Skin Cancer Prognosis Based on Color Matching and Segmentation of Pigmented Skin Lesion

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ABSTRACT

This work develops a new computerized vision of skin cancer diagnosis based on color matching of pigmented skin lesion and some parameters of ABCD method. Initially, the clinical diagnostic criteria have been translated to mathematical concepts. So the lesion edge detection; symmetry; even-symmetry; and segmentation are computed. Then, the suspicious images would be classified into one of three categories: benign (mole), malignant (melanoma/non-melanoma), or unknown tumor using image profile information. The remaining malignant images (melanoma, Basal Cell Carcinoma, or Squamous Cell Carcinoma) would be further classified using matching procedure for color spectrums (Red, Yellow, Brown, Black/Gray) with lesion pigment. The lesion image is segmented into four quarters and the matching procedure of 120 spectrums is started searching for better result with mean squared error less than 0.003. The software has been tested over 40 classified images and it successfully re-classified 92%. This result could be improved if lesion quarters and/or spectrums are increased.

Keywords: BCC, Color Matching Pigment, Melanoma, Skin Cancer, SCC.

ألتنبؤ بسرطان ألجلد بالاعتماد على ألتقطيع ومطابقة أللون لصبغة ألورم

الخلاصه

هذا العمل يطور رؤيه جديده باستخدام الحاسوب للكشف عن سرطان الجلد باستخدام طريقة مطابقة اللون مع لون صبغة الورم وبعض معايير طريقة تشخيص سرطان الجلد الشائعه.في البدأ يتم تحويل معايير الكشف الطبيه الى صيغ رياضيه, حيث يتم أيجاد حافة الورم التناضر, التناضر الزوجي, ومقاطع صورة الورم. بعد ذلك يتم تصنيف الصور المشكوك فيها الى أحد ألاصناف ألثلاثة: ورم حميد (خال), ورم خبيث (ميلونوما/غير ميلونوما) او غير معروف melanoma, BCC,SCCباستخدام ملف المعلومات الشخصيه للصورة. بقية الاورام تصنف مرة أخرى باعتماد أجراء مطابقة صبغة الورم مع طيف الالوان (الاحمر, الاصفر, ألبني, الاسود\الرمادي). تقسم صورة الورم الى اربعة ارباع لايجاد افضل تطابق مع أطياف الالوان ألـ ١٢٠ وبنسبة خطأ لاتتجاوز ألـ ٠,٠٠٣ . تم اختبار البرنامج على ٤٠ صوره مختلطه وقد نجح في أعادة تصنيف ٩٢% منها بصوره صحيحه حيث يمكن تعزيز هذه النتيجة بزيادة نماذج الطيف أو تقطيع صورة الورم أو كلاهما.

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INTRODUCTION

Skin is the largest organ of the body which responsible for conferring protection to the other systems of the body. The three layers that are made up of the skin are [1,2]:

1. Outer epidermis layer,
2. Dermis layer, and
3. Deep sub-cutis layer.

Skin cancer types can be divided into two types: melanoma and non-melanoma. Non-melanoma skin cancer has two major sub-types: Basal Cell Carcinoma (BCC) and Squamous Cell Carcinoma (SCC). There is, therefore, a demand to develop computer-aided diagnostic systems to facilitate the early detection of them. A high performance image processing software is developed to detect and classify variety of skin cancer types. The pigments that color skin are produced by cells called melanocytes. Melanocytes, located in the epidermis, synthesize melanin which determines the color of the skin, hair and eyes. Malignancies of the skin are the most commonly diagnosed cancer type worldwide. The foremost cause of skin cancer remains UV radiation from sunlight. However, this disease, classically seen in older adults, is becoming increasingly common in younger populations due to tanning beds and exposure to other cancer causing elements [3, 4]. Melanoma which accounts for only 4% of skin cancer is responsible for 80% of skin cancer deaths. Most cancers form a tumor but some, like leukaemia, do not. The definitive diagnosis for this kind of cancer requires a histological examination of a biopsy specimen. Most cancers are initially recognized either because signs or symptoms appear or through screening. Neither of these leads to a definitive diagnosis, which usually requires the opinion of a pathologist. The tissue diagnosis given by the pathologist indicates the type of cell that is proliferating, its histological grade, genetic abnormalities, and other features of the tumor.

Together, this information is useful to evaluate. the prognosis of the patient and to choose the best treatment [5].

This paper is mainly organized as follows: the next three sections present detail about skin cancer types and their lesions pigment. Then the common diagnostic rules of melanoma and non-melanoma are discussed. Next, the prognosis procedure is applied to classify 40 suspicious images. This classifying depends on the symmetric, even symmetric, and color matching pigment procedure. The classification results section provides four different tables that are relating to the reclassified of 40 suspicious images.

