Computer Aided Diagnosis System for identification of Gynaecological cancer

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Quantitative analysis of endoscopy images

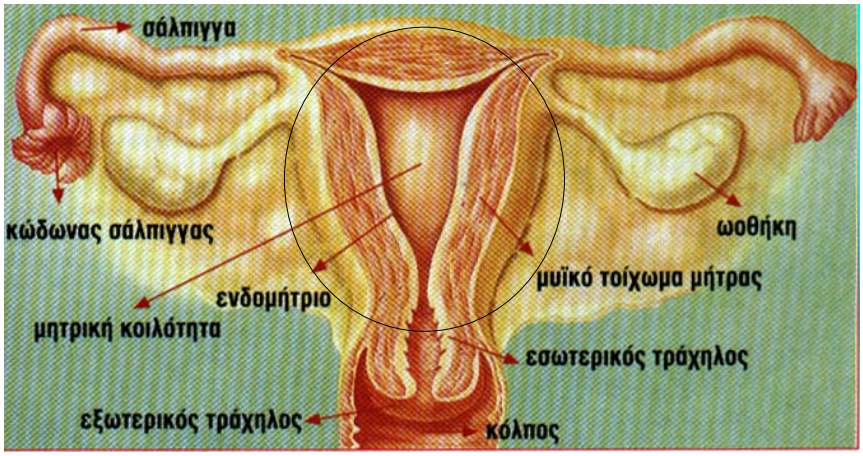
- Similar Research
  - Endoscopy (Xia [05], Yokoi [06])
  - Laryngoscopy (Ilgner [03])
  - Colonoscopy (Karkanis [03])
  - Gastroendoscopy (ESGastrE Guidelines [01])
- No similar work was established for hysteroscopy images analysis of gynaecological cancer
  - European Society of Gynaecological Endoscopy

Gynaecological cancer

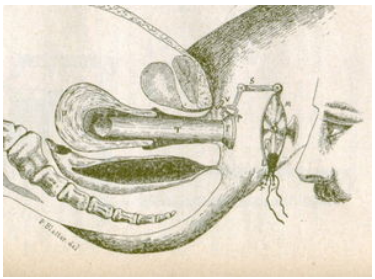
- 2007 (USA), expected 39,080 new cases of endometrium cancer [1], with 7,400 deaths
- Good prognosis
  - Early diagnosis
- Symptoms
  - Starts from the outside tissue

[1] American Cancer Society

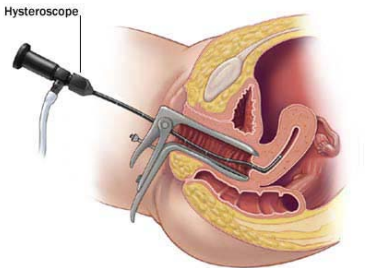
Anatomy of the female reproductive system

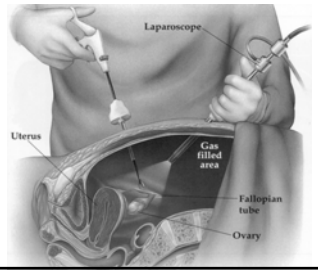


Hysteroscopy/Laparoscopy

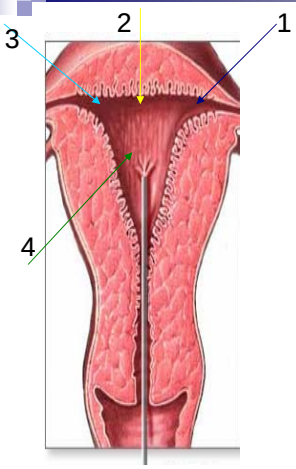


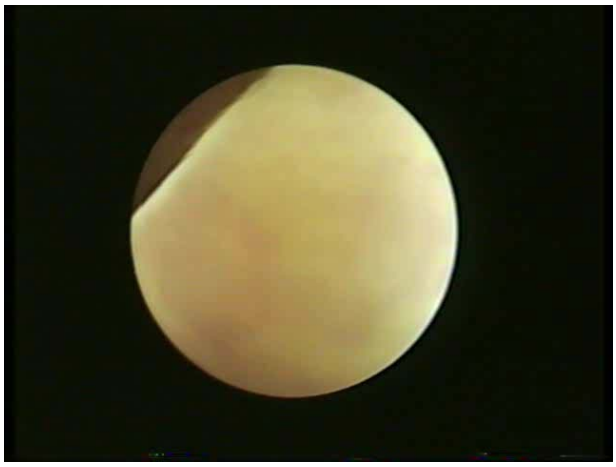
S. Duplay, S. Clado, 1898





Example of hysteroscopy examination
(1/2)





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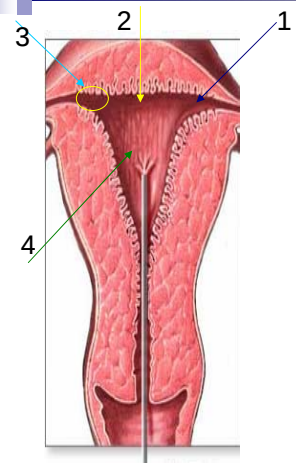
Example of hysteroscopy examination
(2/2)



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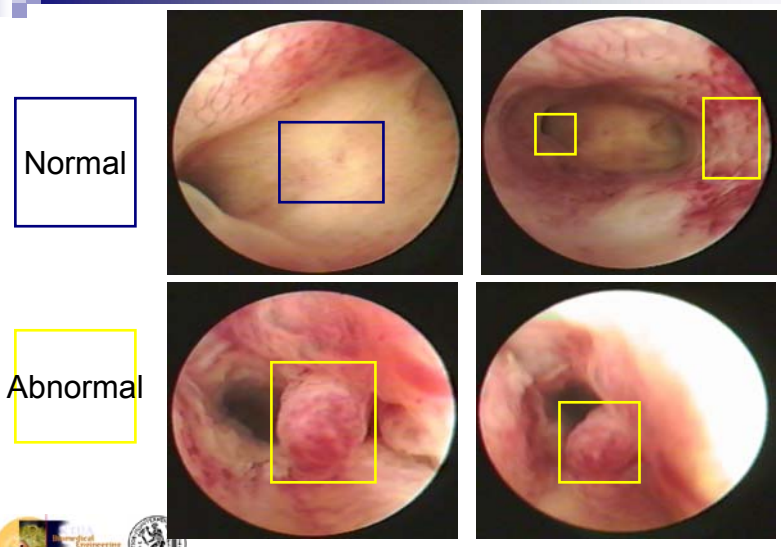
Examples of hysteroscopy ROIs



