130,785 | 149,769 | 13,091 | 199,076 | 214,980 | 228,864 | 14,894 | 1 |
| Homogeneity | 0,255 | 0,313 | 0,378 | 0,062 | 0,164 | 0,191 | 0,260 | 0,048 | 1 |
| 5x5 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,002 | 0,002 | 0,002 | 0,000 | 0,004 | 0,005 | 0,008 | 0,002 | 1 |
| Contrast | 66,575 | 73,495 | 83,820 | 8,623 | 69,632 | 73,727 | 127,037 | 28,702 | 0 |
| Variance | 352,274 | 361,911 | 443,552 | 45,639 | 99,908 | 129,627 | 148,866 | 24,479 | 1 |
| Homogeneity | 0,222 | 0,272 | 0,337 | 0,058 | 0,136 | 0,184 | 0,255 | 0,060 | 0 |
| 6x6 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,007 | 0,008 | 0,009 | 0,001 | 0,006 | 0,008 | 0,016 | 0,005 | 0 |
| Contrast | 5,460 | 19,888 | 82,026 | 38,283 | 19,614 | 39,627 | 88,315 | 34,351 | 0 |
| Variance | 53,806 | 67,104 | 91,228 | 18,711 | 39,854 | 66,280 | 84,479 | 22,313 | 0 |
| Homogeneity | 0,223 | 0,283 | 0,395 | 0,086 | 0,157 | 0,213 | 0,259 | 0,051 | 0 |
| 7x7 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,003 | 0,004 | 0,004 | 0,000 | 0,005 | 0,005 | 0,006 | 0,000 | 1 |
| Contrast | 9,823 | 34,718 | 37,989 | 14,083 | 145,387 | 183,663 | 211,423 | 33,018 | 1 |
| Variance | 116,088 | 128,013 | 132,280 | 8,096 | 142,879 | 158,957 | 165,295 | 11,208 | 1 |
| Homogeneity | 0,279 | 0,302 | 0,366 | 0,044 | 0,191 | 0,243 | 0,331 | 0,070 | 0 |
| 8x8 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,004 | 0,004 | 0,004 | 0,000 | 0,005 | 0,006 | 0,007 | 0,001 | 1 |
| Contrast | 146,746 | 177,348 | 219,807 | 36,531 | 182,898 | 192,621 | 205,115 | 11,108 | 0 |
| Variance | 209,670 | 222,585 | 263,742 | 27,036 | 140,551 | 185,740 | 231,379 | 45,414 | 0 |
| Homogeneity | 0,181 | 0,235 | 0,306 | 0,062 | 0,180 | 0,207 | 0,289 | 0,055 | 0 |
| 9x9 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,004 | 0,004 | 0,005 | 0,001 | 0,005 | 0,005 | 0,006 | 0,001 | 0 |
| Contrast | 92,847 | 134,650 | 217,301 | 62,227 | 152,685 | 275,657 | 340,813 | 94,064 | 0 |
| Variance | 274,098 | 281,545 | 355,591 | 40,746 | 241,219 | 266,176 | 310,354 | 34,568 | 0 |
| Homogeneity | 0,252 | 0,317 | 0,416 | 0,082 | 0,184 | 0,239 | 0,367 | 0,091 | 0 |
| 10x10 | | Close Up | | | | Panoramic | | | H[1] |
| ASM[2] | 0,001 | 0,002 | 0,002 | 0,000 | 0,003 | 0,003 | 0,005 | 0,001 | 1 |
| Contrast | 458,211 | 474,857 | 497,588 | 19,688 | 117,432 | 135,803 | 170,820 | 26,694 | 1 |
| Variance | 466,977 | 530,053 | 635,333 | 84,178 | 147,640 | 164,110 | 180,763 | 16,562 | 1 |
| Homogeneity | 0,112 | 0,144 | 0,198 | 0,043 | 0,116 | 0,156 | 0,215 | 0,049 | 0 |

[1]H IS THE RESULT OF WILCOXON RANK SUM TEST BETWEEN DIFFERENT VIEWING CONDITIONS WITH '1' INDICATING SIGNIFICANT DIFFERENCE, AND '0' NO SIGNIFICANT DIFFERENCE AT Α=0.05

