

# Principal Component Analysis of Psoriasis Lesions Images

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**Abstract.** A set of *RGB* images of psoriasis lesions is used. By visual examination of these images, there seem to be no common pattern that could be used to find and align the lesions within and between sessions. It is expected that the principal components of the original images could be useful during future lesion segmentation and alignment purposes.

## 1 Introduction

We use a set of 175 *RGB* psoriasis lesions images, of size  $556 \times 748$  pixels, taken at the Gentofte Hospital, Denmark, during pilot sessions with three invited patients. For each patient, three lesions were followed once a week during at least three weeks. In each session, five images of each lesion were taken. The images were labelled with four characters, indicating patient (1, 2, 3), lesion (A, B, C), session (a, b, c, d) and capture (1, 2, 3, 4, 5) respectively.

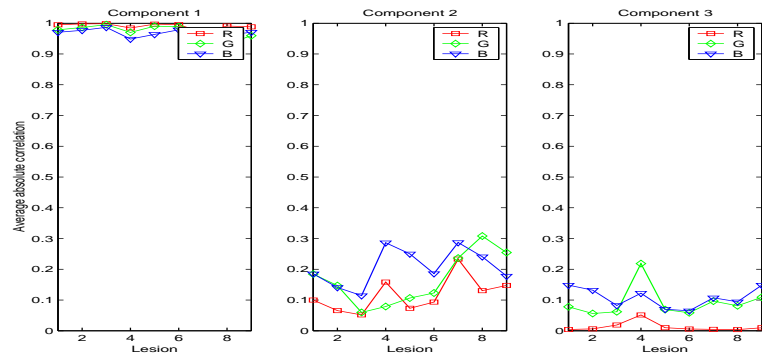
In order to study the variation within and between sessions of a lesions, they first have to be found and matched. In order to find a lesion, the set of image bands, or combination of bands where the lesion is expected to be found has to be specified. Looking at the original images, we can appreciate that for some cases, the lesion has a light color, while the skin is dark, while, for other cases, the opposite situation is seen. This means, that in the whole set of original images there is no common pattern of lesions that could be defined. It could be nice, for instance, to locate the lesion in the same part of the histogram for all the cases. For this reason, in order to be able to define a common pattern of lesion, the linear combination of the original bands given by the principal components is here explored.

Much of the present work was done with the program *maf* [1], which is available at the server of the Institute of Informatics and Mathematical Modelling.

## 2 Principal Component Analysis

The borders of the original images were cut by 10 pixels on each side on before hand. This was done, because of camera problems. Some artefacts appeared on the image borders.

Principal Component Decomposition has been applied to each single psoriasis lesion image. For all the cases, the variance-covariance matrix was diagonalized. For each single image, most of the contribution in its first component is given by the red band, which has an average absolute correlation with the first component of 0.9907. When the correlation matrix is diagonalized, all the bands have almost the same weight in the first component. In Figure 1 and Table 1, it can be seen that all the bands are highly correlated with the first component.



**Fig. 1.** Average absolute correlation per lesion between bands of single images and their principal components.

Band	Comp. 1	Comp. 2	Comp. 3
Red	0.9907	0.1170	0.0128
Green	0.9741	0.1664	0.0921
Blue	0.9674	0.2077	0.1078

**Table 1.** Average absolute correlation values between bands of single images and their principal components

For a given patient and lesion, the captures taken within and between sessions are ordered in a sequence. In order to be able to compare the elements of the sequence given by the corresponding principal components, all the eigenvectors

were oriented to the same sense than the eigenvectors of the first image of that sequence<sup>1</sup>. For each image in the sequence, two scalar products were computed and compared. The first one, was the scalar of the eigenvectors provided by the program *maf* by the eigenvectors of the first image of the first session of that patient and lesion. The second scalar product, was the same as before, but the first eigenvector had the sign<sup>2</sup> changed. The eigenvectors sign, for which the scalar product was positive was selected. The images whose components therefore had to be flipped were: 1Cb1, 1Cb2, 1Cb3, 1Cb4, 1Cb5, 1Cc2, 1Cc3, 2Bd1, 2Bd3, 2Bd4, 2Bd5, 3Ca3, 3Ca4, 3Ca5, 3Cb1, 3Cb2, 3Cb3, 3Cb4, 3Cb5, 3Cc1, 3Cc2, 3Cc3, 3Cc4, 3Cc5, 3Cd1, 3Cd2, 3Cd3, 3Cd4 and 3Cd5.

## 2.1 Eigenvector Values

Tables 2 and 3 show the average and standard deviation values of the eigenvectors. This can be found in detail as one table per patient and lesion, in Appendix B. For a given patient and lesion, each single cell value in Table 2 is the corresponding column data average of the table, with the eigenvector values of the images for this patient and lesion, included in the Appendix B. For a given patient and lesion, each single cell value in Table 3 is the corresponding column data standard deviation of the table, with the eigenvector values of the images for this patient and lesion, included in Appendix B.