Scope of the research

- Developed an integrated standardized protocol for the quantitative analysis of endoscopy images
- Developed and apply a CAD system for identification of gynaecological cancer during a hysteroscopy operation

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2. Methodology
3. Results
4. Conclusions and Future Work

Methodology

- Experimental tissue analysis
- Gamma algorithm
- Texture features algorithms
- Neural Networks algorithms

Samples

- 40 women, age 22-50 years old
- 416 images
  - 208 normal ROIs of the endometrium
  - 208 abnormal ROIs of the endometrium

System architecture

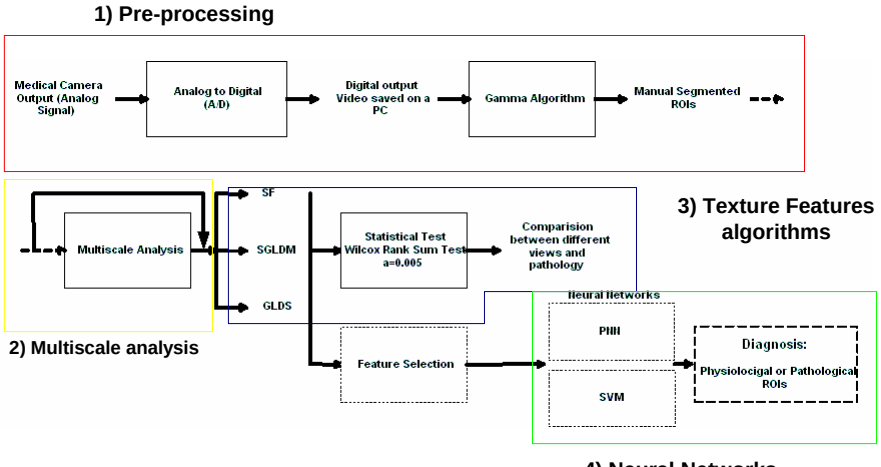
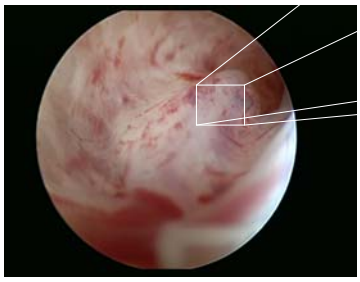


Image capturing

- Video Camera
- Frame Grabber
- Laptop PC (IEEE 1394)

<u>Input Signal</u>
Analog Signal:
PAL 475
horizontal lines
<u>Output Signal</u>
Digital Signal:
720x576 pixels x
24bit



Region Of
Interest:
150x150 pixels
x 24bit

Gamma algorithm (1/2)

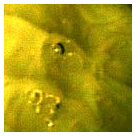
$$\begin{bmatrix} R_p \\ G_p \\ B_p \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} R_{in} \\ G_{in} \\ B_{in} \end{bmatrix} + \begin{bmatrix} k_1 \\ k_2 \\ k_3 \end{bmatrix}$$

Original Image

$$R_{out} = 255\left(\frac{R_p}{255}\right)^{\gamma_R}$$

$$G_{out} = 255\left(\frac{G_p}{255}\right)^{\gamma_G}$$

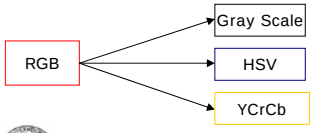
$$B_{out} = 255\left(\frac{B_p}{255}\right)^{\gamma_B}.$$



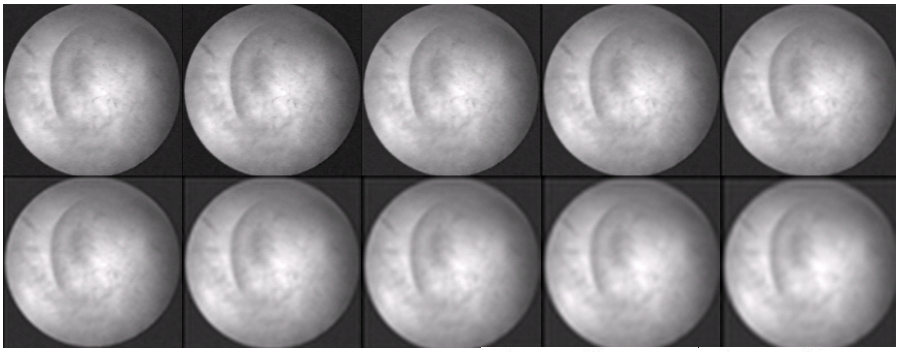
Corrected Image

Color palette (2/2)

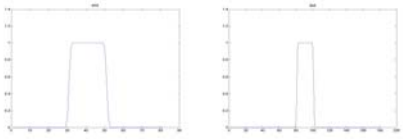
Color	R	G	B
Black	0	0	0
White	255	255	255
Red	203	0	0
Green	64	173	38
Blue	0	0	142
Dark skin	94	28	13
Light skin	241	149	108
Blue sky	97	119	171
Foliage	90	103	39
Blue flower	164	131	196
Orange	255	116	21
Magenta	207	3	124



Multiscale analysis

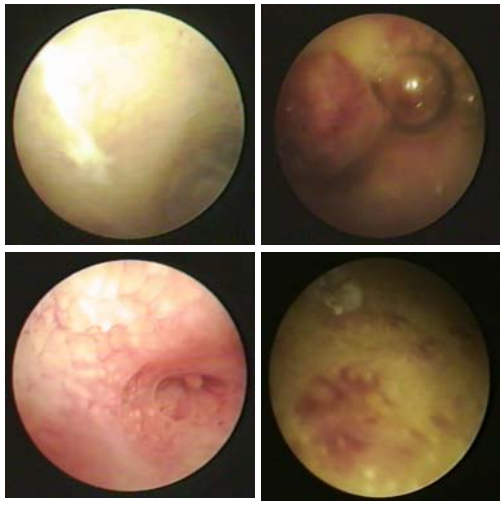


- Scale 1x1 up to 10x10
- Low Pass filters



Problems…

- Illumination
- Different Angle
- Zooming
  (close-up, panoramic)
- Distance
- Reflection
- Refraction