[2]ASM=ANGULAR SECOND MOMENT

**TABLE II:** SGLDM TEXTURE FEATURES (ANGLE1 – ANGLE2) FOR ALL SCALES {$Q_1$, $Q_3$, AND SIQR REPRESENT THE LOWER QUARTILE (25% PERCENTILE), UPPER QUARTILE (75% PERCENTILE) AND THE SEMI-INTER QUARTILE RANGE, RESPECTIVELY}

| Scale | $Q_1$ | Median | $Q_3$ | SIQR | $Q_1$ | Median | $Q_3$ | SIQR | H[1] |
|---|---|---|---|---|---|---|---|---|---|
| 1x1 | | Angle1 | | | | Angle2 | | | |
| ASM[2] | 0,001 | 0,001 | 0,001 | 0,000 | 0,001 | 0,001 | 0,001 | 0,000 | 0 |
| Contrast | 149,712 | 254,531 | 356,072 | 103,180 | 118,712 | 304,900 | 321,611 | 101,450 | 0 |
| Correlation | 0,098 | 0,386 | 0,664 | 0,283 | 0,240 | 0,369 | 0,609 | 0,185 | 0 |
| Variance | 150,494 | 233,603 | 324,738 | 87,122 | 148,283 | 206,802 | 277,644 | 64,681 | 0 |
| Homogeneity | 0,061 | 0,073 | 0,098 | 0,018 | 0,064 | 0,075 | 0,107 | 0,021 | 0 |
| 2x2 | | Angle1 | | | | Angle2 | | | H[1] |
| ASM[2] | 0,004 | 0,008 | 0,009 | 0,003 | 0,003 | 0,006 | 0,010 | 0,003 | 0 |
| Contrast | 3,226 | 5,200 | 28,449 | 12,612 | 3,781 | 7,423 | 25,429 | 10,824 | 0 |
| Correlation | 0,918 | 0,955 | 0,960 | 0,021 | 0,926 | 0,943 | 0,958 | 0,016 | 0 |
| Variance | 34,245 | 55,525 | 173,669 | 69,712 | 35,911 | 88,371 | 172,313 | 68,201 | 0 |
| Homogeneity | 0,296 | 0,428 | 0,487 | 0,096 | 0,323 | 0,442 | 0,461 | 0,069 | 0 |
| 3x3 | | Angle1 | | | | Angle2 | | | |
| ASM[2] | 0,004 | 0,007 | 0,010 | 0,003 | 0,004 | 0,006 | 0,010 | 0,003 | 0 |
| Contrast | 3,914 | 6,167 | 43,625 | 19,855 | 4,645 | 6,110 | 21,942 | 8,648 | 0 |
| Correlation | 0,917 | 0,939 | 0,959 | 0,021 | 0,916 | 0,927 | 0,962 | 0,023 | 0 |
| Variance | 47,426 | 61,033 | 173,473 | 63,024 | 40,647 | 84,418 | 119,040 | 39,197 | 0 |
| Homogeneity | 0,266 | 0,406 | 0,469 | 0,101 | 0,295 | 0,401 | 0,478 | 0,091 | 0 |
| 4x4 | | Angle1 | | | | Angle2 | | | H[1] |
| ASM[2] | 0,005 | 0,006 | 0,010 | 0,003 | 0,004 | 0,006 | 0,013 | 0,004 | 0 |
| Contrast | 4,223 | 11,416 | 74,508 | 35,142 | 9,113 | 13,238 | 29,496 | 10,192 | 0 |
| Correlation | 0,892 | 0,918 | 0,953 | 0,031 | 0,882 | 0,894 | 0,918 | 0,018 | 0 |
| Variance | 41,899 | 101,078 | 197,298 | 77,699 | 32,052 | 86,897 | 152,139 | 60,044 | 0 |
| Homogeneity | 0,207 | 0,318 | 0,437 | 0,115 | 0,240 | 0,317 | 0,467 | 0,113 | 0 |
| 5x5 | | Angle1 | | | | Angle2 | | | H[1] |
| ASM[2] | 0,005 | 0,010 | 0,013 | 0,004 | 0,006 | 0,008 | 0,014 | 0,004 | 0 |
| Contrast | 5,840 | 8,701 | 94,390 | 44,275 | 5,770 | 15,584 | 33,272 | 13,751 | 0 |
| Correlation | 0,829 | 0,868 | 0,928 | 0,050 | 0,844 | 0,881 | 0,920 | 0,038 | 0 |
| Variance | 31,524 | 39,478 | 190,244 | 79,360 | 36,399 | 75,685 | 117,676 | 40,638 | 0 |
| Homogeneity | 0,177 | 0,352 | 0,402 | 0,112 | 0,239 | 0,297 | 0,430 | 0,095 | 0 |
| 10x10 | | Angle1 | | | | Angle2 | | | H[1] |
| ASM[2] | 0,015 | 0,017 | 0,019 | 0,002 | 0,015 | 0,016 | 0,018 | 0,002 | 0 |
| Contrast | 15,561 | 24,612 | 248,969 | 116,704 | 19,120 | 37,065 | 104,593 | 42,737 | 0 |
| Correlation | 0,625 | 0,729 | 0,758 | 0,066 | 0,632 | 0,700 | 0,774 | 0,071 | 0 |
| Variance | 32,146 | 56,929 | 230,060 | 98,957 | 44,146 | 67,669 | 142,880 | 49,367 | 0 |
| Homogeneity | 0,114 | 0,212 | 0,252 | 0,069 | 0,145 | 0,200 | 0,232 | 0,044 | 0 |