**Table 2.** Average Eigenvector Values

(Patient, Lesion)	Red 1 <sup>st</sup> C.	Green 1 <sup>st</sup> C.	Blue 1 <sup>st</sup> C.	Red 2 <sup>nd</sup> C.	Green 2 <sup>nd</sup> C.	Blue 2 <sup>nd</sup> C.	Red 3 <sup>rd</sup> C.	Green 3 <sup>rd</sup> C.	Blue 3 <sup>rd</sup> C.
(1,A)	0.8083	0.4781	0.3429	-0.5847	0.6401	0.4845	-0.0517	-0.5922	0.7975
(1,B)	0.8279	0.4660	0.3111	-0.5422	0.6864	0.4192	-0.0977	-0.5171	0.8207
(1,C)	0.7814	0.4999	0.3732	-0.5463	0.4249	0.5698	-0.2980	-0.6469	0.6070
(2,A)	0.7334	0.4909	0.4650	-0.6098	0.2071	0.7475	-0.2738	0.8339	-0.4552
(2,B)	0.8252	0.4582	0.3271	-0.5191	0.4052	0.7443	0.2107	-0.7843	0.5744
(2,C)	0.7781	0.4859	0.3964	-0.6119	0.4708	0.6260	0.1190	-0.7293	0.6655
(3,A)	0.7303	0.5049	0.4497	-0.6741	0.4937	0.5403	0.0504	-0.7052	0.7068
(3,B)	0.8260	0.3830	0.3932	-0.5452	0.6376	0.5251	-0.0539	-0.6606	0.7464
(3,C)	0.7781	0.4480	0.4370	-0.6181	0.6483	0.4331	0.0868	0.6077	-0.7843

## 2.2 Eigenvalues

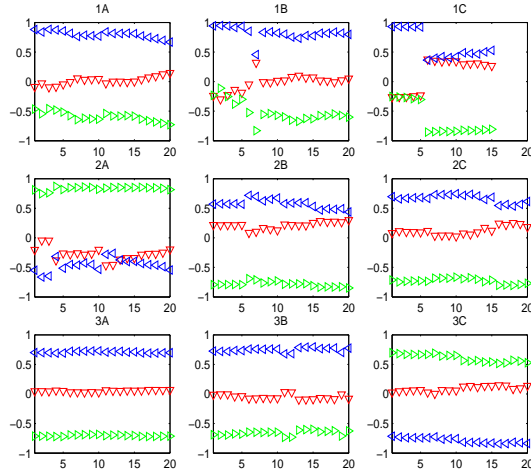
In order to evaluate how much of the total variance is explained by each of the eigenvalues, Table 4 was constructed using the data of Table 16. Each cell in

<sup>1</sup> The eigenvectors give a direction, which has two senses or orientations.

<sup>2</sup> This means, that the other orientation of the eigenvector was tested.

**Table 3.** Standard Deviation of the Eigenvector Values

(Patient, Lesion)	Red $1^{st}C.$	Green $1^{st}C.$	Blue $1^{st}C.$	Red $2^{nd}C.$	Green $2^{nd}C.$	Blue $2^{nd}C.$	Red $3^{rd}C.$	Green $3^{rd}C.$	Blue $3^{rd}C.$
(1,A)	0.0138	0.0153	0.0126	0.0177	0.0736	0.0423	0.0666	0.0765	0.0589
(1,B)	0.0129	0.0164	0.0149	0.0312	0.1270	0.2125	0.1023	0.1738	0.1072
(1,C)	0.0076	0.0045	0.0103	0.0162	0.2958	0.3502	0.0445	0.2727	0.2385
(2,A)	0.0459	0.0244	0.0498	0.0488	0.1421	0.0731	0.1076	0.0314	0.1048
(2,B)	0.0243	0.0283	0.0277	0.0355	0.0932	0.0548	0.0592	0.0421	0.0758
(2,C)	0.0220	0.0258	0.0128	0.0216	0.0906	0.0627	0.0726	0.0446	0.0666
(3,A)	0.0684	0.0470	0.0563	0.0731	0.0429	0.0573	0.0148	0.0127	0.0133
(3,B)	0.0585	0.0869	0.0791	0.1177	0.0651	0.0582	0.0403	0.0402	0.0344
(3,C)	0.0330	0.0260	0.0337	0.0445	0.0724	0.0580	0.0452	0.0653	0.0460



**Fig. 2.** Values of the third eigenvectors of the images of the data-set. Triangle down indicates the weight for the red band; triangle right, for the green band; and triangle left, for the blue band.

