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Clinical and Laboratory Investigations

Computer description of colours in dermoscopic melanocytic lesion images reproducing clinical assessment

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Summary

Background The assessment of colours is essential for the diagnosis of malignant melanoma (MM), both for pattern analysis on dermoscopic images, and when employing semiquantitative methods.
Objectives To develop a computer program for colour assessment in MM images mimicking the human perception of lesion colours, and to compare the automatic colour evaluation with one performed by human observers.
Methods A colour palette comprising six colour groups (black, dark brown, light brown, blue–grey, red and white) was created by selecting single colour components inside melanocytic lesion images acquired by means of a digital videomicroscope, and was implemented in the image analysis program. Subsequently, colours were assessed by the computer program on 331 melanocytic lesion images composing our image database, and the results were compared with the evaluation of lesion colours performed by the clinician.
Results The black, white and blue–grey colours were more frequently found in MMs than in naevi, both by the clinicians and by the computer. In MM images we observed 4·27 ± 1·14 colours (mean ± SD) per lesion, as opposed to 3·22 ± 0·68 in naevi. The correlation between clinical and computer evaluation of the colours was very good, with a value of 0·781 for overall assessment.
Conclusions This innovative method for automatic colour evaluation, reproducing clinical assessment of melanocytic lesion colours, may provide numerical parameters to be employed for computer-aided diagnosis of MM.

Key words: dermoscopy, epiluminescence microscopy, image analysis, malignant melanoma, polarized light, videomicroscopy

The assessment of colours is essential for the diagnosis of malignant melanoma (MM), both for pattern analysis on dermoscopic images, and when employing semiquantitative methods such as the ABCD rule of dermoscopy.[1–3] A blue, red or white colour component is more often present in MMs than in benign naevi. Therefore, the detection of these colours within an image may have great diagnostic importance. Moreover, malignant lesions frequently show more than three colours, whereas in naevi three or fewer colours are usually observed.[4]

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In order to overcome subjectivity and variability in the interpretation of dermoscopic images, several image analysis programs have recently been introduced as a possible support to clinical diagnosis.[5–21] The emphasis has been placed on assessment of lesion size, shape, colour and texture, which are expressed by mathematical parameters. These were chosen primarily for computational convenience; however, they do not model human interpretation of dermoscopic imagery. So far, methods for image analysis and automatic classification of melanocytic lesions have described colours in lesion images mostly by their red/green/blue (RGB) or hue/saturation/value (HSV) components.[5–19] Our purpose was to develop a computer program for colour assessment in MM

images mimicking the human perception of lesion colours, and to compare the automatic colour evaluation with one performed by human observers. To this aim, a colour palette comprising six colour groups (black, dark brown, light brown, blue–grey, red and white) was created by selecting single colour components inside melanocytic lesion images acquired by means of a digital videomicroscope, and was implemented in the image analysis program. Subsequently, colours were assessed by the computer program on 331 melanocytic lesion images composing our image database, and the results were compared with the evaluation of lesion colours performed by the clinician.

Materials and methods

Image database

The image database comprised 331 images of melanocytic lesions (113 MMs and 218 naevi) recorded from a corresponding number of patients. The lesions included in this study were all considered equivocal from a clinical point of view and were excised for histopathological examination.

All images were captured during routine clinical examination by means of a digital videomicroscope (VMS-110A, Scalar Mitsubishi, Tama-shi, Tokyo, Japan) using $\times 20$ magnification to enable the whole lesion to be included in the monitor area. The instrument has been described elsewhere.[14] The images were digitized by means of a Matrox Orion frameboard and stored by an image acquisition program (VideoCap 8·09, DS-Medica, Milan, Italy), which runs under Microsoft Windows. The camera system is calibrated monthly on a set of colour patches with known colour properties and the obtained colour profile is adjusted on a white test patch (Minolta® standard white) between each patient examination, according to the method proposed by Haeghen *et al.*[22] The digitized images offer a spatial resolution of 768×576 pixels and a colour resolution of 16 million colours. The diameter of the lesions ranged between 2·81 and 13·81 mm (mean ± SD 6·43 ± 2·31).