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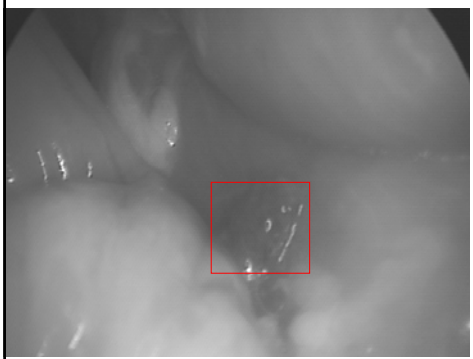
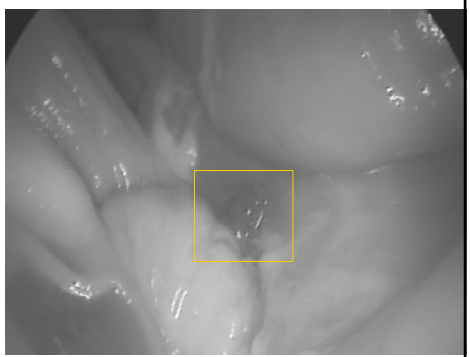
Experimental tissue, close up (2cm) vs panoramic view (5cm)





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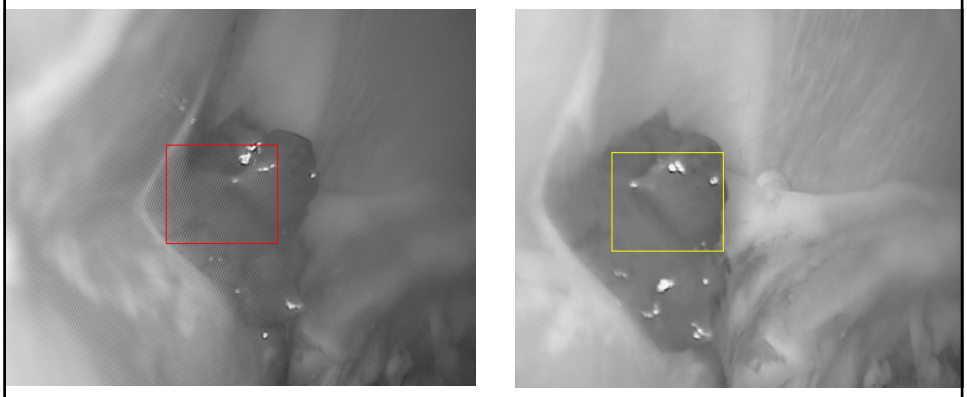
Experimental tissue, angle 1 vs angle 2 view (3^0 difference)



Texture features algorithms

- **Statistical Features (SF)**

1) Mean, 2) Variance, 3) Median, 4) Mode, 5) Skewness, 6) Kurtosis, 7) Energy και 8) Entropy.

- **Spatial Gray Level Dependence Matrices (SGLDM)**

1) ASM, 2) Contrast, 3) Correlation, 4) Variance, 5) Homogeneity, 6) Sum Average, 7) Sun Variance, 8) Entropy, 9) Sum Entropy, 10) Dif. Variance, 11) Dif. Entropy, 12) Inf. Correlation1, και 13) Inf. Correlation2.

- **Gray level difference statistics (GLDS)**

1) Homogeneity, 2) Contrast, 2) Energy, 4) Entropy και 5) Mean.

Neural Networks

- Support Vector Machines (SVM)
- Probabilistic Neural Nets (PNN)

Data analysis:
- Principal Component Analysis (PCA)

- Training
  - Leave one out method

Receiver Operating Characteristic: ROC curves

- Accuracy (CC)
- Precision (PR)
- Sensitivity (SE)
- Specificity (SP)
- True Positive (TP)
- False Positive (FP)
- False Negative (FN)
- True Negative (TN)

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Results

- Gamma algorithm
- Different viewing conditions
- Real images
- Texture features
- Neural networks

Gamma algorithm coefficients

A matrix	No Correction	Exp 1	Exp 2	Exp 3	Median values for Exps 1, 2, 3
a_{11}	1	0,827	0,927	0,975	0,927
a_{12}	0	0,065	0,011	0,105	0,065
a_{13}	0	0,042	0,004	0,104	0,042
a_{21}	0	0,065	0,011	0,105	0,065
a_{22}	1	0,780	0,935	0,895	0,895
a_{23}	0	0,071	0,062	0,134	0,071
a_{31}	0	0,042	0,004	0,104	0,042
a_{32}	0	0,044	0,032	0,023	0,032
a_{33}	1	0,868	1,011	1,044	1,011
k matrix					
k_{11}	0	7,693	1,101	-1,673	1,101
k_{21}	0	10,083	2,090	0,528	2,090
k_{31}	0	-8,161	1,598	-5,689	-5,689
γ matrix					
γ_R	1	1,285	1,078	1,038	1,078
γ_G	1	1,220	1,046	0,999	1,046
γ_B	1	1,180	0,971	1,040	1,040

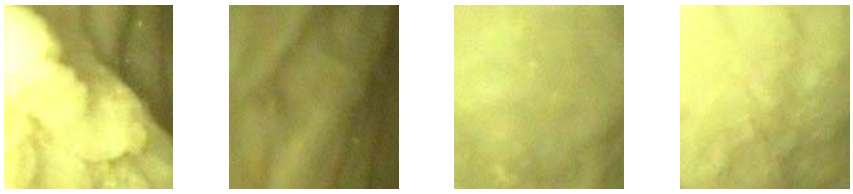
Mean square error (MSE)

MSE for each Channel		
Channels	$MSE_{org-cam} = \frac{1}{NM}\sum_{i,j=1}^{NM}(I_{org_{i,j}} - I_{camera_{i,j}})^2$	$MSE_{org-cor} = \frac{1}{NM}\sum_{i,j=1}^{NM}(I_{org_{i,j}} - I_{cor_{i,j}})^2$
Exp 1		
Red	3342	482
Green	2088	350
Blue	1228	415
Exp 2		
Red	1605	570
Green	2180	443
Blue	2545	670
Exp 3		
Red	3301	578
Green	1973	415
Blue	3035	316
Mean values of Exp 1, 2 and 3		
Red	2749	543
Green	2080	403
Blue	2269	467

Gamma algorithm, examples

Original images

After gamma correction



Experimental tissue, close up (2cm) vs panoramic view (5cm) before gamma correction