Table 4 is computed as follows:

$$p_{p,l,r} = 100 \frac{1}{n_s n_c} \sum_{s=1}^{n_s} \sum_{c=1}^{n_c} \frac{\lambda_{p,l,s,c,r}}{\sum_{t=1}^3 \lambda_{p,l,s,c,t}} \quad (1)$$

where  $p$  is the patient number,  $l$  corresponds to the lesion and  $r$  to the number of the principal component. The index  $s$  varies over the sessions and the index  $c$ , over captures from the given session.  $\lambda_{p,l,s,c,r}$  is the eigenvalue of the  $r$ -th principal component of the  $c$ -th capture taken during the  $s$ -th session of lesion  $l$  of patient  $p$ .

**Table 4.** Average and standard deviation per patient and lesion of the percentage of the explained total variance of the principal components of the original images

(Patient, Lesion)	Mean 1 <sup>st</sup> C.	Std. Dev. 1 <sup>st</sup> C.	Mean 2 <sup>nd</sup> C.	Std. Dev. 2 <sup>nd</sup> C.	Mean 3 <sup>rd</sup> C.	Std. Dev. 3 <sup>rd</sup> C.
(1,A)	97.65	0.74	1.92	0.62	0.43	0.15
(1,B)	98.65	0.72	1.08	0.74	0.27	0.08
(1,C)	99.19	0.19	0.56	0.16	0.25	0.07
(2,A)	94.70	1.96	3.47	1.13	1.83	0.90
(2,B)	98.42	0.76	1.41	0.73	0.17	0.06
(2,C)	98.26	1.01	1.58	0.97	0.16	0.05
(3,A)	93.42	2.20	6.10	2.13	0.48	0.11
(3,B)	95.76	2.52	3.97	2.52	0.27	0.06
(3,C)	95.88	1.38	3.41	1.23	0.71	0.31

### 3 Discussion

From Table 4 it can be deduced, that, for all the cases, almost all the total variance is explained by the first principal component.

If we think of the images as being composed of three classes: background, normal skin and lesion, looking at the images shown in Appendix A we can deduce that for the cases (1, A), (1, B) and (1, C) the first component histogram peak corresponding to the lesion is the central one, while for the remaining cases, it is in one of the extremes. On the other hand, it is interesting to observe that there is more contrast between the lesions and the rest in the third principal component. In fact, they are roughly enhanced from the rest. This allowed us, for instance, to find out, that the visual registration of some lesions, during the image acquisition process, was of regular quality. This detail that can not easily be seen in the first principal component. Compare, for instance, the images of the first and third session of the case (2, C).

Taking a look at the values of the third eigenvectors, it can be deduced that a rough estimation of the third component can be obtained by subtracting the green band from the blue band, while the red band almost does not have any influence (See Figure 2). Note also in Table 5, that the large variance of the third eigenvector values for the case (1,  $C$ ) is due to the fact that the magnitude of the weights for the  $B$  and  $G$  band are kind of flipped. For the blue bands of the first session, the magnitude of the weights -in the third component- is more similar to the magnitude of the weights for the green band in the next sessions, and viceversa.

The  $|B - G|$  bands do not have, for all the cases, the probability density function of the lesion class located in one extreme of the normalized histogram. However, the contrast between the lesion and the normal skin is still significant. See, for instance, the case (2,  $C$ ), or note in the case (2,  $A$ ) how clear the lesions are enhanced from the rest.

## 4 Conclusions

The  $R, G, B$  bands are highly correlated with the first principal component, where the largest contribution is given by the red band. There is high contrast between the lesions and the rest in the third principal component. This component could roughly be estimated by subtracting the blue from the green band. In this estimation, there is a high contrast between the lesion and normal skin. It is tempting to use this estimation of the third principal component as input for a classification scheme. On the other hand, it has been shown that it could be useful to provide the person who carries out the image acquisition with the third principal component in order to do a better visual registration of the lesion to be captured.