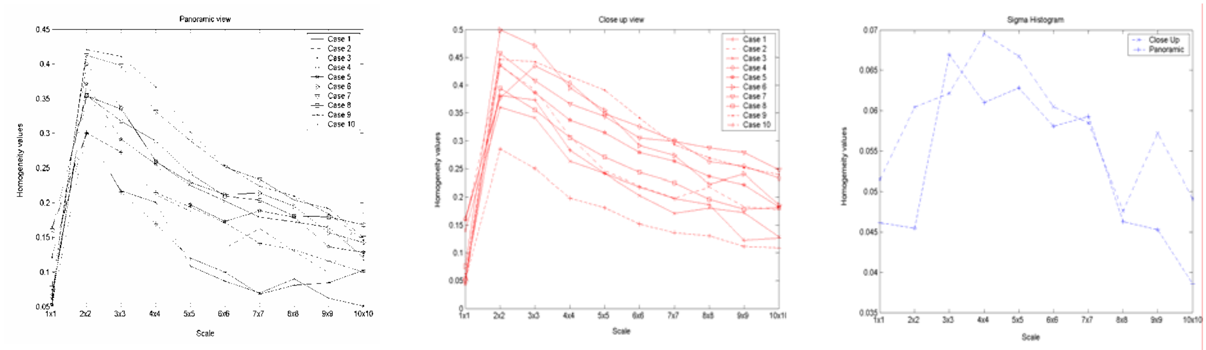
[1]H IS THE RESULT OF WILCOXON RANK SUM TEST BETWEEN DIFFERENT VIEWING CONDITIONS WITH '1' INDICATING SIGNIFICANT DIFFERENCE, AND '0' NO SIGNIFICANT DIFFERENCE AT A=0.05

[2]ASM=ANGULAR SECOND MOMENT

Also other texture features like the correlation showed that for the different distance viewing positions it is difficult to extract conclusions because of the variability of the correlation values with scale as illustrate in Fig 5.

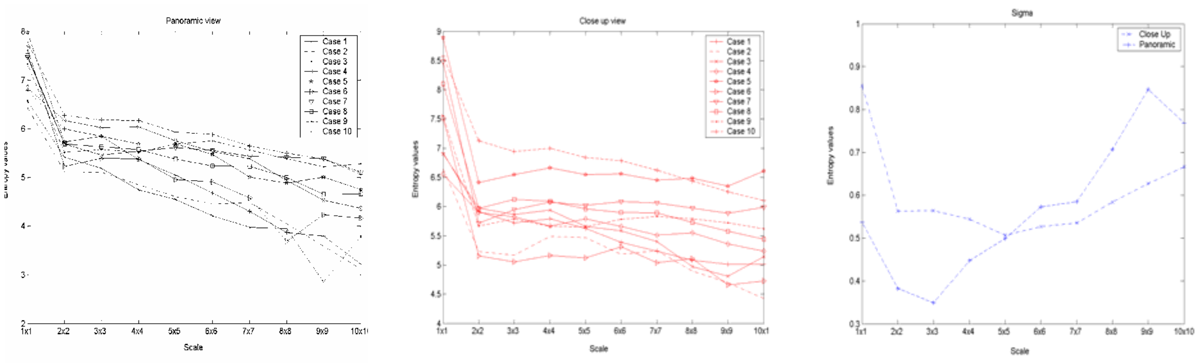
The multiscale texture features ASM, contrast, variance and homogeneity for angle1 vs. angle2 views are tabulated in Table II for scales 1x1 to 5x5 and 10x10. As shown in Table II, for all scales all four features have no significant difference.

Figures 6 and 7 illustrate the multiscale analysis results for the second experiment (capturing under consecutive angle views) for the texture features homogeneity and entropy respectively. It is shown that these features have similar values for scales 2x2 up to 5x5. The same applies for their standard deviation values (Fig. 6c and 7c).