	Panoramic View					Close up View					
	P5%	P25%	P50%	P75%	P95%	P5%	P25%	P50%	P75%	P95%	H
SF											
Mean	36,49	42,42	50,73	58,72	89,41	39,50	41,91	80,65	125,33	149,09	0
Variance	55,78	108,13	201,17	244,69	431,18	55,61	259,80	633,07	1708,22	1795,52	0
Median	36,86	42,62	50,29	62,08	88,36	40,16	43,51	83,46	131,32	161,01	0
Mode	40,00	42,00	51,00	69,00	88,00	40,00	53,00	101,00	155,00	169,00	0
Skewness	-0,42	-0,21	-0,12	0,23	0,28	-0,91	-0,40	-0,27	-0,03	0,26	0
Kurtosis	2,09	2,31	2,56	2,66	2,74	1,89	1,91	2,33	2,77	3,33	0
Entropy	3,39	3,74	4,03	4,06	4,39	3,40	4,08	4,51	4,94	5,00	0
SGLDM											
Contrast	27,49	27,50	28,04	30,00	32,17	27,71	28,06	29,68	34,68	62,59	0
Correlation	0,75	0,87	0,92	0,94	0,97	0,73	0,95	0,97	0,98	0,99	0
Variance	55,54	106,97	199,49	243,39	425,94	55,08	258,21	626,46	1688,81	1787,09	0
Homogeneity	0,20	0,20	0,21	0,21	0,21	0,19	0,19	0,21	0,21	0,21	0
Entropy	6,33	6,72	7,04	7,13	7,38	6,38	7,08	7,55	7,98	8,10	0
GLDS											
Homogeneity	0,20	0,20	0,21	0,21	0,21	0,19	0,19	0,21	0,21	0,21	0
Contrast	27,50	27,50	28,04	30,01	32,17	27,71	28,06	29,68	34,68	62,54	0
Energy	0,10	0,10	0,10	0,10	0,10	0,08	0,09	0,10	0,10	0,10	0
Entropy	2,44	2,44	2,45	2,48	2,51	2,44	2,45	2,47	2,55	2,74	0
Mean	4,13	4,13	4,17	4,33	4,46	4,14	4,18	4,25	4,62	5,50	0

Experimental tissue, close up (2cm) vs panoramic view (5cm) after gamma correction

	Panoramic View					Close up View					Statistical Analysis		
											Panoramic vs Close up after gamma	Before vs After Gamma for Panoramic views	Before vs After Gamma for close up views
	P5%	P25%	P50%	P75%	P95%	P5%	P25%	P50%	P75%	P95%	H	H	H
SF													
Mean	86,48	97,19	110,26	122,79	169,87	92,16	95,16	151,04	212,50	223,83	0	1	0
Variance	166,31	351,08	506,72	646,23	1094,79	172,50	815,22	1075,93	1505,68	2731,20	0	0	0
Median	87,80	97,59	110,49	129,64	168,85	93,66	99,32	159,48	227,37	242,01	0	1	0
Mode	92,00	97,00	114,00	139,00	170,00	97,00	119,00	182,00	244,00	245,00	0	1	0
Skewness	-0,51	-0,37	-0,28	0,05	0,13	-1,98	-0,84	-0,44	-0,38	0,03	0	0	0
Kurtosis	2,18	2,39	2,64	2,68	2,88	1,74	2,06	2,58	2,76	5,88	0	0	0
Entropy	3,91	4,30	4,45	4,55	4,84	3,89	3,95	4,53	4,82	4,86	0	1	0
SGLDM													
Contrast	65,89	72,00	78,41	89,66	91,19	41,61	45,87	63,18	89,62	90,42	0	1	1
Correlation	0,75	0,87	0,92	0,94	0,97	0,74	0,94	0,97	0,98	0,99	0	0	0
Variance	165,55	346,97	502,15	642,44	1081,54	170,73	809,78	1061,78	1487,91	2721,95	0	1	0
Homogeneity	0,13	0,13	0,14	0,14	0,15	0,13	0,13	0,20	0,27	0,44	0	1	0
Entropy	7,33	7,78	7,83	8,03	8,21	6,09	7,29	7,57	8,07	8,20	0	1	0
GLDS													
Homogeneity	0,13	0,13	0,14	0,14	0,15	0,13	0,13	0,20	0,27	0,44	0	1	0
Contrast	65,90	72,01	78,42	89,67	91,21	41,61	45,83	63,17	89,64	90,43	0	1	1
Energy	0,06	0,06	0,06	0,06	0,07	0,06	0,06	0,08	0,10	0,19	0	1	0
Entropy	2,86	2,90	2,94	3,01	3,01	2,21	2,60	2,80	3,00	3,01	0	1	0
Mean	6,40	6,67	6,95	7,46	7,52	3,37	4,54	5,90	7,43	7,45	0	1	0

Experimental tissue, angle 1 vs angle 2 view (3^0 difference) before gamma correction (1/2)

	Angle 1 View					Angle 2 View					
	P5%	P25%	P50%	P75%	P95%	P5%	P25%	P50%	P75%	P95%	H
SF											
Mean	31,98	37,07	43,43	92,53	182,63	27,79	34,06	42,64	49,79	64,03	0
Variance	49,56	93,37	181,76	343,80	476,76	58,52	63,58	93,85	263,72	448,90	0
Median	32,10	37,23	43,74	89,29	182,07	26,32	33,89	45,63	52,12	70,77	0
Mode	40,00	40,00	42,00	87,00	183,00	22,00	34,75	50,00	61,25	80,00	0
Skewness	-0,35	-0,14	-0,06	0,07	0,40	-0,47	-0,38	-0,24	0,08	0,39	0
Kurtosis	1,94	2,34	2,57	2,81	3,44	1,63	2,13	2,30	2,50	2,67	0
Entropy	3,36	3,63	3,94	4,28	4,41	3,44	3,46	3,62	4,03	4,18	0
SGLDM											
Contrast	27,55	28,33	28,77	32,80	37,37	26,86	28,17	28,62	29,18	30,29	0
Correlation	0,71	0,83	0,92	0,94	0,97	0,74	0,78	0,85	0,94	0,97	0
Variance	49,31	92,78	180,49	340,48	471,72	58,22	63,18	93,61	261,78	448,53	0
Homogeneity	0,20	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0
Entropy	6,33	6,61	6,95	7,31	7,42	6,41	6,45	6,60	7,03	7,15	0
GLDS											
Homogeneity	0,20	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0
Contrast	27,56	28,34	28,78	32,80	37,35	26,86	28,17	28,62	29,19	30,29	0
Energy	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0
Entropy	2,44	2,45	2,46	2,49	2,52	2,43	2,45	2,46	2,46	2,48	0
Mean	4,15	4,20	4,24	4,37	4,42	4,09	4,18	4,22	4,25	4,33	0