## Acknowledgments

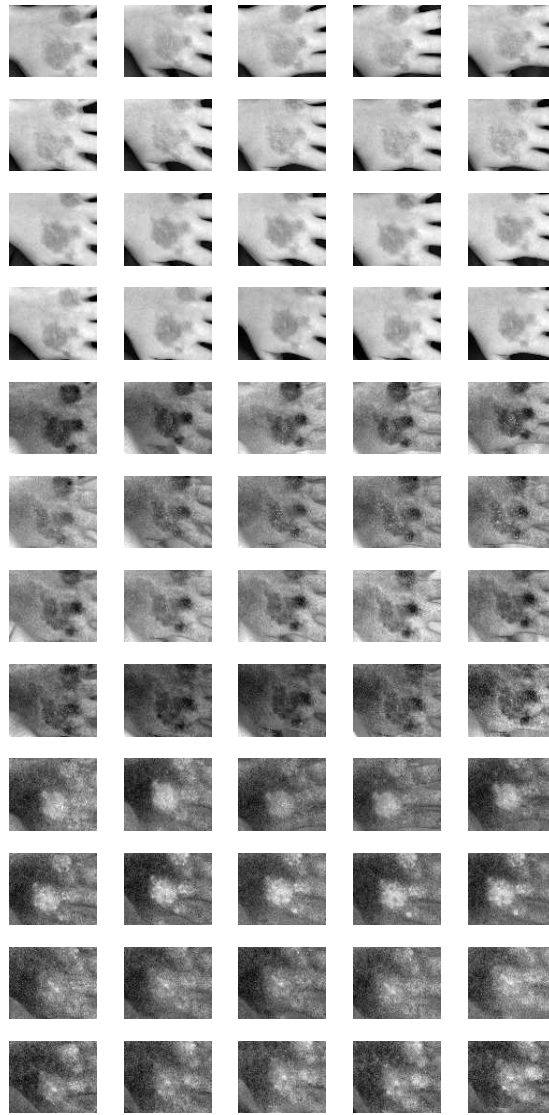
To the SITE Project funded by a grant from the Danish Technical Research Foundation (Project Number *STVF* 56-00-0123) for supporting the present work. To the dermatologists Lone Skov and Bo Bang of the Gentofte Hospital of Denmark and to the anonymous patients, for their collaboration during the image acquisition sessions.

## Appendix

### A Principal Components

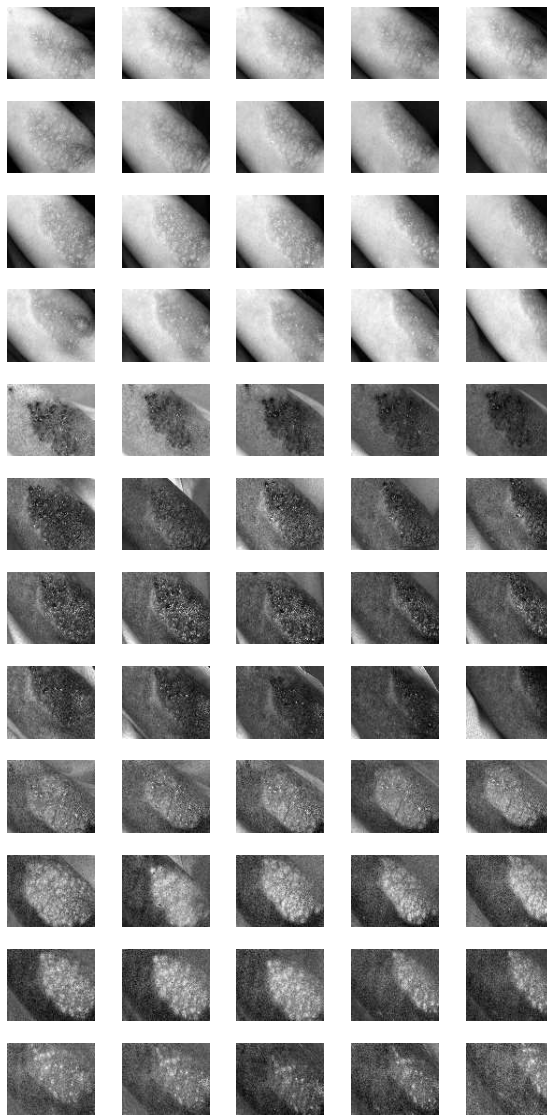
In this section, for the set of images corresponding to a given patient and lesion, the principal components are shown in one single figure. Each figure is arranged

as follows. From top to bottom, three blocks are considered. All the blocks have the same number of rows. The number of rows of the block is the number of sessions for which images of the same patient and lesion has been taken. The first block (first third of the rows) is composed by the first principal components of the images of the given patient and lesion. The second block (second third of the rows), by the second principal components, and so on, for the third block (remaining rows). Within a block, the row number indicates the number of the session, and the column number indicates the number of capture within a session.

