

Segmentation of Cell Images

With Application to

Cervical Cancer Screening

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Statement of Originality

The work contained in this thesis is, to the best of my knowledge and belief, original, except as acknowledged in the text. This material has not been submitted, either in whole or in part, for a degree at this or any other university.

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Abstract

This thesis develops image segmentation methods for the application of automated cervical cancer screening. The traditional approach to automating this task has been to emulate the human method of screening, where every one of the hundreds of thousands of cells on each slide is analysed for abnormality. However, due to the complexity of cervical smear images and the low error tolerance imposed upon the segmentation stage, only limited success has previously been found. A different approach is to detect *malignancy associated changes* (MACs) in a relatively small sample of the total population of cells. Under this paradigm, the requirement to segment every cell is loosened, but delineation accuracy and error checking become essential.

Following a review of generic and cervical smear segmentation, it is concluded that prior work on the traditional approach to automation is not suitable for a MACs solution. However, the previously proposed framework of a dual-magnification system is found to be relevant and is therefore adopted. Here, scene images are first captured at low resolution in order to rapidly locate the cells on a slide. Cells that are deemed to be suitable for further analysis are then imaged at high resolution for the more accurate segmentation of their nuclei.

A *water immersion* algorithm is developed for low resolution scene segmentation. This method achieves a rapid and robust initial segmentation of the scene without the requirement of incorporating extensive *a priori* knowledge of the image objects. A *global minimum searching contour* is presented as a *top-down* method for segmenting the high resolution cell nucleus images where the image objects are well characterised by shape and appearance. This latter method is tested upon 20,000 images and found to achieve an accurate segmentation rate of 99.47%. An error checking method, that uses segmentation *stability* as an indicator of segmentation success, is developed that is capable of detecting 100% of the failures of the nucleus segmenter, at the expense of discarding only 9% of the data.

Throughout this work, contemporary issues in the field of generic image segmenta-

tion are presented and some of these are addressed for the cervical smear application. Finally, an avenue of future work is proposed which may lead to the much wider proliferation of computer vision solutions to everyday problems.

Contents

Statement of Originality	iii
Abstract	v
Publications	xix
Acknowledgements	xxi
1 Introduction	1
1.1 Cervical Cancer Screening	3
1.1.1 Manual Screening	5
1.1.2 Automated Screening	6
1.1.3 A Quality Control Device	7
1.1.4 A Pre-screener	8
1.1.5 Adjunct Screener	8
1.2 Malignancy Associated Changes	10
1.3 Computer Vision	14
1.4 Image Capture	15
1.4.1 Focus	17
1.4.2 Resolution	18
1.4.3 A Practical System	21
1.5 Image Segmentation	24
1.6 Specification of a Pap Smear Segmentation Scheme	26
1.6.1 Low Magnification Scene Segmentation	29
1.6.2 High Magnification Nucleus Segmentation	31
1.7 Research Goal	33
1.8 Structure of Thesis	33

2	Reviews of Generic and Pap Smear Digital Image Segmentation	35
2.1	Generic Image Segmentation Review	35
2.1.1	Similarity Based Methods	36
2.1.2	Discontinuity Based Methods	43
2.1.3	Hybrid Similarity- and Discontinuity-Based Techniques	53
2.1.4	Active Contours	55
2.1.5	Morphological Watersheds	65
2.1.6	Texture Segmentation	68
2.1.7	Global Methods	70
2.2	Choice of Segmentation Method	72
2.2.1	Classifications	73
2.2.2	The Universal Segmenter	75
2.2.3	Manual Algorithm Generation	76
2.2.4	Automatic Algorithm Generation	79
2.3	Segmentation Evaluation	80
2.3.1	The State-of-the-Art	83
2.3.2	Artefact Rejection	89
2.4	Image Segmentation for Pap Smears	91
2.4.1	Alternative Preparations	92
2.4.2	Previous Approaches to Low Resolution Scene Segmentation	93
2.4.3	Previous Approaches to High Resolution Nucleus Segmentation	98
2.5	Conclusion	99
2.6	Summary	100
3	Low Resolution Scene Segmentation	103
3.1	Overview of the Wilson and Spann Method	103
3.2	Water Immersion	108
3.2.1	Method	108
3.2.2	Algorithm Details	112
3.2.3	Boundary Re-estimation	113
3.3	Implementation Issues	118
3.3.1	Decision point A	118
3.3.2	Decision point B	118
3.4	Results and Conclusions	120
3.5	Summary	132