Dermatologists' evaluation of lesion colours

The images were evaluated by two clinicians employing the videomicroscopic technique on a regular basis. For each image the presence of black, dark brown, light brown, blue–grey, red and white was assessed and the number of colours counted. Investigators' evaluations were input directly into the computer and were immediately ready for statistical analysis.

Reproducibility of colour assessment, which was tested on 20 randomly selected melanocytic lesion images not included in the sequence employed for the study, proved excellent (data not shown).

Image analysis program

The image analysis program was created using MS visual C++ 6·0 both for interactive development of the palette and for colour region detection and analysis.

Interactive development of the colour palette. Thirty images of pigmented skin lesions, unequivocally showing black, dark brown, light brown, red, white and blue–grey colour components, were chosen as a sample population for the development of the colour palette and were not further considered in the study. Square colour patches of arbitrary size were selected manually on different regions of interest pertaining to different images, and an average RGB colour was extracted by the program. To avoid the selection of too many colour patches, a tolerance factor was used based on the distance of RGB values. Thus, colours that were similar to previously selected ones were merged with the others. The final palette obtained with our database consisted of 98 colour patches. The colour patches corresponding to the same colour (as perceived by the human observer) were collected to form a colour group. On a visual basis, 15 were attributed to black, 10 to dark brown, 28 to light brown, 9 to red, 12 to white and 24 to blue. The number of patches selected for each colour group corresponds to the minimum number of colour shades permitting a sufficiently accurate description of the colour (Fig. 1).

Colour region detection. Image analysis with colour assessment (presence/absence and number of colours) was performed on the same images which had undergone clinical evaluation. The palette was used to extract the colour regions from the images according to a nearest neighbour approach[23] (Fig. 2). Each pixel of the image was assigned to the colour patch that minimized its Euclidean distance in the RGB colour space. After assigning all pixels to their corresponding patches, those belonging to the same group were merged together to form the region corresponding to that particular colour.

Figure 1. Colour palette employed for colour group attribution. The black colour comprises 15 patches of black hues; dark brown, 10 patches; light brown, 28 patches; red, 9 patches; white, 12 patches; blue–grey, 24 patches. The coloured square at the beginning of the line corresponds to the false colour attributed to the pixels belonging to that colour group.

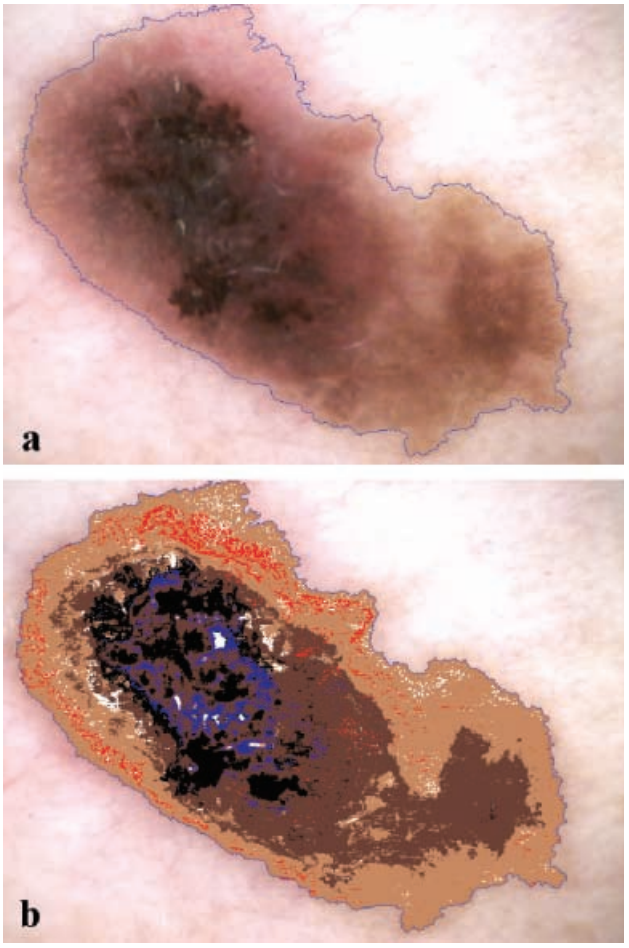

Figure 2. Example of colour area identification in a malignant melanoma: (a) ×20 videomicroscopic image, and (b) corresponding image with highlighted colour areas.