SKIN CANCER CLASSIFICATION

Skin cancer can be divided into two types [6, 7]:

1. Melanoma and
2. Non-melanoma.

Melanoma is the most serious form of skin cancer. It appears without warning but it may also begin in a mole or other dark spot in the skin. It can spread very quickly and once it penetrates below the surface of the skin, it can become quite deadly. That is why it is important to detect melanoma early. Early detection offers the best long term prognosis [7]. Non-melanoma skin cancer has two major sub-types: basal cell carcinoma and Squamous cell carcinoma. BCC is the most commonly diagnosed skin

cancer. Like SCCs and BCCs, melanomas can occur on exposed skin, but they also occur on skin that is generally covered, but which has been sun burnt in the past. Malignant melanomas may spread throughout the body and cause death. Melanomas either develop from an existing mole or appear as a new brown, red or black spot which changes and grows in size [6, 7]

TYPES OF NON MELANOMA MALIGNANT TUMOUR

THE BCC CANCER

BCC is the most common type of skin cancer. It grows from cells in the lower part of the upper layer of the skin. The growth tends to be quite slow, taking a period of months to years, and only rarely do these cancers spread throughout the body. BCCs most commonly appear on the face, head, neck, and trunk regions and can occur in difficult to treat areas such as near the eye and the lower legs. BCC is by far the most common form of skin cancer [6, 7, and 8]. Although they are rarely a threat to life, but if it lefts untreated they can grow, erode and destroy adjoining structures.

Loss of whole organs, such as the nose, ear and eye, can occasionally occur. BCC's are more easily and successfully treated in their early stages. The larger a tumor the more extensive the treatment required [7, 8].

- Nodular and Non Nodular Ulcer Active BCCs: These are most common. They start as round, hard, red or red-grey pearly bumps, which might continue to extend and ulcerate if left untreated.
- Pigmented BCC: This is similar to the nodular BCC but it has areas of pigmentation (darker areas). And could be confused with melanoma, a more serious cancer.
- Superficial BCC: The superficial BCC occurs mainly on the trunk as a red patch, usually up to 3cm in diameter. The edge of these tumors can be difficult to distinguish.
- Morphoeic BCC: This looks like a firm yellow-white scar-like area and is often mistaken for one. These BCCs are often bigger than they first appear to the naked eye and may require special treatment techniques.

THE (SCC or SqCC) CANCER

SCC is a common form of skin cancer typically found on the ear, face, lips, hands or lower legs. Invasive SCC usually grows within a solar keratosis (scaly spots due to sun damage) and presents as a tender scaly or ulcerated lump. The pre-invasive phase, SCC in situ (often called Bowen's disease), characteristically presents with one or more dry or crusted red or brown patches. Invasive SCC needs to be attended to promptly as there is a risk of secondary spread.

COMMON MELANOMA DIAGNOSTIC RULES

Three diagnostic models with similar reliability have become more widely accepted by clinicians [7, 9]:

1. The ABCD-rule of dermatoscopy which is based on a semi-quantitative analysis.
2. The ELM 7-point checklist scoring diagnosis analysis which defining only seven standard ELM criteria.
3. pattern analysis, which is based on the “expert” qualitative assessment of numerous individual ELM criteria;

THE ABCD RULE

A popular method for remembering the signs and symptoms of melanoma is the mnemonic "ABCDE" [7]:

- **A**symmetry - The shape of one half does not match the other
- **B**order - The edges are often ragged, notched, blurred, or irregular in outline; the pigment may spread into the surrounding skin
- **C**olour - The color is uneven. Shades of black, brown, and tan may be present. Areas of white, grey, red, pink, or blue also may be seen.
- Diameter - Size changes and usually increases. Typically, melanomas are at least 6mm in diameter
- Enlarging: Enlarging or evolving

A weakness in this system is the **D** in Diameter. Many melanomas present themselves as lesions smaller than 6 mm in diameter; and likely all melanomas were malignant on day 1 of growth, which is merely a dot. Some will advocate the system "ABCDE", with **E** for evolution. Certainly moles which change and evolve will be a concern. Elevation can help identify a melanoma, but lack of elevation does not mean that the lesion is not a melanoma. Most melanomas are detected in the very early stage, or in-situ stage, before they become elevated. By the time elevation is visible, they may have progressed to the more dangerous invasive stage. According to these four values there are Total Dermatoscopic Value (TDV) calculated by formula [7, 10]:

$$TDV = A*1.3 + B*0.1 + C*0.5 + D*0.5 \quad \ldots (1)$$

This score TDV contributes to the differentiation between benign and malignant lesions:

1. 1.00 - 4.75 benign skin lesions,
2. 4.75 - 5.45 suspicious,
3. Greater than 5.45 is melanoma.

Some melanomas do not fit the ABCD rule described above, therefore, mole should be noticeable if it [10, 11]:

1. different from others
2. changes shape, size or colour
3. new skin lesions
4. itches or bleeds

PROGNOSIS PROCEDURE

The 40 classified images in Figure (1a, 1b, 1c, and 1d) would be diagnosed and re-classified again to test the prognostic procedure accuracy for lesion classification. The main processes have been explained in the block diagram in Figure (2). These operations include: segmentation; symmetrisation, color modeling; color matching; and image profile constructing. Steps 1 to 4 illustrate those operations in details.