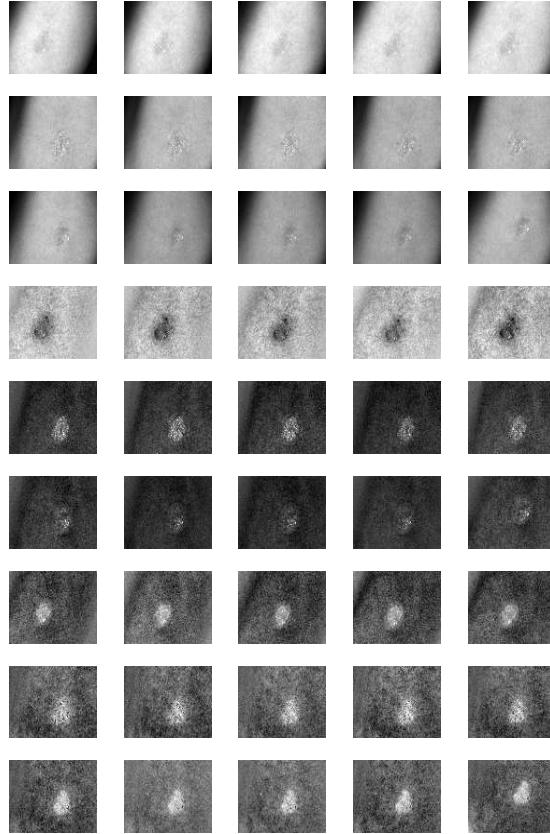


**Fig. 3.** Principal Components of the images of the case (Patient 1, Lesion A).

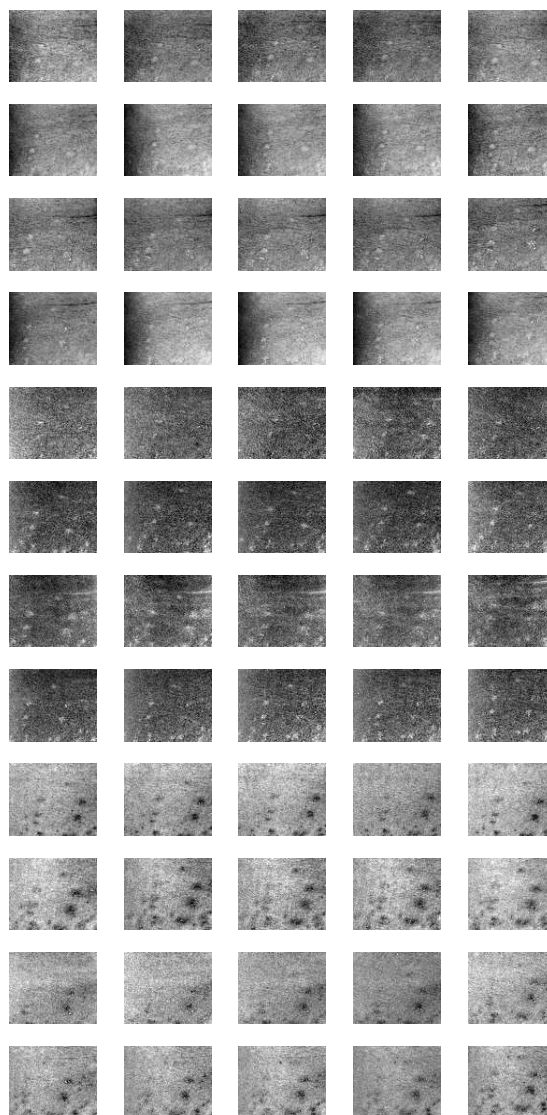




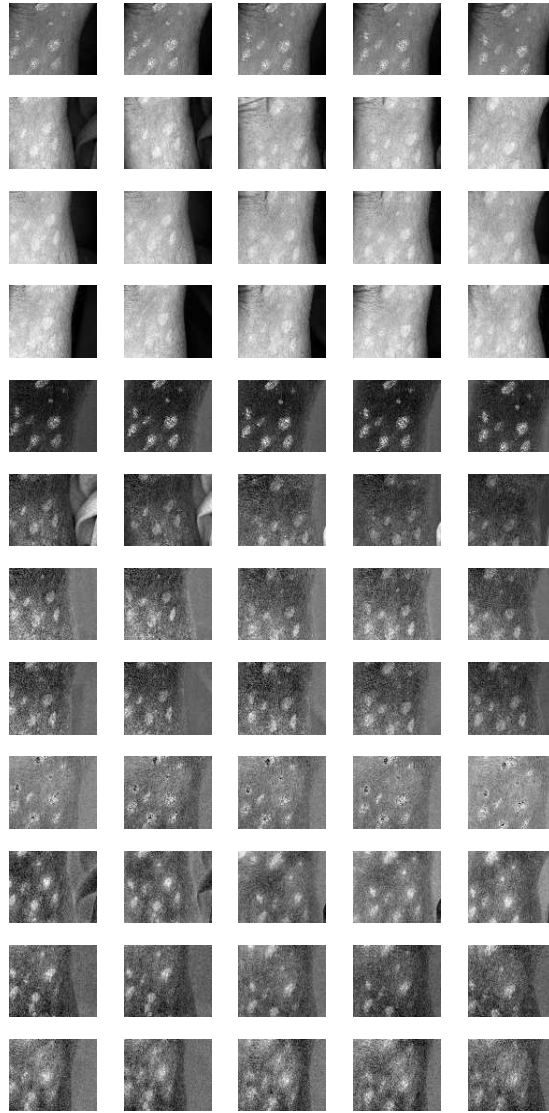
**Fig. 4.** Principal Components of the images of the case (Patient 1, Lesion B).