Threshold values for areas of colour regions, corresponding to 2% of the lesion area for black, dark brown and light brown, and 0·5% for red, white and blue–grey, were introduced, in order to avoid the inclusion in the calculation of colour areas which were too small and without clinical relevance.

Comparison between clinical evaluation and computer assessment

Finally, the clinically assessed type and number of colours was compared with the computer determined type and number of colours.

Statistics

For statistical analysis the SPSS statistical package (release 10.0.06, 1999; SPSS Inc., Chicago, IL, U.S.A.) was employed. $P < 0{\cdot}01$ was considered significant.

As basic statistics the frequency of single colour estimation, as assessed by the clinician and the computer, and mean ± SD of the overall number of colours per lesion, were calculated both for MMs and for naevi. Differences between naevus and MM values were evaluated using the χ^2 test. Concordance between clinical and computer evaluation was calculated employing the Spearman correlation coefficient, whereas reproducibility of judgement was assessed by Cohen's κ index. For a melanoma risk estimate, the odds ratio (OR) calculation was performed both considering the presence of single colours and the simultaneous presence of multiple colours.

Colour data were analysed by means of multivariate discriminant analysis. Discriminant analysis enables the identification of variables which are important for distinction among the groups and develops a procedure for group classification based on a score attribution. A linear combination of independent variables is formed and serves as a basis for assigning cases to groups. A score (D) is obtained for each lesion by the linear discriminant equation and is used for the attribution of cases to groups.

A receiver operating characteristic analysis was performed to investigate sensitivity and specificity of the discriminant equation on pigmented skin lesion classification employing both clinical and computer data.[24] Diagnostic accuracy was estimated by the ratio between the percentage of the sum of true positives and true negatives, and the total number of lesions, and was calculated for each threshold (D) value. The area under the curve (AUC) and its 95% confidence interval (CI) were employed to estimate the probability of correctly classifying the lesions as benign or malignant.

Results

The presence of black was detected in 85·8% of MMs and in 56·4% of naevi by the clinician, and in 83·2% of

Colour	Naevi % presence		MMs % presence (odds ratio)		Correlation between clinician and computer evaluation
	Clinician	Computer	Clinician	Computer	
Black	56·4	56·0	85·8* (4·682)	83·2* (3·893)	0·893
Dark brown	97·7	97·2	98·2 (1·303)	97·3 (1·038)	0·750
Light brown	98·6	100	93·8 (0·211)	92·0 (1·087)	0·730
Red	52·3	45·4	59·3 (1·329)	46·0 (1·025)	0·736
White	11·5	11·9	45·1* (6·350)	33·6* (3·742)	0·806
Blue–grey	6·0	9·2	45·1* (12·971)	51·3* (10·440)	0·756

Table 1. Percentage presence of single colours in naevi and malignant melanomas (MMs), as evaluated by the clinician and the computer, and correlation coefficients between clinical and computer evaluation

*Significant ($P < 0·05$) in comparison with naevi.

MMs and 56·0% of naevi by the computer (Table 1). Differences were significant in both cases, whereas no significant differences were observable for dark brown, light brown and red between the number of MMs and the number of naevi showing these colours. White was more frequently observed in MMs: 45·1% and 33·6% of MMs, as assessed by the clinician and the computer, respectively, showed white colour shades, whereas this was the case in only 11·5% and 11·9% of naevi, respectively. Also, the frequency of blue–grey was significantly higher in MMs than in naevi, both as assessed by the clinician (45·1% vs. 6·0%) and by the computer (51·3% vs. 9·2%). Significant ORs were 4·682 and 3·893 for black, 6·350 and 3·742 for white and 12·971 and 10·440 for blue–grey, for clinical and computer evaluation, respectively.

Correlation between clinical and computer evaluation of the colours was excellent: correlation coefficients ranged between 0·730 (for light brown) and 0·893 (for black), with a value of 0·781 for overall assessment.