1. **Lesion boundary detection:** lesion boundary can be detected and extracted by finding the perpendicular lines of top-bottom and right-left edge values. These values $((r_1, c_1)$, $(r_2, c_2))$ are used to find the symmetry, semi-symmetry, or non-symmetric of the lesion, while the perpendicular diagonal lines $(d_1\ d_2, d_3, d_4)$ are used to find the even-symmetry of the lesion. See Figure (3).

2. **Segmentation**: segmentation is the process of gathering pixels of a given interested image spots into homogenous features regions. Therefore, to detect and extract the lesion border from the surrounding skin, image is cropped to new dimension values that have been computed in step 1. See Figure (3)
3. **Color matching pigment procedure:** This procedure starts segmenting the 40 lesion images into four sub-images or quarters. The process of matching 120 spectrums of reddish, yellowish, brownish, and blackish is determined for each sub-image/quarter individually. That means: the total number of matching operations is equal to,

$$\text{No. of sub-images} \times \text{No. of images} \times \text{No. of spectrums} = 4 \times 40 \times 120 = 19200 \quad \ldots (2)$$

The procedure attempts matching the pigment mean value with multi spectrum mean values. Figure (5a, 5b, 5c, 5d) are examples of color – pigment matching procedure for some suspicious images. The RGB values for each spectrum have been chosen carefully, so pigment value would be well approximated. The Mean Squared Error (MSE) formula is applied to find the best matching results with MSE is less than 0.003. So,

$$MSE = (m - \mu)^2 \quad \ldots (3)$$

Where: m is the mean value of (m×n) sub-image/quarter. μ is the grey-scale mean value for spectrum. Figure (6a, 6b, 6c, and 6d) are examples of mel-10 error values for m_1= 0.39599; m_2=0.46252; m_3=0.61743; and m_4=0.41352 that have been compared with 120 spectrums of Brownish, Yellowish, Reddish, and Blackish respectively. For this example, the total number of operation is: 4 × 120 = 480 matching operation. Hence, for 40 suspicious images, the number of operations would be 480 × 40 = 19200 matching operation.

4. **Profile constructing:** the suspicious image profiles have been constructed and images are ready for classification.

CLASSIFICATION RESULTS

Table (1, 2, 3, and 4) represent the constructed profile of 40 classified images and their new classification/diagnostic result. The profile has vital information for each lesion. This information includes:

- Shape symmetry
- Shape even symmetry
- Number and code of the matching color per quarter
- Pigment localization (pigment symmetry)

CONCLUSIONS

A spatial processing method for skin cancer diagnosis is presented using direct and simple procedure for pigmented lesion. The procedure succeeded re-classifying 92% of the 40 classified images. The acceptable result obtained with mean squared matching error less than 0.003 where, the only high matched colors have been registered as matching events. The classification results could be improved by increasing the number of quarters per lesion and/or color models. Table (5) shows

colors – pigments matching rate. The maximum rate is registered for reddish in melanoma images with 12 matching events, while zero rate is registered for yellowish in benign/SCC images matching event.

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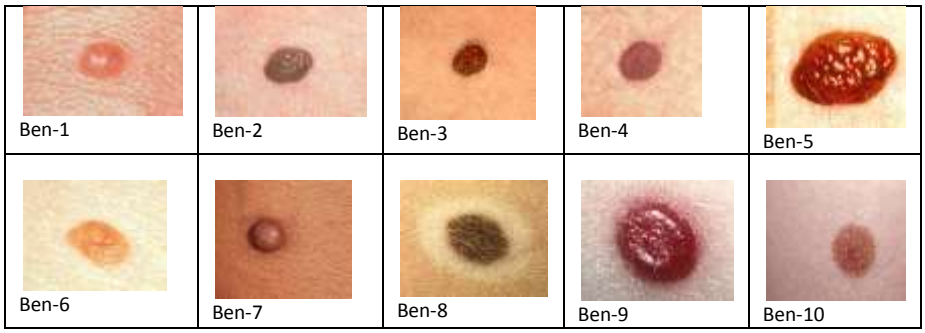
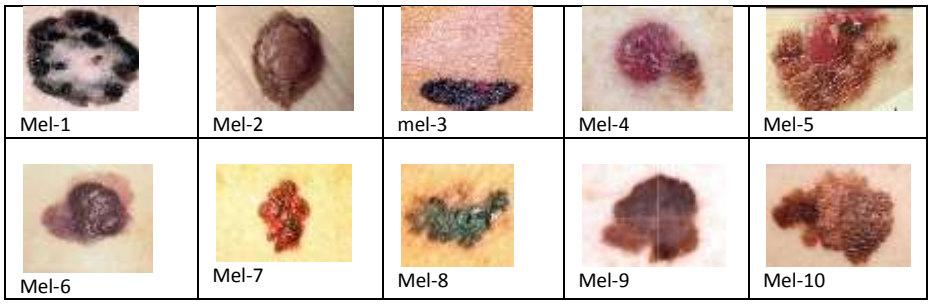
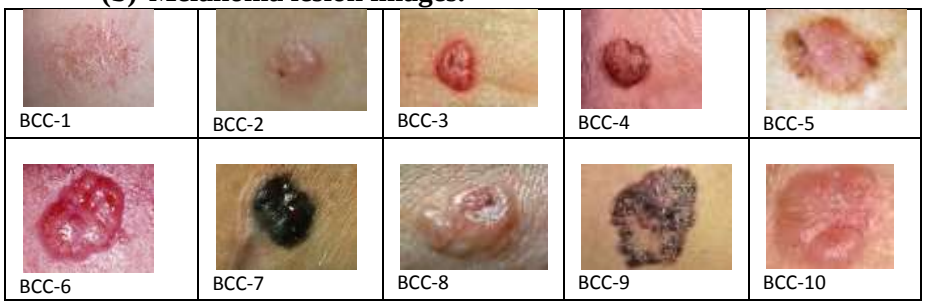