Experimental tissue, angle 1 vs angle 2 view (3^0 difference) after gamma correction (2/2)

	Angle 1 View					Angle 2 View					Statistical Analysis		
	P5%	P25%	P50%	P75%	P95%	P5%	P25%	P50%	P75%	P95%	Angle 1 vs Angle 2 after gamma	Before vs After Gamma for Angle 1	Before vs After Gamma for Angle 2
											H	H	H
SF													
Mean	33,68	38,98	45,56	94,08	181,43	29,47	35,91	44,78	51,99	66,35	0	0	0
Variance	51,96	97,59	199,06	314,46	484,39	62,07	66,4	104	276,13	456,75	0	0	0
Median	33,98	39,25	45,91	90,93	180,9	27,96	35,77	47,91	54,35	73,26	0	0	0
Mode	42	42,75	44	88,25	182	24	35,25	51	63,75	84	0	0	0
Skewness	-0,38	-0,18	-0,1	0,05	0,36	-0,51	-0,41	-0,26	0,05	0,36	0	0	0
Kurtosis	1,95	2,34	2,59	2,85	3,49	1,64	2,1	2,34	2,51	2,66	0	0	0
Entropy	3,38	3,65	3,98	4,23	4,42	3,47	3,48	3,67	4,05	4,19	0	0	0
SGLDM													
Contrast	27,81	28,98	30,4	31,05	32,57	26,92	27,91	29,12	30,7	31,34	0	0	0
Correlation	0,72	0,84	0,92	0,94	0,97	0,75	0,79	0,85	0,94	0,97	0	0	0
Variance	51,69	96,95	197,6	311,39	479,23	61,75	65,99	103,74	273,98	456,32	0	0	0
Homogeneity	0,2	0,2	0,21	0,22	0,23	0,2	0,2	0,21	0,21	0,21	0	0	0
Entropy	6,37	6,64	7,02	7,21	7,42	6,43	6,49	6,68	7,05	7,15	0	0	0
GLDS													
Homogeneity	0,21	0,21	0,22	0,22	0,23	0,21	0,21	0,22	0,22	0,22	0	0	0
Contrast	27,81	28,98	30,4	31,04	32,55	26,92	27,91	29,12	30,7	31,34	0	0	0
Energy	0,1	0,1	0,1	0,1	0,11	0,1	0,1	0,1	0,1	0,1	0	0	0
Entropy	2,44	2,45	2,47	2,48	2,48	2,43	2,44	2,46	2,49	2,5	0	0	0
Mean	4,12	4,16	4,27	4,31	4,35	4,09	4,16	4,26	4,37	4,41	0	0	0

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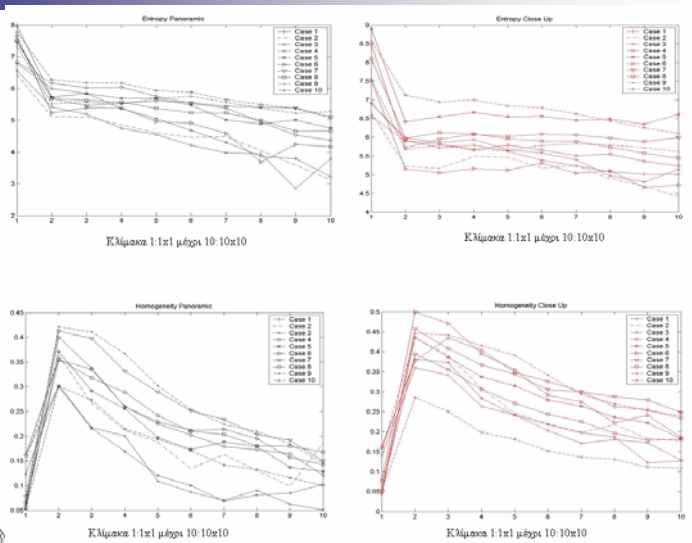
Multiscale analysis for close up (2cm) vs panoramic view (5cm) before and after gamma correction



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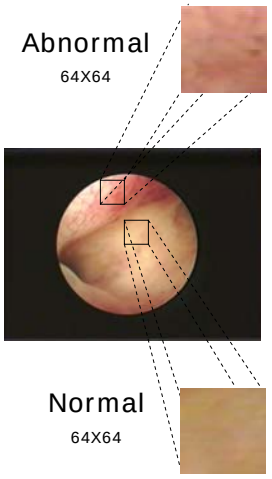
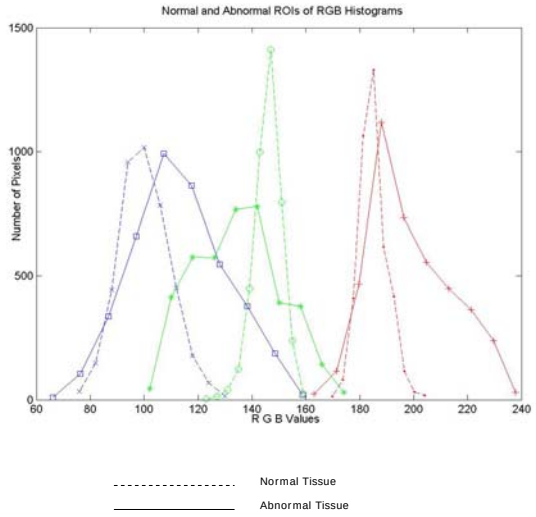
ROIs with their corresponding RGB histograms





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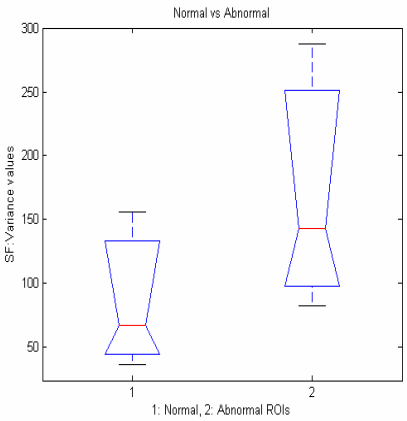
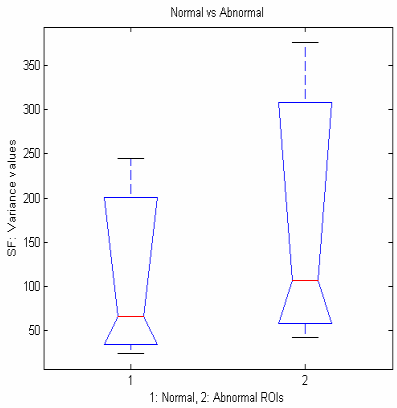
Before vs after gamma correction (1/2)