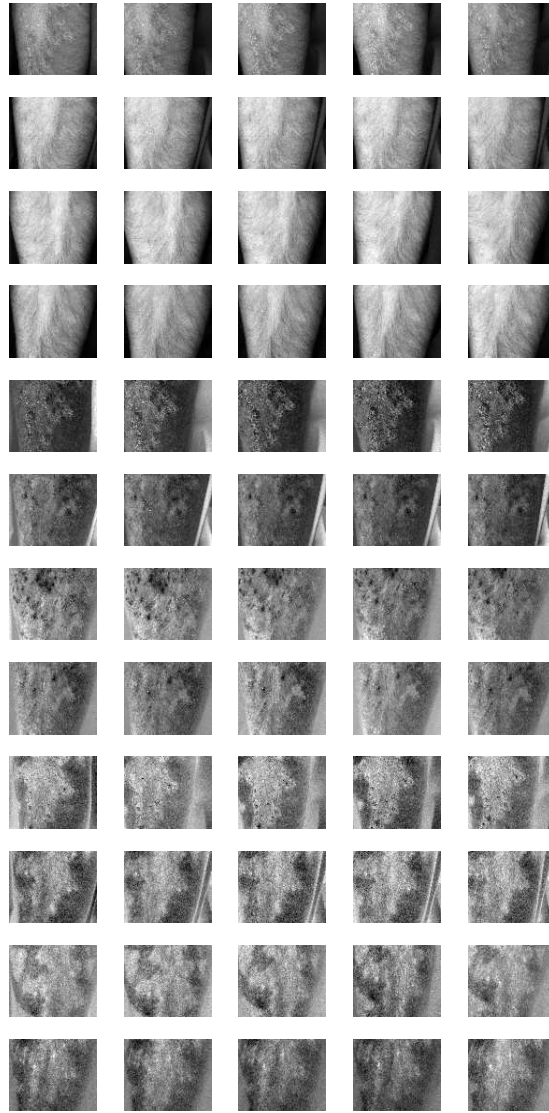
**Fig. 5.** Principal Components of the images of the case (Patient 1, Lesion C).



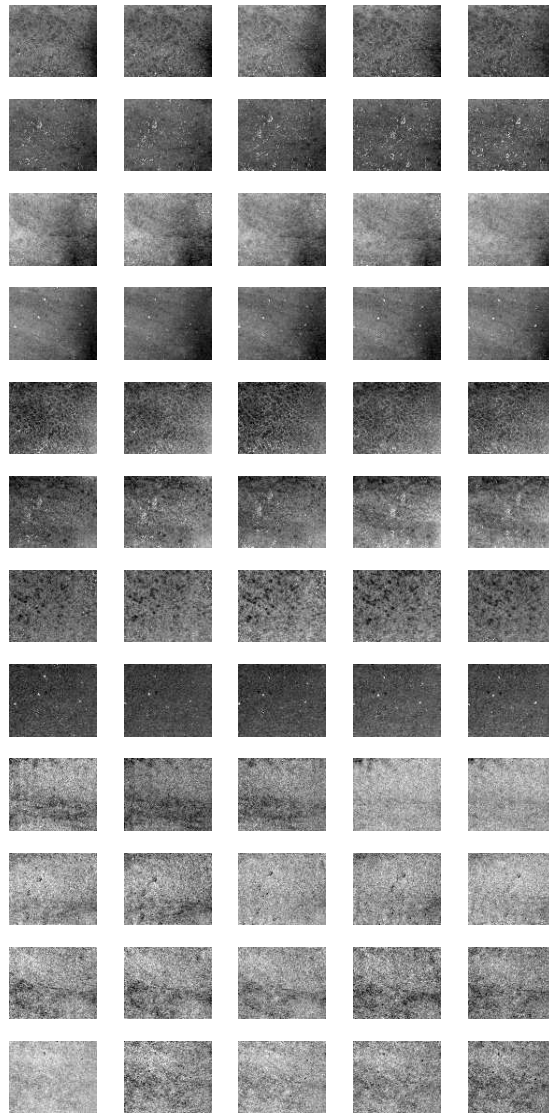
**Fig. 6.** Principal Components of the images of the case (Patient 2, Lesion A).