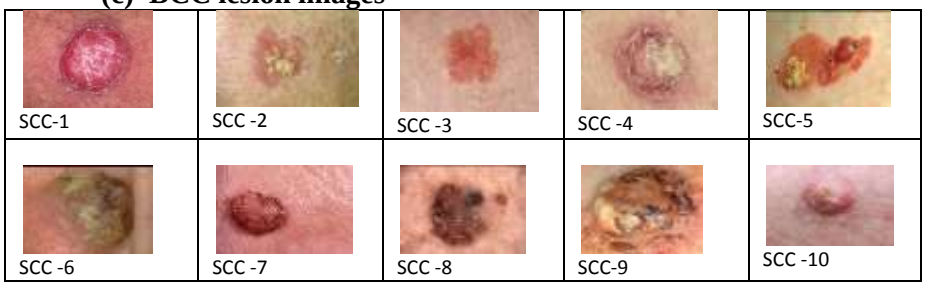
(a) Benign lesion images.



(b) Melanoma lesion images.



(c) BCC lesion images



(d) SCC lesion images.

Figure (1) Example of classified images.

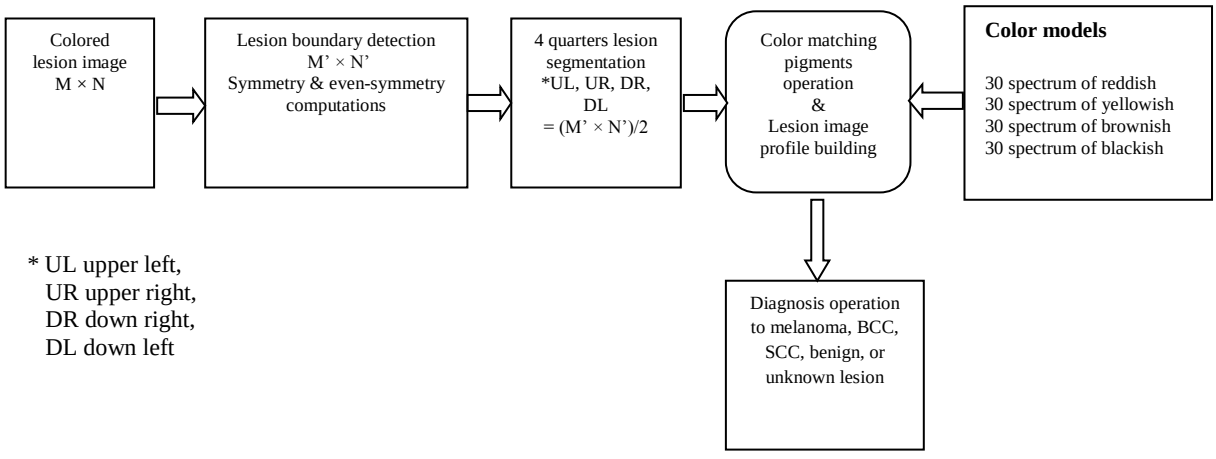


Figure (2) Prognosis operations block diagram.