4	High Resolution Nucleus Segmentation	135
4.1	Method	140
4.1.1	Construction of the Search Space	140
4.1.2	Contour Evaluation	141
4.1.3	Initialisation	143
4.1.4	Directional Gradient	144
4.2	Results	147
4.3	Analysis of the Modes of Failure	150
4.4	Conclusions	152
4.5	Summary	155
5	Accuracy and Precision	157
5.1	Removing the Imposed Discretisation	158
5.1.1	Evaluating the Accuracy of the Active Contour	163
5.2	Sub-Pixel Edge Correction	170
5.3	Conclusions	172
5.4	Summary	175
6	Error checking and quality control	177
6.1	Error Checking	177
6.2	The Effect of Lambda	178
6.3	Lambda Sensitivity	181
6.4	Image Grading	183
6.5	Method	183
6.6	Conclusions	187
6.7	Summary	188
7	Conclusions and Future Work	191
7.1	Thesis Summary	191
7.2	Thesis Contribution	193
7.3	Limitations	195
7.4	Recommendations for Future Research	196
7.4.1	The Pap smear application	196
7.4.2	Generic Image Segmentation	197
A	Scene Image Edge Detection	199

List of Figures

1.1	Block diagram of a potential automatic screening device	2
1.2	Block diagram of a manual screening laboratory.	7
1.3	Typical block diagram of a screening laboratory incorporating a quality control machine.	8
1.4	Typical block diagram of a screening laboratory incorporating a pre-screening machine.	9
1.5	Typical block diagram of a screening laboratory incorporating an adjunct screening machine.	9
1.6	Development of a tumour	11
1.7	The MAC shift	13
1.8	Basic components of an optical system	16
1.9	Depth of field	17
1.10	Lens effect on a single point of light.	19
1.11	Actual x100 image of a 0.01mm graticule slide	22
1.12	x100 images of a pin-hole test slide	23
1.13	Image of a single light object on a dark background.	24
1.14	Segmentation result	25
1.15	High-level flow diagram of the proposed approach for data acquisition in an automated screening device.	27
1.16	Typical Pap smear slide images	28
1.17	Typical low resolution scene image of a Pap stained cervical smear.	29
1.18	An example of a desired scene segmentation result	30
1.19	Typical input image to the high resolution nucleus segmentation stage	32
1.20	Ideal output of a nucleus segmentation stage	32
2.1	Visually transforming a 2D image to a 3D surface	36
2.2	Globally thresholding the 3D image surface	37

2.3	Image histogram of the image of figure 1.13	38
2.4	Quadtree approach to global thresholding	39
2.5	Local thresholding approach of Chow & Kaneko (1972)	40
2.6	Defining neighbour pixels or regions	41
2.7	Seeded region growing segmentation	43
2.8	Derivative functions of a synthetic image	44
2.9	Convolving a 1D signal with a derivative mask	46
2.10	Partial derivatives of the image of figure 2.1(a).	47
2.11	Polar representation of the first derivative of figure 2.1(a)	48
2.12	Absolute gradient of the image of figure 2.1(a).	48
2.13	Output of a gradient operator on the image of figure 2.1(a)	49
2.14	Threshold planes on the gradient landscape of figure 2.13	50
2.15	Canny's non-maximal suppression	52
2.16	Bottom-up approach to segmentation.	53
2.17	Deformable model approach to image segmentation.	56
2.18	Parametric description of a continuous contour	58
2.19	Discrete description of a continuous contour	59
2.20	Local minimum solution	59
2.21	Sequence of the Kass snake model (failure)	60
2.22	Cohen's energy scheme	61
2.23	Sequence of Cohen's balloon method.	62
2.24	Gunn and Nixon's dual active contour	63
2.25	Sequence of Gunn and Nixon's dual active contour	64
2.26	Generation of the discrete search space	65
2.27	Calculating the gradient image: a usual first step in watershed seg- mentation	66
2.28	Watershed of a gradient image	67
2.29	Final result of watershedding a gradient image	68
2.30	Texture image and 3D representation	69
2.31	Global image segmentation	71
2.32	Variable order surface fitting	72
2.33	Classification of image segmentation methods after Zhu & Yuille (1996)	74
2.34	Simplified model for the human generation of a segmentation algorithm	77
2.35	Methods of segmentation evaluation	84