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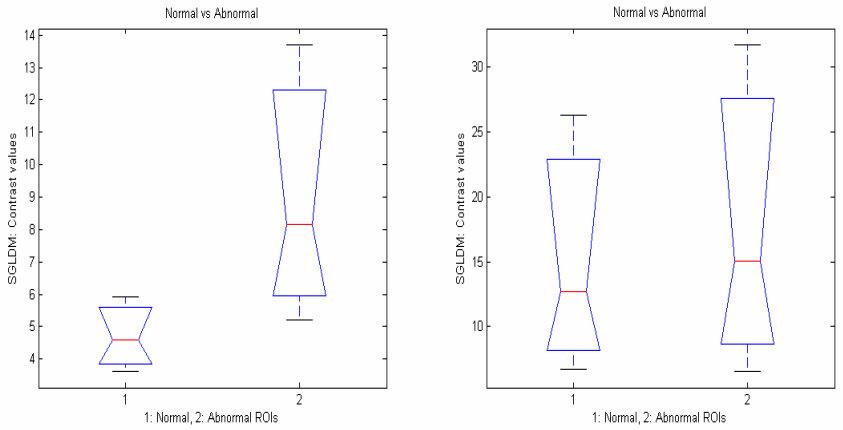
Before vs after gamma correction (2/2)



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Texture features analysis for real images before gamma correction (1/2)

	Normal ROIs					Abnormal ROIs					
	P5%	P25%	P50%	P75%	P95%	P5%	P25%	P50%	P75%	P95%	H
SF											
Mean	87,37	116,29	136,80	156,64	192,98	75,32	108,04	124,99	152,15	195,89	1
Variance	15,01	36,43	67,25	155,76	351,77	33,38	82,60	142,85	287,53	617,21	1
Median	87,66	116,81	136,96	157,58	192,24	75,41	106,67	123,21	153,35	197,99	1
Mode	85,95	116,00	136,00	158,00	188,05	74,00	103,50	125,00	159,00	202,10	1
Skewness	-1,00	-0,43	-0,11	0,14	0,58	-1,06	-0,43	-0,11	0,22	0,63	0
Kurtosis	1,93	2,26	2,63	3,08	4,28	1,81	2,22	2,61	3,07	4,68	0
Energy	0,02	0,03	0,04	0,05	0,08	0,01	0,02	0,03	0,03	0,05	1
Entropy	2,73	3,15	3,44	3,82	4,19	3,12	3,54	3,81	4,09	4,41	1
SGLDM											
Contrast	2,96	3,62	4,58	5,93	15,27	3,04	5,20	8,16	13,70	25,42	1
Correlation	0,85	0,93	0,96	0,98	0,99	0,91	0,95	0,97	0,98	0,99	1
Variance	14,75	35,61	65,93	154,00	344,69	32,83	81,91	140,56	280,55	605,91	1
Homogeneity	0,34	0,42	0,45	0,48	0,50	0,29	0,36	0,39	0,44	0,50	1
Entropy	4,65	5,11	5,48	6,01	6,49	5,10	5,64	6,04	6,44	6,79	1
GLDS											
Homogeneity	0,34	0,42	0,45	0,48	0,50	0,29	0,36	0,39	0,44	0,50	1
Contrast	2,95	3,62	4,57	5,92	15,23	3,04	5,19	8,15	13,67	25,36	1
Energy	0,16	0,22	0,24	0,26	0,28	0,13	0,17	0,20	0,23	0,28	1
Entropy	1,43	1,52	1,61	1,73	2,13	1,45	1,66	1,84	2,04	2,31	1
Mean	1,29	1,43	1,58	1,78	2,81	1,31	1,68	2,03	2,54	3,41	1

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Texture features analysis for real images after gamma correction (2/2)

	Normal ROIs					Abnormal ROIs					Normal vs Abnormal ROIs	Original vs Corrected Images For Normal ROIs	Original vs Corrected Images For Abnormal ROIs
	P5%	P25%	P50%	P75%	P95%	P5%	P25%	P50%	P75%	P95%	H	H	H
SF													
Mean	110,11	138,44	156,06	173,91	204,36	98,48	129,37	144,65	170,48	206,06	1	1	1
Variance	13,23	29,44	54,63	127,94	286,63	31,33	66,9	124,39	223,33	492,3	1	1	1
Median	110,18	138,83	156,44	174,42	203,53	98,2	127,92	143,75	171,43	207,7	1	1	1
Mode	109,95	135,75	156	175	201,05	98	124	146,5	176	211,4	1	1	1
Skewness	-1,01	-0,46	-0,14	0,12	0,56	-1,14	-0,47	-0,14	0,18	0,62	0	0	0
Kurtosis	1,94	2,26	2,64	3,09	4,39	1,82	2,24	2,62	3,16	4,85	0	0	0
Energy	0,02	0,03	0,04	0,06	0,09	0,02	0,02	0,03	0,04	0,06	1	1	1
Entropy	2,66	3,02	3,34	3,68	4,09	3,11	3,44	3,74	3,99	4,32	1	1	1
SGLDM													
Contrast	2,54	3,1	3,82	4,87	12,27	2,55	4,82	7,04	10,99	21,94	1	1	1
Correlation	0,85	0,93	0,96	0,98	0,99	0,91	0,95	0,97	0,98	0,99	1	1	0
Variance	13,02	28,83	53,97	126,41	284,3	30,89	65,53	120,85	221,38	488,55	1	1	1
Homogeneity	0,37	0,45	0,48	0,5	0,53	0,31	0,38	0,42	0,46	0,53	1	1	1
Entropy	4,47	4,93	5,31	5,78	6,28	5,01	5,49	5,93	6,28	6,65	1	1	1
GLDS													
Homogeneity	0,37	0,45	0,48	0,5	0,53	0,31	0,38	0,42	0,46	0,53	1	1	1
Contrast	2,54	3,09	3,81	4,86	12,24	2,55	4,81	7,03	10,97	21,89	1	1	1
Energy	0,17	0,24	0,25	0,27	0,3	0,14	0,18	0,21	0,24	0,3	1	1	1
Entropy	1,37	1,45	1,54	1,64	2	1,37	1,63	1,77	1,96	2,24	1	1	1
Mean	1,18	1,33	1,44	1,63	2,45	1,19	1,62	1,89	2,31	3,16	1	1	1