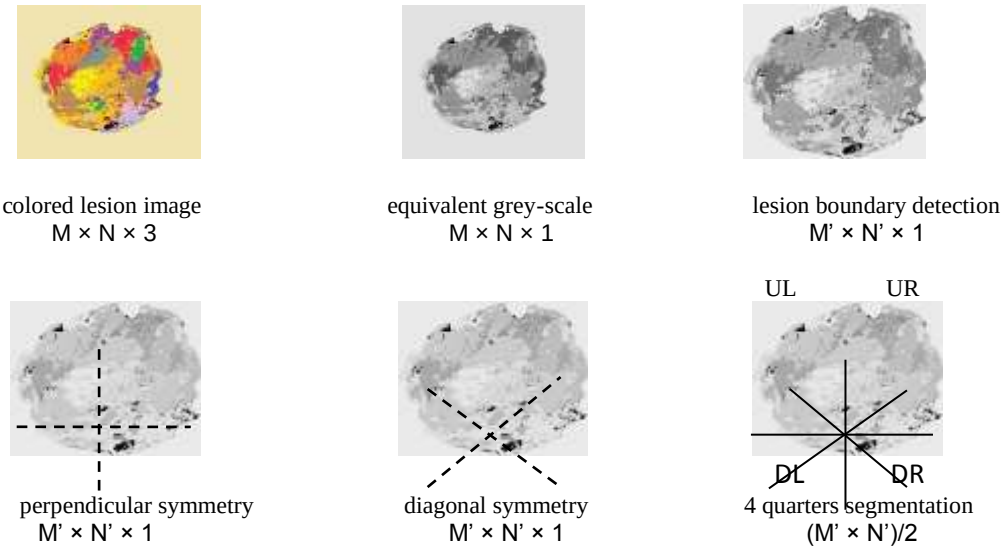


Figure (3): Example of lesion detection and segmentation

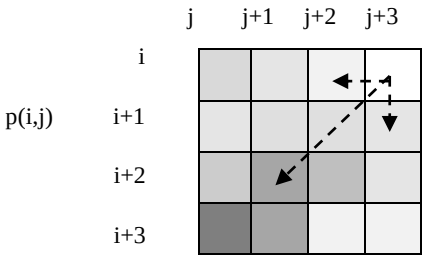


Figure (4) Boundary detection procedure: True edge if { p(i, j-1) AND p(i+1,j) AND p(i+2,j-2) } < Threshold, where Threshold ≤ 0.35.

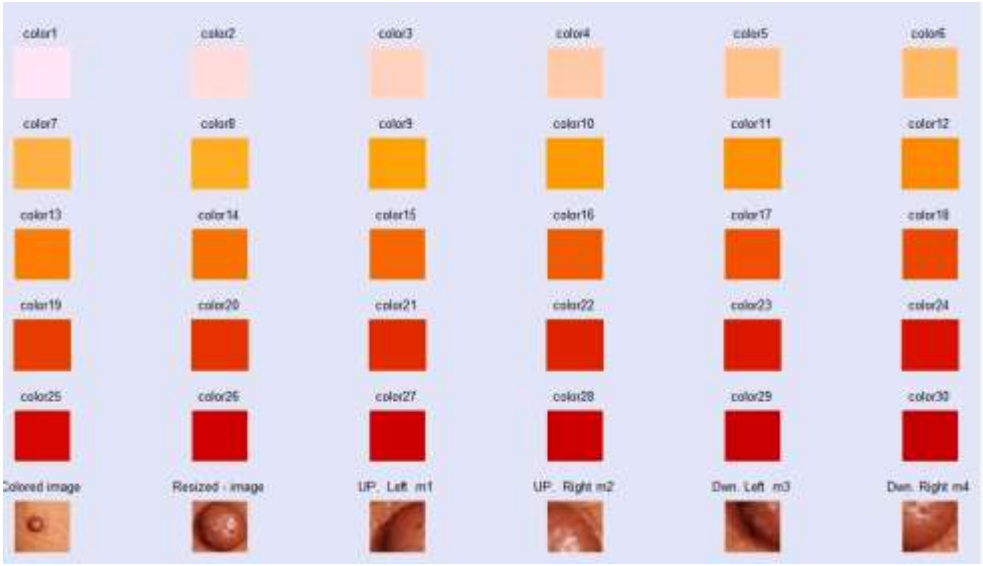


Figure (5-a) Example of 30 Reddish spectrums match ben-7 lesion pigments.

Figure (5-b) Example of 30 Blackish spectrums match mel-8 lesion pigments.

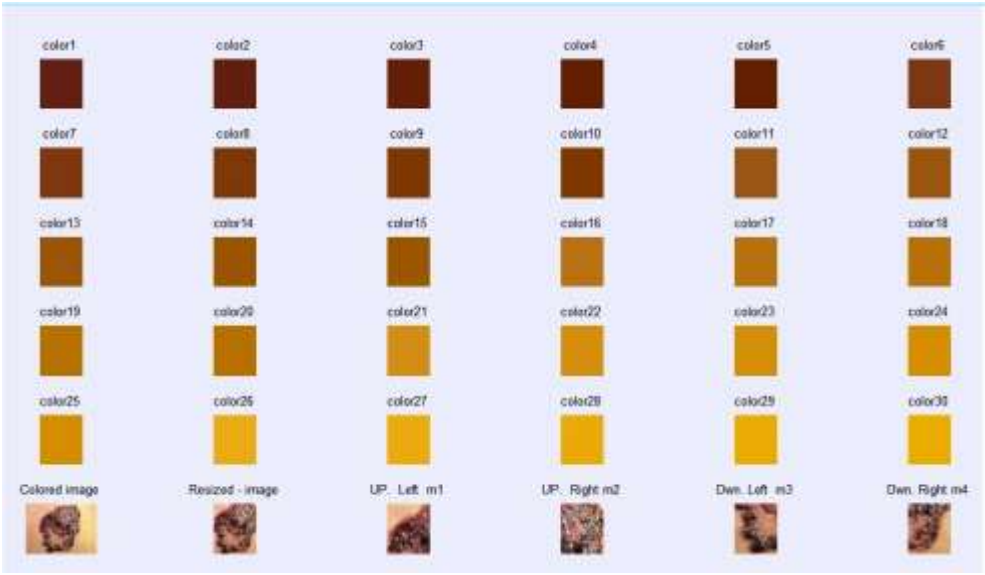


Figure (5-c) Example of 30 Brownish spectrums match BCC- 9 lesion pigments.