2.36	High resolution nucleus image with superimposed hand-drawn perceived border	87
2.37	Nucleus border delineation of six different people	88
2.38	Screen dump of the graphical user interface for segmentation evaluation.	89
2.39	Placement of an artefact rejection stage	89
2.40	Gray level histogram of the scene image of figure 1.17	94
2.41	Edge detection approach to scene segmentation.	96
3.1	Quadtree structure	104
3.2	Synthetic 256x256 image	105
3.3	Gray level histogram of the image in figure 3.2	105
3.4	Increasing levels in the quadtree structure and corresponding gray level histograms	106
3.5	Lowest level classification	107
3.6	Scene image of figure 1.17 after four levels of quadtree smoothing.	109
3.7	Gray level histogram of the image of figure 3.6.	110
3.8	Scene image as a 3D surface	111
3.9	Water immersion of a surface	111
3.10	Pseudo-code for the water immersion algorithm	113
3.11	Water immersion sequence of a scene image	114
3.12	Results of the water immersion superimposed upon original scene image	115
3.13	Water immersion artefact removal	115
3.14	Final regions-of-interest map for a low resolution scene image	116
3.15	Final segmentation at original resolution	117
3.16	Block diagram of the implementation alternatives for scene segmentation	119
3.17	Region merging effect of quadtrees	120
3.18	Quadtree merging of regions of close proximity	121
3.19	Separation of merged regions.	122
3.20	Example 1	123
3.21	Example 2	124
3.22	Example 3	125
3.23	Illumination gradient	126
3.24	Watershed segmentation from all minima.	128
3.25	Interactive marker selection	129
3.26	Resulting watershed using interactive marker selection	130
3.27	Cytological test program	133

4.1	Water immersion of a nucleus image	136
4.2	Border location of a cell nucleus	137
4.3	Sample of results using the morphological technique of watersheds . . .	138
4.4	Example of failure using the morphological technique of watersheds . .	138
4.5	Subtle failures of the watershed technique	139
4.6	Construction of the search space for nucleus segmentation	140
4.7	Unwrapping of the search space to a trellis	141
4.8	Trellis search	142
4.9	Initialisation correction technique	143
4.10	Directional gradient direction	145
4.11	Calculation of the directional gradient	145
4.12	Effect of directional gradient information	146
4.13	Addition of an extra border	148
4.14	Plot of percentage of correct segmentations against λ	149
4.15	Subset of the unsupervised nucleus segmentation results.	150
4.16	Examples of segmentation failure due to presence of background. . . .	151
4.17	Example failure due to an unsuitable choice of λ	152
4.18	Four segmentation failures at all attempts	153
5.1	C code interface to the implementation of the segmentation method of chapter 4.	157
5.2	Implementation of an evolutionary contour	159
5.3	Circle representation using an N point contour.	159
5.4	Second derivative as an external force function	161
5.5	Algorithm for single active contour implementation	162
5.6	Removing the imposed discretisation	162
5.7	A typical generated ‘ellipse with bumps’ image	165
5.8	Calculation of the fitting error.	166
5.9	Accuracy versus number of contour points	167
5.10	Cross-sectional profile of a ramp edge	169
5.11	Nucleus image with evolutionary active contour superimposed	171
5.12	Sub-pixel crossing alternatives	171
5.13	One level of sub-pixel edge correction	173
5.14	Masked nucleus after sub-pixel edge correction	174
6.1	Block diagram of the proposed error checking method	178