As regards the number of colours per lesion, MMs showed 4·27 ± 1·14 and 4·04 ± 1·11 colours per lesion (mean ± SD), for the clinical and the computer evaluation, respectively, whereas in naevi 3·22 ± 0·68 and 3·20 ± 0·63 colours were detected (Table 2). These differences were statistically significant. Significant differences were also observed for the presence of three colours, which was more frequent in naevi, and the presence of four, five or six colours, which was more frequent in MMs. ORs for five colours were 5·301 and 4·330 for the clinician and the computer, respectively. According to clinical assessment, 71·6% of naevi showed one to three colours, whereas 74·3% of MMs had four to six colours (for computer evaluation 76·1% and 71·7%, respectively. The risk of being an MM for a lesion with four to six colours corresponded to an OR of 7·288 for the clinician and 8·081 for the computer.

Table 3 shows the concordance between clinical assessment and computer evaluation for the presence of one to three colours as opposed to four to six colours: 91·9% of lesions scored as having one to three colours by the clinician were also considered as having one to three colours by the computer, whereas 80·8% of those clinically classified as having four to six colours were evaluated accordingly by the computer. The Spearman correlation coefficient was 0·736, whereas the κ-value was 0·734.

Diagnostic accuracy based on colours as the only diagnostic descriptor, calculated by discriminant analysis, was 80·3% both for clinical evaluation (sensitivity = 69·9%, specificity = 85·8%) and for computer assessment (sensitivity = 65·5%, specificity = 88·1%). No difference was observed between AUC values

No. of colours	Naevi		MMs		Odds ratio
	Clinician	Computer	Clinician	Computer	
1	0	0·5	0	0	NE/NE
2	10·1	6·9	4·4	8·8	0·412/1·314
3	61·5	68·8	21·2*	19·5*	0·169/0·110
4	24·3	20·2	36·3*	44·2*	1·773/3·139
5	4·1	3·7	18·6*	14·2*	5·301/4·330
6	0	0	19·5*	13·3*	NE/NE
Mean ± SD	3·22 ± 0·68	3·20 ± 0·63	4·27 ± 1·14*	4·04 ± 1·11*	

Table 2. Percentage of lesions showing one to six colours and odds ratio according to clinician/computer evaluation

*Significant ($P < 0·05$) in comparison with naevi; MMs, malignant melanomas; NE, not evaluable.

Table 3. Concordance between computer evaluation and clinical assessment for the presence of one to three colours as opposed to four to six colours

	Computer		
Clinician	1–3 colours	4–6 colours	Total
1–3 colours	170	15	185
	91·9%	8·1%	100%
4–6 colours	28	118	146
	19·2%	80·8%	100%
Total	198	133	331
	59·8%	40·2%	100%

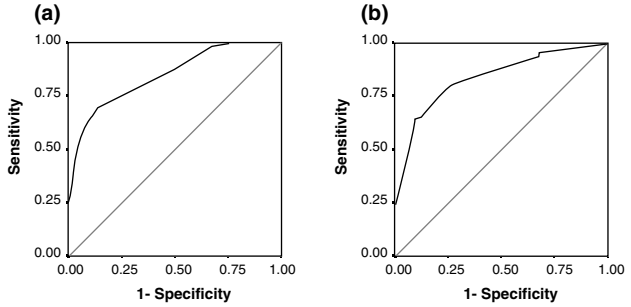

Figure 3. Receiver operating characteristic curves referring to (A) clinical and (B) computer evaluations. (A) Area under the curve (AUC) = 0·843 (95% confidence interval, CI 0·798–0·889); (B) AUC = 0·834 (95% CI 0·786–0·882).

referring to clinical (0·843, 95% CI 0·798–0·889) or computer (0·834, 95% CI 0·786–0·882) evaluation (Fig. 3).