Figure (5-d) Example of 30 Yellowish spectrums match SCC-5 lesion pigments.

Table (1) benign image profiles (80% correct classification rate, MSE< 0.003).

Image	Symmetrisation				Colors matching								Predicted results
	Symmetrical		Even Symmetry		Reddish		Yellowish		Brownish		Blackish		
	r-c	d1- d2	e1-e3	e2-e4	quarter	Color	quarter	Color	quarter	Color	quarter	Color	
Ben-1	15	6.92	4.14	1.12	1, 4	19, 22	Nil	-	1	11	Nil	-	-ve
	semi		yes										
Ben-2	19	12.43	2.74	0.27	1	25	Nil	-	Nil	-	1	19	-ve
	semi		yes										
Ben-3	8	11.27	2.81	1.30	4	24	Nil	-	Nil	-	2	22	-ve
	semi		yes										
Ben-4	2	15.55	7.06	1.43	Nil	-	Nil	-	Nil	-	Nil	-	-ve
	semi		yes										
Ben-5	48	25.98	0	3.07	1	20	Nil	-	4	6	1	16	+ve
	no		yes										
Ben-6	11	5.62	2.80	9.99	Nil	-	Nil	-	Nil	-	Nil	-	-ve
	semi		yes										
Ben-7	4	1.41	2.82	2.72	1,2	23, 14	Nil	-	1,3, 4	9,5, 16	Nil	-	-ve
	yes		yes										
Ben-8	29	49.09	5.62	2.58	2	21	Nil	-	4	2	Nil	-	-ve
	no		yes										
Ben-9	33	42.24	1.40	5.77	3,4	23, 30	Nil	-	2,3	15,8	1,4	17,21	+ve
	no		yes										
Ben10	3	7.06	5.65	2.87	3,4	24,25	Nil	-	Nil	-	1,2,4	17,17,19	-ve
	yes		yes										

Table (2) Melanoma image profiles (90% correct classification rate, MSE< 0.003).

Image	Symmetrisation				Colors matching								Predicted results
	Symmetric		Even Symmetry		Reddish		Yellowish		Brownish		Blackish		
	r- c	d1- d2	e1-e3	e2-e4	quarter	Color	quarter	Color	quarter	Color	quarter	Color	
Mel-1	45	18.05	2.78	5.82	2,3, 4	20,15,14	3	29	Nil	-	2	16	+ve
	no		yes										
Mel-2	32	22.52	19.70	20.99	2, 4	24, 21	Nil	-	1	17	Nil	-	+ve
	no		no										
Mel-3	35	30.57	18.17	17.35	Nil	-	1, 4	9, 27	Nil	-	4	12	+ve
	no		no										
Mel-4	100	92.57	32.55	55.33	1	18	2	21	2,3, 4	26,12,13	2	9	+ve
	no		no										
Mel-5	30	27.98	13.09	58.32	4	12	1, 4	27, 25	Nil	-	2, 4	15, 11	+ve
	no		no										
Mel-6	24	58.32	17.68	2.43	Nil	-	Nil	-	2	8	Nil	-	-ve
	no		no										
Mel-7	43	22.17	55.03	29.44	3	11	3	24	1, 2	21, 20	Nil	-	+ve
	no		no										
Mel-8	141	59.15	2.49	75.05	1	13	2, 4	28, 25	Nil	-	Nil	-	+ve
	no		no										
Mel-9	15	14.08	25.32	7.16	4	23	1	27	3, 4	20, 9	2, 4	19, 18	+ve
	semi		no										
Mel-10	196	85.12	14.50	108.66	1, 2	19, 16	2	30	1, 2	11, 17	Nil	-	+ve
	no		no										

Table (3) BCC image profiles (100% correct classification rate, MSE < 0.003).