6.2	Plot of the percentage of correct segmentations against λ for a set of 269 randomly selected cells.	179
6.3	Example segmentations for $\lambda = 0.0$	179
6.4	The effect of increasing λ	180
6.5	Example of a segmentation for $\lambda = 0.9$	180
6.6	Segmentation results showing insensitivity to different values of λ	181
6.7	Example images that are not stable over a range of λ	182
6.8	Comparison of two contours	184
6.9	A plot of the percentage of \mathcal{F} against MAD	184
6.10	A plot of the percentage of elements of \mathcal{C} rejected against MAD	185
6.11	A plot of the percentage of elements of \mathcal{C} rejected against level	186
6.12	Finding the minimum of figure 6.11	186
A.1	Prewitt	199
A.2	Canny	200
A.3	Laplacian of Gaussian	200
A.4	Zero-crossing detector	201

List of Tables

1.1	Depth of focus for microscope lenses	18
1.2	Theoretical and practical resolution of microscope objective lenses . . .	20
1.3	Summary of the characteristics of the cells of interest	31
1.4	<i>A priori</i> knowledge of nuclei images	31
2.1	Image features that have been held responsible for inadequate cell segmentation	99
4.1	Three modes of failure	152
5.1	Sampling values against number of contour points	166
6.1	Minimum MAD thresholds for the detection of every element of \mathcal{F} . . .	185
6.2	Average MAD for levels 0-6	186

Publications

The following is a list of publications that have been produced by the author during his Ph.D. candidacy:

Patents

1. Method of Unsupervised Cell Nuclei Segmentation. *International Patent Application No. PCT/AU99/00231*. International Filing date: 30/3/99. Priority date: 3/4/98 (PP2786)

Refereed Journal Papers

2. Pascal Bamford and Brian Lovell. Unsupervised cell nucleus segmentation with active contours. *Signal Processing Special Issue: Deformable Models and Techniques for Image and Signal Processing*, **71**(2), 1998.
3. P. Bamford and B. Lovell. A methodology for quality control in cell nucleus segmentation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, In preparation.

Invited Refereed Conference Papers

4. Pascal Bamford, Paul Jackway, and Brian Lovell. Progress in the robust automated segmentation of real cell images. In *B. Pham and M. Braun and A. J. Maeder and M. Eckert, eds, 'Proceedings of the ARC Special Research Workshop on Automated Medical Image Analysis'*, Ballarat, Australia, July 1998. SPIE, Bellingham USA, pages 34–56.

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5. P. Bamford and B. Lovell. A methodology for quality control in cell nucleus segmentation. In *Proceedings of DICTA-99, Digital Image Computing: Techniques and Applications*, pages 21–25, Perth, December 1999.
6. P. Bamford and B. Lovell. Improving the robustness of cell nucleus segmentation. In Paul H. Lewis and Mark S. Nixon, editors, *Proceedings of the Ninth British Machine Vision Conference, BMVC '98*, pages 518–524, University of Southampton, England, UK, September 1998.
7. P. Bamford and B. Lovell. Bayesian analysis of cell nucleus segmentation by a viterbi search based active contour. In *Proceedings of the 14th International Conference On Pattern Recognition, ICPR'98*, pages 133–135, Brisbane, Australia, August 1998. IEEE Computer Society Press.
8. P. Bamford and B. Lovell. A two stage scene segmentation scheme for the automatic collection of cervical cell images. In *Proceedings of IEEE Tencon '97*, pages 683–686, Queensland University of Technology, Brisbane, December 1997.
9. P. Bamford and B. Lovell. Robust cell nucleus segmentation using a viterbi search based active contour. In *Proceedings of the first joint Australia and New Zealand Biennial Conference DICTA and IVCNZ' 97*, pages 89–93, Auckland, New Zealand, December 1997. Technical Keynote 2.

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10. P. Bamford and B. Lovell. A water immersion algorithm for cytological image segmentation. In *Proceedings of the APRS Image Segmentation Workshop*, pages 75–79, University of Technology Sydney, Sydney, December 1996.

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