Discussion

Colour assessment represents an essential step in dermoscopic diagnosis. In the ABCD rule of dermoscopy the presence or absence of red, blue–grey, white, dark brown, light brown and black in melanocytic lesions gives rise to a score varying between 0·5 and 3 (on a total possible score ranging from 1 to 8·9).[3] According to the method of Menzies *et al.* the presence of a single colour (black, grey, blue, dark brown, tan and red) is considered a negative feature, enabling exclusion of the diagnosis of MM, whereas the presence of five to six of the latter colours (white is not scored as a colour) represents a positive feature.[25]

Blue and grey are considered together in the ABCD rule, whereas according to Menzies *et al.* they are considered separately for the colour count and together for the assessment of the pepper-like pattern. The seven-point checklist considers the blue-whitish colour for the assessment of the veil, blue for the description of pepper-like granules and white associated with scar-like depigmentation.[26]

Digital dermoscopy, enabling computer screening and monitoring of pigmented skin lesions, is based on image acquisition techniques employing a computer and different video systems, which have been developed during the last decade. Most of these systems still require the experience of a dermatologist for diagnosis. For automatic discrimination of melanocytic lesions and their classification into benign or malignant, several methods have been proposed in recent years based on the numerical description of lesion parameters and their statistical analysis. Most of these image analysis programs are suitable for the analysis of images in the visible spectrum,[5–12,14–21] whereas there is one report on the near infrared spectrum.[14] They consider global features (including size and shape descriptors), gradient, grey level and texture features, and colours. In most studies colour descriptors are statistical parameters calculated from different colour channels, such as mean and SD of the RGB or HSV colour channels.

Binder *et al.* considered the number and range of different colours in a reduced colour model, which represented one of the most important variables for automatic classification.[15] Red, green and blue average, decile and quartile values were employed by us and were included in the equation for discriminant analysis classification.[14,16] The image analysis program employed by Andreassi *et al.* evaluates red, green and blue average, quartile and decile values, and colour islands including extension and imbalance of so-called peripheral dark regions, dark, green, green dominant, blue–grey and transition areas.[17] In a recent paper by Kahofer *et al.* mean and SD, skewness, kurtosis, minimum and maximum were calculated in the intensity image and in red, green and blue images for each element.[27] Day and Barbour employed a colour variance parameter in the Lab colour space proposed by Umbaugh.[28,29] The final feature was relative chromaticity green, a feature measuring the average colour difference between the skin and the lesion. This feature was previously used by Ercal *et al.*[7] Cotton and Claridge employed an optical model of the skin to interpret the colours occurring in a lesion.[30] They found that all normal skin colours lie on a two-dimensional surface patch within a three-dimensional colour space. Ganster *et al.* adopted an original approach.[19] Besides minimum, maximum, average and variance of the intensity and hue channels, they considered 15 significant colours obtained by the

median cut colour quantization algorithm of Heckbert.[31]

Statistical parameters employed for colour description were chosen primarily for computational convenience; however, they do not model the methods employed by the human brain for the clinical diagnostic procedure, where areas which share similar colours (representing a set of 'pixels' consisting of a mixture of RGB components) are considered together as homogeneous colour areas and simply called red, blue–grey, white, dark brown, light brown, black, etc. During the last few years software refinement has led to an increased diagnostic accuracy of automatic diagnostic systems. In recent studies a 100% sensitivity on selected image series has been reported. However, so far no study has evaluated the diagnostic potential of these automatic systems in prospective series involving thousands of lesions, mimicking the conditions of clinical practice. Therefore, the identification of new image descriptors may be of potential practical use in clinical conditions, where the computer-aided diagnosis of MM can be performed by means of automatic classifiers.

We have presented a new automatic method for the assessment of colours in melanocytic lesion images based on the interactive identification of a colour palette comprising the more representative colours perceived by the human eye in a melanocytic lesion. Some good results were produced as regards the comparison between human and computer assessment of the type and the number of colours, where over 70% of the dermatologist's decisions were replicated. The highest correlation coefficients were observed for black, white and blue–grey, which in our images represented the most important colours for diagnosis. Moreover, sensitivity and specificity values and diagnostic accuracy were similar for computer assessment and clinical evaluation. As regards the presence of single colours and their potential aid for diagnosis, according to our data black, blue–grey and white were more frequently found in MMs. This is in accordance with Menzies *et al.* who found that dark brown, black, grey–blue and red–blue were each significantly different in MM, although each colour lacked adequate specificity to be useful in a clinical setting as an independent feature of MM.[25]