Image	Symmetrisation				Colors matching								Predicted results
	Symmetrical		Even Symmetry		Reddish		Yellowish		Brownish		Blackish		
	r-c	d1- d2	e1-e3	e2-e4	quarter	Color	quarter	Color	quarter	Color	quarter	Color	
Scc-1	14	39.20	20.77	13.90	Nil	-	1	29	4	20	1,2	13,15	+ve
	no		no										
Scc-2	127	41.01	39.02	0	3, 4	8, 11	3,4	19,24	1	28	3	8	+ve
	no		no										
Scc-3	20	28.10	5.61	35.31	2	17	Nil	-	Nil	-	2,4	14,14	+ve
	no		no										
Scc-4	6	183.89	19.79	0	1	12	1,3	25,26	1, 3	21, 23	1,4	11,10	+ve
	no		no										
Scc-5	171	214.8	81.68	14.87	Nil	-	3,4	27,23	Nil	-	2,3,4	14,12,10	+ve
	no		no										
Scc-6	41	67.74	5.50	42.33	1	14	3	23	Nil	-	3	10	+ve
	no		no										
Scc-7	13	1.39	1.39	9.99	4	26	Nil	-	4	1	Nil	-	Suspicious
	no		yes										
Scc-8	126	264.79	185.81	42.64	Nil	-	2	22,27	1,2,3	27,30,21	1,4	9,12	+ve
	no		no										
Scc-9	3	70.69	60.76	2.80	Nil	-	3	23	2	15	3	10	+ve
	no		no										
Scc-10	145	187.46	33.66	159.12	1, 2	16, 15	1,3	30,29	2	18	3	13	+ve
	no		no										

Table (4) SCC image profiles (100% correct classification rate, MSE < 0.003)

Image	Symmetrisation				Colors matching								Predicted results
	Symmetric		Even Symmetry		Reddish		Yellowish		Brownish		Blackish		
	r- c	d1- d2	e1-e3	e2-e4	quarter	Color	quarter	Color	quarter	Color	quarter	Color	
Bcc-1	9	47.78	1.41	46.71	Nil	-	Nil	-	3,4	2, 19	Nil	-	Suspicious
	no		no										
Bcc-2	35	9.80	2.80	28.22	2,3, 4	18,20, 20	Nil	-	Nil	-	1,3, 4	15,16, 16	+ve
	no		no										
Bcc-3	19	9.82	2.80	19.81	4	20	Nil	-	Nil	-	4	16	+ve
	no		no										
Bcc-4	24	57.29	24.08	0.61	4	20	Nil	-	1	25	4	16	+ve
	no		no										
Bcc-5	160	230.00	9.41	61.41	2	8	Nil	-	Nil	-	Nil	-	Suspicious
	no		no										
Bcc-6	12	8.41	36.18	4.38	Nil	-	Nil	-	2, 4	10, 17	2	18	Suspicious
	yes		no										
Bcc-7	8	22.51	4.20	17.02	Nil	-	Nil	-	1	13	Nil	-	Suspicious
	no		no										
Bcc-8	90	49.46	0	46.43	4	23	Nil	-	2, 4	16, 9	3, 4	17,18	+ve
	no		no										
Bcc-9	18	21.09	2.80	11.12	1	17	Nil	-	4	20	Nil	-	+ve
	no		no										
Bcc-10	0	18.38	59.39	22.62	1,2,3,4	20,19,19,16	Nil	-	2,3, 4	11, 11, 18	1	16	+ve
	no		no										

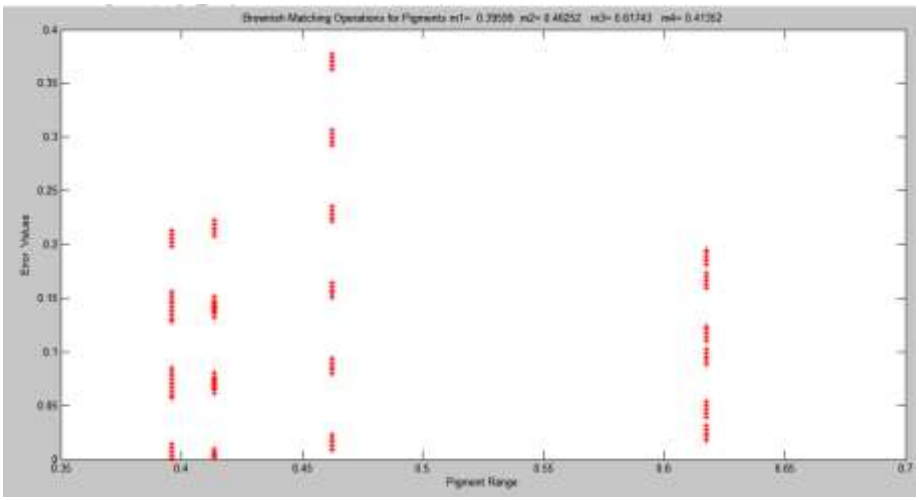


Figure (6-a) Error values for mel-10 Brownish matching operations with four quarters mean values($m_1 = 0.395,\ m_2 = 0.462, m_3 = 0.617, m_4 = 0.413$)**.**