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Selected Texture features from real images of the RGB channels

	Normal						Abnormal						
					Red color								
SF	P5%	P25%	P50%	P75%	P95%	IQR	P5%	P25%	P50%	P75%	P95%	IQR	H
Median	153	183	199	216	240	16,5	142	177	193	212	241	18	0
Variance	13	25	42	83	206	29	28	51	87	155	301	52	1
Entropy	2,6	3	3,2	3,5	3,9	0,3	3	3,3	3,5	3,8	4,1	0,3	1
SGLDM													
ASM·10⁴	27	41	59	82	125	20	20	30	40	56	84	13	1
Sum Variance	40	85	150	313	797	113	89	189	324	587	1173	198	1
GLDS													
Homogeneity	0,28	0,317	0,34	0,364	0,393	0,023	0,257	0,293	0,316	0,34	0,38	0,023	1
Contrast	8	11	13	16	25	3	10	13	16	20	32	4	1
					Green color								
SF													
Median	93	124	144	160	194	18	78	106	128	157	192	26	1
Variance	25	43	85	163	348	60	42	101	167	330	668	114	1
Entropy	2,9	3,3	3,5	3,9	4,2	0,3	3,2	3,6	3,9	4,2	4,4	0,3	1
SGLDM													
ASM·10⁴	18	27	38	53	72	13	12	16	24	34	57	9	1
Sum Variance	87	154	316	631	1357	238	154	378	636	1285	2634	453	1
GLDS													
Homogeneity	0,263	0,308	0,327	0,344	0,367	0,018	0,229	0,266	0,297	0,322	0,37	0,028	1
Contrast	9	11	13	17	29	3	9	14	18	28	41	7	1
					Blue color								
SF													
Median	74	97	114	142	170	23	68	94	107	127	161	17	1
Variance	52	73	97	155	279	41	64	101	160	250	484	75	1
Entropy	3,3	3,5	3,6	3,9	4,1	0,2	3,4	3,7	3,9	4,1	4,4	0,2	1
SGLDM													
ASM·10⁴	13	17	22	27	35	5	9	12	16	22	30	5	1
Sum Variance	153	220	302	508	1063	144	198	323	521	880	1723	279	1
GLDS													
Homogeneity	0,175	0,198	0,209	0,225	0,245	0,014	0,152	0,174	0,198	0,217	0,249	0,021	1
Contrast	41	56	69	88	155	16	37	58	79	124	200	33	1

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Neural networks analysis for SVM (PNN) for each color system (RGB, HSV, YCrCb)

SVM (PNN) classifier	%CC	%FP	%FN	%SE	%SP	%PR
		RGB				
SF	75 (66)	21 (18)	28 (49)	71 (50)	78 (81)	77 (72)
SGLDM	72 (67)	23 (25)	31 (40)	68 (59)	76 (74)	74 (70)
GLDS	69 (63)	3 (18)	27 (55)	72 (44)	66 (81)	68 (70)
SF+SGLDM	70 (67)	34 (24)	25 (40)	75 (59)	65 (75)	68 (71)
SF+GLDS	73 (68)	30 (14)	22 (49)	77 (50)	69 (85)	71 (77)
SGLDM+GLDS	74 (67)	22 (21)	29 (43)	70 (56)	77 (78)	76 (72)
SF+SGLDM+GLDS	73 (68)	22 (19)	31 (43)	68 (56)	77 (80)	75 (74)
		HSV				
SF	72 (70)	30 (22)	25 (37)	75 (62)	69 (77)	71 (73)
SGLDM	74 (70)	27 (21)	23 (37)	76 (62)	72 (78)	73 (74)
GLDS	69 (67)	24 (26)	37 (39)	62 (60)	75 (73)	72 (69)
SF+SGLDM	74 (70)	36(21)	15 (37)	84 (62)	63 (78)	69 (74)
SF+GLDS	76 (70)	20 (17)	26 (42)	73 (57)	79 (82)	77 (76)
SGLDM+GLDS	72 (71)	31 (20)	24 (37)	75 (62)	68 (79)	70 (75)
SF+SGLDM+GLDS	75 (69)	30 (21)	19 (39)	80 (60)	69 (78)	72 (73)
		YCrCb				
SF	73 (68)	21 (11)	31 (51)	68 (48)	78 (88)	76 (81)
SGLDM	74 (69)	28 (14)	23 (47)	76 (52)	71 (85)	72 (78)
GLDS	75 (68)	24 (13)	25 (50)	75 (49)	75 (86)	75 (78)
SF+SGLDM	76 (70)	25 (13)	22 (46)	77 (53)	75 (86)	75 (79)
SF+GLDS	79 (69)	25 (12)	16 (48)	83 (51)	74 (87)	76 (81)
SGLDM+GLDS	76 (69)	25 (15)	23 (46)	76 (53)	75 (84)	75 (77)
SF+SGLDM+GLDS	77 (70)	25 (15)	20 (44)	79 (55)	74 (84)	75 (78)

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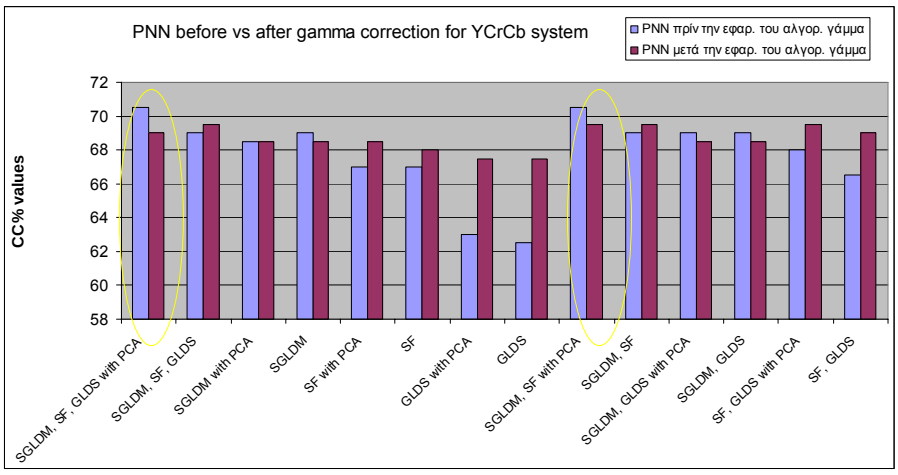
PNN before vs after gamma correction for the color system YCrCb