Confirming other authors' observations, our data show that the number of colours in MMs is higher than in naevi: 71·6% of our naevi showed three or fewer colours, whereas 74·3% of our MMs showed four or more colours. Assessing the association between individual diagnostic criteria and MM diagnosis, Argenziano *et al.* showed that the presence of five to six colours in the ABCD score corresponds to an OR of 5, whereas 'more than one colour' according to Menzies *et al.* has an OR of 18·5.[2] MacKie *et al.* found that sensitivity and specificity figures for the presence of more than three colours in a dermoscopic image were 92% and 51%, respectively.[4] On our image database sensitivity proved lower (69·9%) and specificity higher (85·8%) compared with the data of MacKie *et al.* but this may depend on the different type of images employed by us (videomicroscopic ones).[10,32]

Reproducibility of colour assessment is generally high, pointing towards the high diagnostic relevance of colour parameters.[2] In a recent consensus study on dermoscopy via the internet,[2] intraobserver agreement showed a κ-value of 0·64 for the number of colours in the ABCD rule, and of 1 for the presence of a single colour according to Menzies *et al.*[25] When assessing the informativeness of compressed videomicroscopic images, differences between κ-values of uncompressed and compressed images referring to intraobserver agreement on colours were lower than for other features, indicating that reproducibility of colour evaluation is high, even in lower quality images, and that colours are less affected by compression than morphological details in the image (Seidenari *et al.*, unpublished data). This underlines the potential of colour assessment-based diagnosis in an era where the importance of teledermatology is ever increasing.

Of course, caution must be taken in selecting colour features. The absolute colour measure is strictly dependent on the acquisition technique and the imaging system; for example, RGB is a device-dependent colour space.[32] However, our method, which has been tested on videomicroscopic images, shows an enormous flexibility, as the interactive development of the palette makes it adaptable to other imaging systems.

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References

1 Pehamberger H, Steiner A, Wolff K. *In vivo* epiluminescence microscopy of pigmented skin lesions. I. Pattern analysis of pigmented skin lesions. *J Am Acad Dermatol* 1987; **17**: 571–83.

2 Argenziano G, Soyer HP, Chimenti S *et al.* Dermoscopy of pigmented skin lesions: results of a consensus meeting via the internet. *J Am Acad Dermatol* 2003; **48**: 679–93.