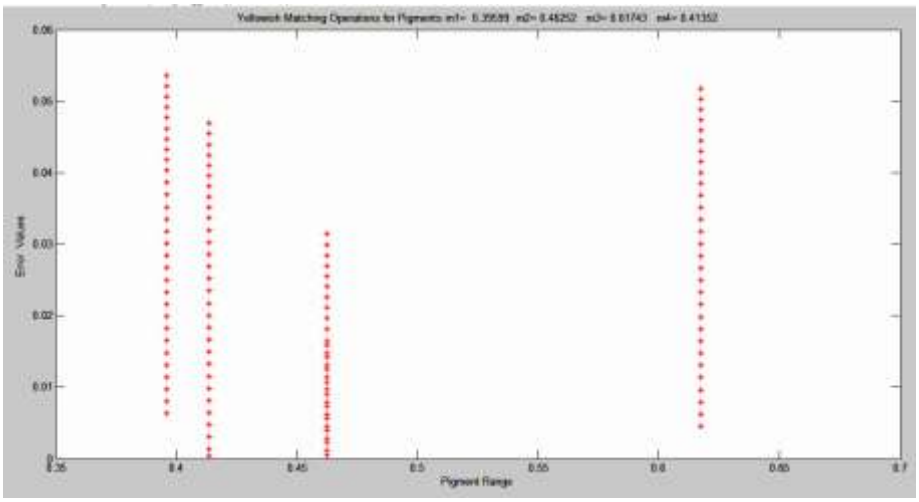


Figure (6-b) Error values for mel-10 Yellowish matching operations with four quarters mean values ($m_1 = 0.395,\ m_2 = 0.462, m_3 = 0.617, m_4 = 0.413$)**.**

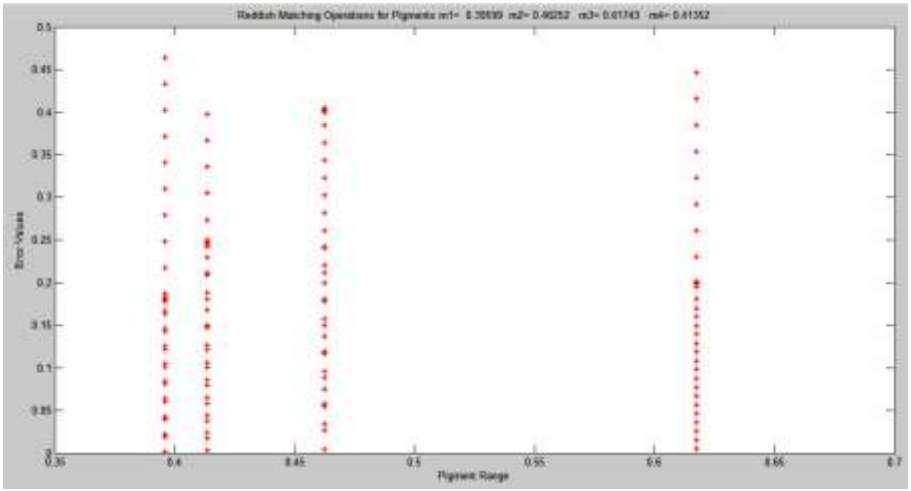


Figure (6-c) Error values for mel-10 Reddish matching operations with four quarters mean values $(m_1 = 0.395,\ m_2 = 0.462,\ m_3 = 0.617,\ m_4 = 0.413\ )$**.**

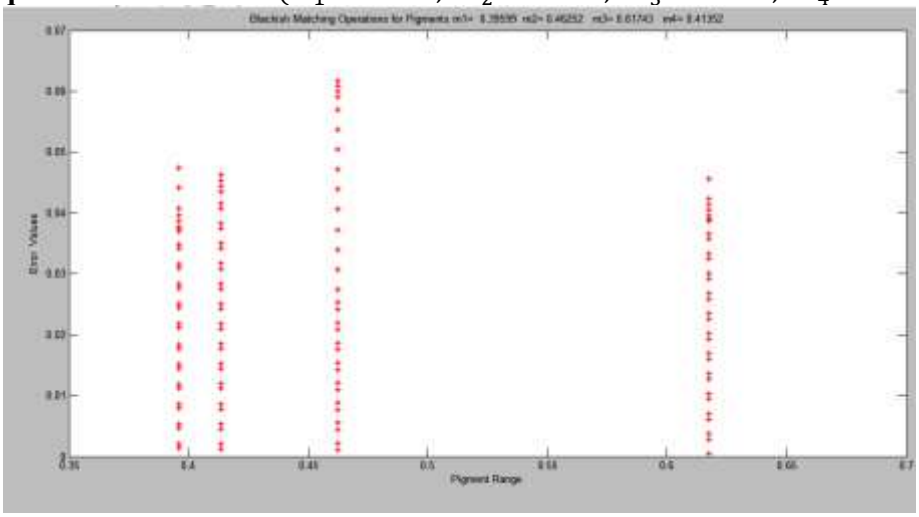


Figure (6-d) Error values for mel-10 Blackish matching operations with four quarters mean values $(m_1 = 0.395,\ m_2 = 0.462,\ m_3 = 0.617,\ m_4 = 0.413\ )$.

Table (5) Color matching pigments rate.

	Reddish	Yellowish	Brownish	Blackish
Benign	9	0	8	5
Melanoma	12	8	8	6
BCC	7	0	11	4
SCC	8	9	9	8