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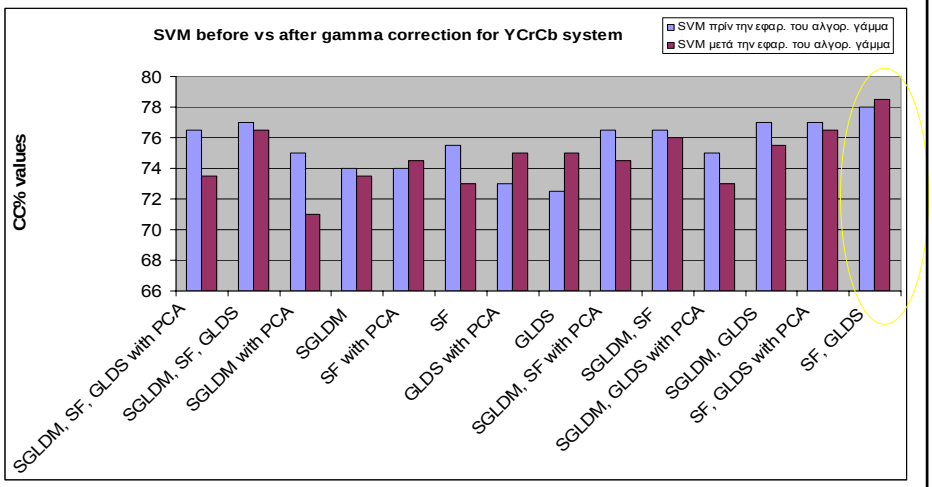
SVM before vs after gamma correction for the color system YCrCb



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Proposed protocol

Color Correction:

1. Calibrate the camera following the guidelines by the manufacturer (i.e. white balance).
2. Capture the color ROIs using the color palette and their corresponding digitally generated values based on the data given by the manufacturer.
3. Compute the gamma correction parameters.

Image Acqusition:

4. Acquire images at an angle that is nearly orthogonal to the object under investigation (only allowing 3 degree deviation) and at distances of 3cm (close-up) to 5cm (panoramic).
5. Manually segment the ROIs under investigation in this examination.
6. Gamma correct the ROI images and visually assess the gamma corrected ROIs.

Texture Analysis:

7. Color convert the ROIs from the RGB to the HSV and to the YCrCb systems.
8. Compute texture features (eg: the SF, SGLDM, GLDS feature sets and at different scales) on the gamma corrected ROIs of step 7 each channel of the color systems.
9. Compare texture features extracted from a collection of normal and abnormal cases to determine significant differences. Verify that variations in acquisition angle and distance to object do not yield significant differences.

Neural Networks:

10. Apply SVM, PNN (CAD system) and extract ROC curves.
11. Perform visual expert analysis of the results.

Texture characteristics of normal vs abnormal ROIs

Texture characteristics of normal vs abnormal ROIs of the endometrium

	Normal	Abnormal
Gray level	High	Slighthly darker
Variance	Low	Very High
Contrast	Low	High
Homogeneity	Normal range	Slighthly lower
Entropy	Normal range	Slighthly higher

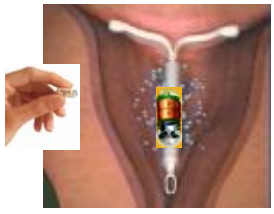
Neural networks result

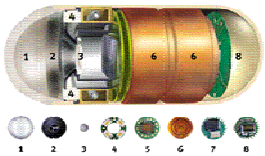
- 74% normal images
- 83% abnormal images
- **CC=79%**
- YCrCb system with the combination of SF+GLDS

Future work

- Established a European network
  - Collaboration with the European Society of Gynaecologcal Endoscopy (ESGE)
  - Collaboration with the European Academy of Gynaecologcal Cancer (EAGC)
- Automated segmentation
- More organs for analysis
- 3-D visual analysis
- Collaboration with the Karl Storz Company
- Monitoring the endometrium with Microcapsule
  - Experimental tissue

Hysteroscopy Microcapsule





Publications in scientific journals

1. **M.S. Neophytou**, C.S. Pattichis, M.S. Pattichis, V. Tanos, E.C. Kyriacou, D. Koutsouris, "*A Standardised Protocol for Texture Feature Analysis of Endoscopic Images in Gynaecological Cancer*", BioMedical Engineering OnLine, http://www.biomedical-engineering-online.com/start.asp, to be published 2007.

Will be submitted:

2. **M.S. Neophytou**, C.S. Pattichis, M.S. Pattichis, V. Tanos, E.C. Kyriakou, D. Koutsouris, "*Texture Based Classification of Endoscopy Images*", IEEE Transactions on Information Technology in Biomedicine.

Publications in scientific conferences

1. **M.S. Neophytou**, et. all, 1st International Conference on Medical Informatics & Engineering, 2003.
2. **M.S. Neophytou**, et. all,, 12th Annual Congress of the European Society for Gynaecological Endoscopy, 2003.
3. **M.S. Neophytou,** et. all, Transvaginal Endoscopy the Art and Science, 2004.
4. **M.S. Neophytou**, et. all, II EFOMP Mediterranean Conference on Medical Physics, 2004.
5. **M.S. Neophytou,** et. all, 26th Annual International conference of the IEEE engineering in Medicine and Biology Society, 2004.
6. V. Tanos, **M.S. Neophytou**, et. all, EAGC 2nd International Congress in Gynaecological Malignancies, 2004.
7. **M.S. Neophytou**, et. all, 27th Annual International conference of the IEEE engineering in Medicine and Biology Society, 2005.
8. V. Tanos, **M.S. Neophytou**, et. all, 33rd Meeting of the International Society for Oncodevelopment Biology and Medicine, 2005.
9. **M.S. Neophytou**, et. all, 28th Annual International conference of the IEEE engineering in Medicine and Biology Society, 2006.
10. T. Dimitrova, **M.S. Neophytou,** et. all, 28th Annual International conference of the IEEE engineering in Medicine and Biology Society, 2006.
11. T. Dimitrova, **M. Neofytou**, et. all, International Scientific Conference Computer Science, 2006.
12. **M.S. Neophytou**, et. all, 29th Annual International conference of the IEEE engineering in Medicine and Biology Society, 2007.

Computer Aided Diagnosis System for identification of Gynaecological cancer

Dr. Marios Neofytou
Prof. Constantinos Pattichis