3 Nachbar F, Stolz W, Merkle T *et al.* The ABCD rule of dermatoscopy. *J Am Acad Dermatol* 1994; **30**: 551–9.
4 MacKie RM, Fleming C, McMahon AD, Jarret P. The use of the dermatoscope to identify early melanoma using the three-colour test. *Br J Dermatol* 2002; **146**: 481–4.
5 Cascinelli N, Ferrario M, Bufalino R *et al.* Results obtained by using a computerized image analysis system designed as an aid to diagnosis of cutaneous melanoma. *Melanoma Res* 1992; **2**: 163–70.
6 Umbaugh SE, Moss RH, Stoecker WV, Hance GA. Automatic color segmentation algorithms—with application to skin tumor feature identification. *IEEE Eng Med Biol* 1993; **9**: 75–82.
7 Ercal F, Chawla A, Stoecker WV *et al.* Neural network diagnosis of malignant melanoma from color images. *IEEE Trans Biomed Eng* 1994; **9**: 837–44.
8 Schindewolf T, Schiffner R, Stolz W *et al.* Evaluation of different image acquisition techniques for a computer vision system in the diagnosis of malignant melanoma. *J Am Acad Dermatol* 1994; **31**: 33–41.
9 Green AC, Martin NG, Pfitzner J *et al.* Computer image analysis in the diagnosis of melanoma. *J Am Acad Dermatol* 1994; **31**: 958–64.
10 Seidenari S, Burroni M, Dell'Eva G *et al.* Computerized evaluation of pigmented skin lesion images recorded by a videomicroscope: comparison between polarizing mode observation and oil/slide mode observation. *Skin Res Technol* 1995; **1**: 187–91.
11 Hall PN, Claridge E, Morris Smith JD. Computer screening for early detection of melanoma—is there a future? *Br J Dermatol* 1995; **132**: 325–38.
12 Aitken JF, Pfitzner J, Battistutta D *et al.* Reliability of computer image analysis of pigmented skin lesions of Australian adolescents. *Cancer* 1996; **78**: 252–7.
13 Gutkowicz-Krusin D, Elbaum M, Szwaykowski P, Kopf AW. Can early malignant melanoma be differentiated from atypical melanocytic nevus by *in vivo* techniques? Part II. Automatic machine vision classification. *Skin Res Technol* 1997; **3**: 15–22.
14 Seidenari S, Pellacani G, Pepe P. Digital videomicroscopy improves diagnostic accuracy for melanoma. *J Am Acad Dermatol* 1998; **39**: 175–81.
15 Binder M, Kittler H, Seeber A *et al.* Epiluminescence microscopy-based classification of pigmented skin lesions using computerized image analysis and an artificial neural network. *Melanoma Res* 1998; **8**: 261–6.
16 Seidenari S, Pellacani G, Giannetti A. Digital videomicroscopy and image analysis with automatic classification for detection of thin melanomas. *Melanoma Res* 1999; **9**: 163–71.
17 Andreassi L, Perotti R, Rubegni P *et al.* Digital dermoscopy analysis for the differentiation of atypical nevi and early melanoma. *Arch Dermatol* 1999; **135**: 1459–65.
18 Pellacani G, Martini M, Seidenari S. Digital videomicroscopy with image analysis and automatic classification as an aid for diagnosis of Spitz nevus. *Skin Res Technol* 1999; **5**: 266–72.
19 Ganster H, Pinz A, Rohrer R *et al.* Automated melanoma recognition. *IEEE Trans Med Imaging* 2001; **20**: 233–9.
20 Grana C, Pellacani G, Cucchiara R, Seidenari S. A new algorithm for border description of polarized light surface microscopic images of pigmented skin lesions. *IEEE Trans Med Imaging* 2003; **22**: 959–64.
21 Cucchiara R, Grana C, Seidenari S, Pellacani G. Exploiting color and topological features for region segmentation with recursive fuzzy c-means. *Machine Graphics Vision* 2002; **11**: 169–82.
22 Haeghen YV, Naeyaert JMAD, Lemahieu I. An imaging system with calibrated color image acquisition for use in dermatology. *IEEE Trans Med Imaging* 2000; **19**: 722–30.
23 Bressan M, Guillamet D, Vitrià J. Using a local ICA representation of high dimensional data for object recognition and classification. Computer Vision and Pattern Recognition, 2001. CVPR 2001. *Proceedings of the 2001 IEEE International Conference* 2001; **1**: 1004–9. http://ieeexplore.ieee.org
24 Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology* 1982; **143**: 29–36.
25 Menzies SW, Ingvar C, McCarthy WH. A sensitivity and specificity analysis of the surface microscopy features of invasive melanoma. *Melanoma Res* 1996; **6**: 55–62.
26 Argenziano G, Fabbrocini G, Carli P *et al.* Epiluminescence microscopy for the diagnosis of doubtful melanocytic skin lesions. Comparison of the ABCD rule of dermoscopy and a new 7-point checklist based on pattern analysis. *Arch Dermatol* 1998; **134**: 1563–70.
27 Kahofer P, Hoffmann-Wellenhof R, Smolle J. Tissue counter analysis of dermatoscopic images of melanocytic skin tumors: preliminary findings. *Melanoma Res* 2002; **12**: 71–5.
28 Day GR, Barbour RH. Automated skin lesion screening—a new approach. *Melanoma Res* 2001; **11**: 31–5.
29 Umbaugh SE. Computer vision in medicine: color metrics and image segmentation methods for skin cancer diagnosis. PhD Thesis. Department of Electrical Engineering, University of Missouri-Rolla, 1990.
30 Cotton SD, Claridge E. Developing a predictive model of human skin coloring. In: *Proceedings of SPIE Medical Imaging: Physics of Medical Imaging* (Vanmelter RL, Beutel J, eds) 1996; **2708**: 814–25.
31 Heckbert P. Color image quantization for frame buffer display. *Comput Graph* 1982; **16**: 297–307.
32 Pellacani G, Seidenari S. Comparison between morphological parameters in pigmented skin lesion images acquired by means of epiluminescence surface microscopy and polarized-light videomicroscopy. *Clin Dermatol* 2002; **20**: 222–7.