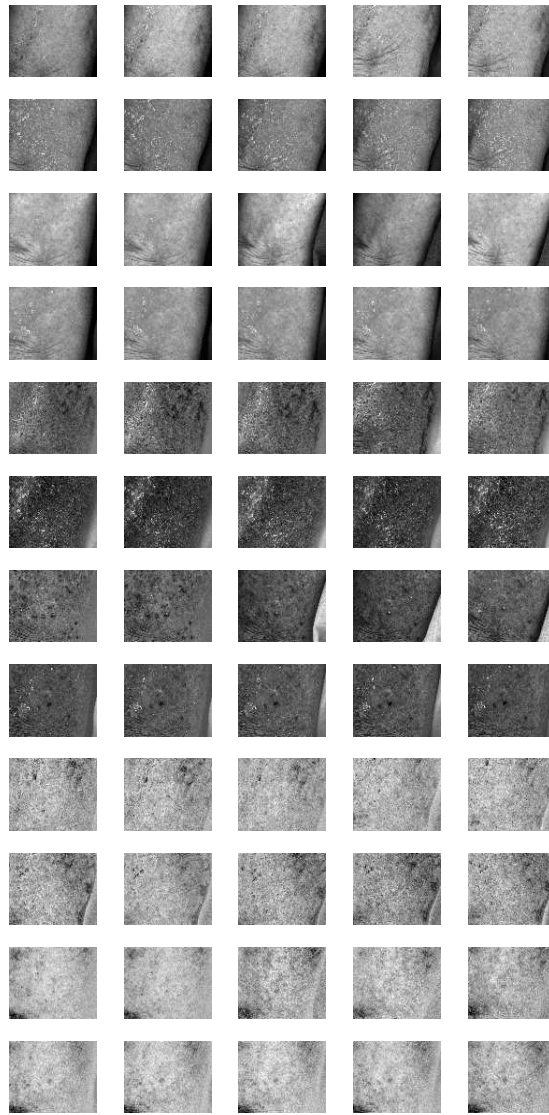
**Fig. 7.** Principal Components of the images of the case (Patient 2, Lesion B).



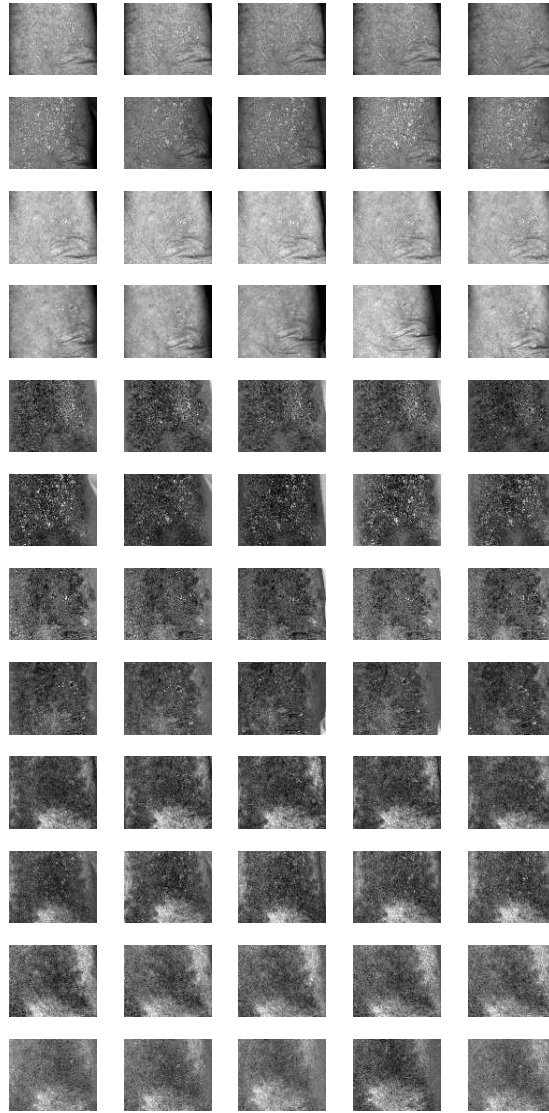
**Fig. 8.** Principal Components of the images of the case (Patient 2, Lesion C).