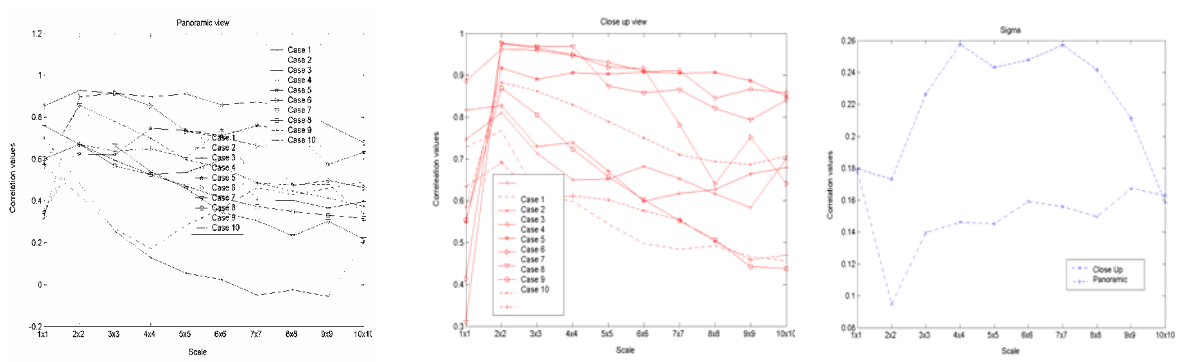

a) b) c)

**Figure 3**: Multiscale analysis for homogeneity feature a) panoramic view, b) close up view, and c) standard deviation values.



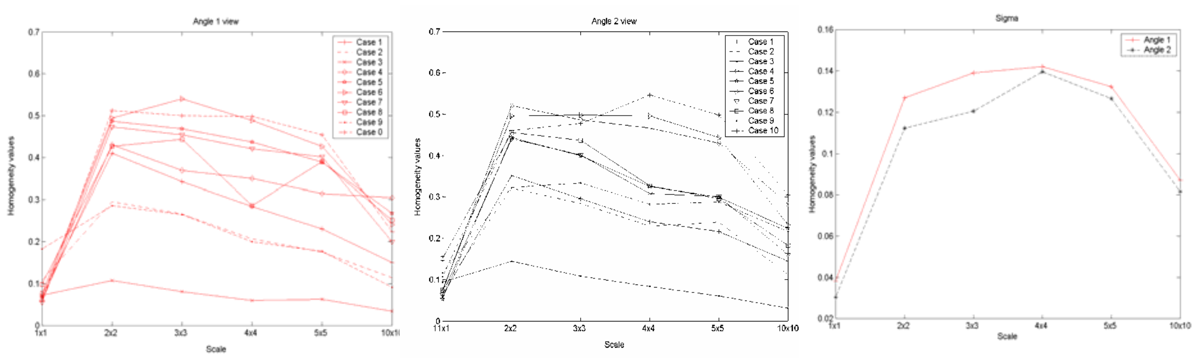

a) b) c)

**Figure 4**: Multiscale analysis for entropy feature a) panoramic view, b) close up view, and c) standard deviation values.



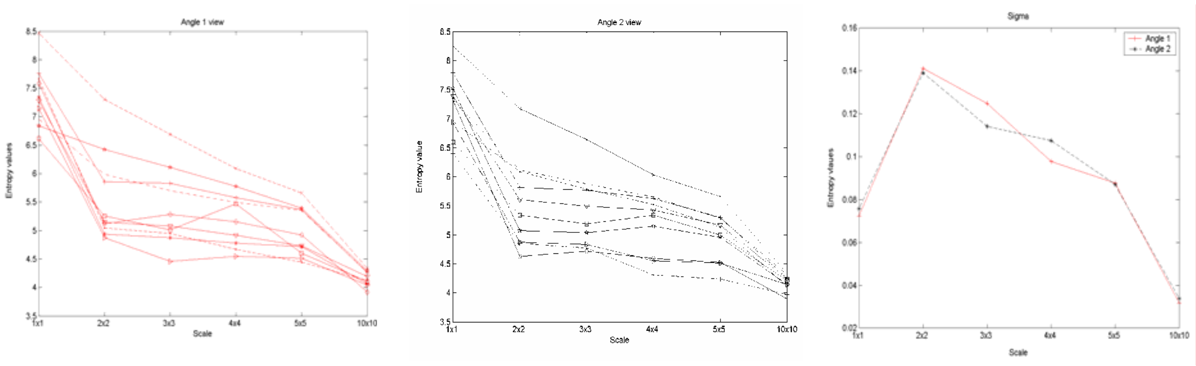

a) b) c)

**Figure 5**: Multiscale analysis for correlation feature a) panoramic view, b) close up view, and c) standard deviation values.




a) b) c)

**Figure 6**: Multiscale analysis for homogeneity feature a) angle 1 view, b) angle 2 view, and c) standard deviation values.




a) b) c)

**Figure 7**: Multiscale analysis for entropy feature a) angle 1 view, b) angle 2 view, and c) standard deviation values.

## 4. Concluding Remarks

Results indicate that there is significant variability between the close up and panoramic views for multiscale texture features. However, there is some variance (within reasonable bounds) between the multiscale texture features of consecutive angles. It is hoped that the results of this study will prove useful in computer aided diagnosis in laparoscopy imaging. However, more experiments have to be carried out and more images have to be analyzed to support this further.

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