**Fig. 9.** Principal Components of the images of the case (Patient 3, Lesion A).



**Fig. 10.** Principal Components of the images of the case (Patient 3, Lesion B).



**Fig. 11.** Principal Components of the images of the case (Patient 3, Lesion C).



## B Eigenvector Values of the Original Images

**Table 5.** Eigenvectors Values of the original images of (Patient 1, Lesion A)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.7938	0.5007	0.3452	-0.6015	0.7302	0.3241	-0.0898	-0.4649	0.8808
a2	0.8216	0.4642	0.3308	-0.5692	0.6986	0.4336	-0.0298	-0.5445	0.8382
a3	0.8048	0.4871	0.3392	-0.5858	0.7440	0.3215	-0.0957	-0.4574	0.8841
a4	0.8051	0.4827	0.3446	-0.5869	0.7321	0.3457	-0.0854	-0.4806	0.8728
a5	0.8398	0.4434	0.3133	-0.5408	0.7333	0.4120	-0.0470	-0.5154	0.8556
b1	0.8017	0.4847	0.3498	-0.5977	0.6576	0.4586	-0.0077	-0.5767	0.8169
b2	0.8277	0.4564	0.3265	-0.5584	0.6131	0.5588	0.0549	-0.6449	0.7623
b3	0.8273	0.4570	0.3267	-0.5609	0.6398	0.5254	0.0311	-0.6179	0.7856
b4	0.8133	0.4712	0.3413	-0.5805	0.6177	0.5306	0.0392	-0.6297	0.7759
b5	0.8179	0.4662	0.3371	-0.5735	0.6145	0.5417	0.0455	-0.6364	0.7700
c1	0.8009	0.4904	0.3437	-0.5981	0.6830	0.4193	-0.0291	-0.5414	0.8403
c2	0.8024	0.4863	0.3459	-0.5968	0.6532	0.4661	0.0008	-0.5804	0.8143
c3	0.8084	0.4784	0.3431	-0.5887	0.6566	0.4715	0.0003	-0.5832	0.8124
c4	0.7968	0.4911	0.3521	-0.6043	0.6545	0.4545	-0.0073	-0.5749	0.8182
c5	0.8189	0.4665	0.3344	-0.5739	0.6638	0.4795	0.0017	-0.5846	0.8113
d1	0.8061	0.4760	0.3516	-0.5906	0.6092	0.5292	0.0377	-0.6342	0.7722
d2	0.7904	0.4942	0.3620	-0.6085	0.5650	0.5573	0.0709	-0.6607	0.7473
d3	0.8041	0.4803	0.3504	-0.5875	0.5517	0.5920	0.0910	-0.6819	0.7258
d4	0.7852	0.4993	0.3662	-0.6069	0.5029	0.6155	0.1232	-0.7055	0.6979
d5	0.7988	0.4857	0.3550	-0.5835	0.4820	0.6536	0.1464	-0.7292	0.6684

**Table 6.** Eigenvectors Values of the original images of (Patient 1, Lesion B)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.8089	0.4881	0.3279	-0.5361	0.8413	0.0700	-0.2416	-0.2324	0.9421
a2	0.8169	0.4822	0.3165	-0.4924	0.8688	-0.0529	-0.3005	-0.1126	0.9471
a3	0.8170	0.4759	0.3257	-0.5299	0.8423	0.0987	-0.2274	-0.2532	0.9403
a4	0.8244	0.4669	0.3199	-0.5485	0.7985	0.2480	-0.1396	-0.3799	0.9144
a5	0.8218	0.4737	0.3166	-0.5379	0.8282	0.1573	-0.1877	-0.2996	0.9354
b1	0.8472	0.4299	0.3122	-0.5292	0.7353	0.4235	-0.0475	-0.5240	0.8504
b2	0.8351	0.4739	0.2793	-0.4483	0.2921	0.8448	0.3188	-0.8307	0.4564
b3	0.8372	0.4512	0.3092	-0.5469	0.6992	0.4605	-0.0085	-0.5546	0.8321
b4	0.8366	0.4544	0.3062	-0.5477	0.7078	0.4461	-0.0141	-0.5408	0.8410
b5	0.8452	0.4453	0.2954	-0.5342	0.6901	0.4882	0.0135	-0.5705	0.8212
c1	0.8271	0.4611	0.3215	-0.5617	0.6577	0.5020	0.0200	-0.5957	0.8029
c2	0.8184	0.4741	0.3248	-0.5692	0.5908	0.5718	0.0792	-0.6528	0.7534
c3	0.8188	0.4745	0.3230	-0.5652	0.5680	0.5983	0.1004	-0.6725	0.7333
c4	0.8268	0.4719	0.3062	-0.5584	0.6227	0.5481	0.0680	-0.6241	0.7784
c5	0.8276	0.4704	0.3062	-0.5568	0.6193	0.5536	0.0708	-0.6287	0.7745
d1	0.8387	0.4548	0.2996	-0.5443	0.6804	0.4907	0.0193	-0.5746	0.8182
d2	0.8297	0.4633	0.3113	-0.5580	0.6751	0.4826	0.0134	-0.5741	0.8187
d3	0.8090	0.4870	0.3291	-0.5877	0.6801	0.4383	-0.0104	-0.5480	0.8364
d4	0.8151	0.4852	0.3165	-0.5789	0.6615	0.4767	0.0220	-0.5718	0.8201
d5	0.8568	0.4366	0.2745	-0.5131	0.6688	0.5380	0.0513	-0.6018	0.7970

**Table 7.** Eigenvectors Values of the original images of (Patient 1, Lesion C)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.7917	0.4946	0.3585	-0.5512	0.8314	0.0703	-0.2633	-0.2533	0.9309
a2	0.7923	0.4928	0.3598	-0.5519	0.8302	0.0783	-0.2601	-0.2606	0.9298
a3	0.7913	0.4922	0.3626	-0.5541	0.8281	0.0850	-0.2584	-0.2682	0.9281
a4	0.7860	0.4991	0.3647	-0.5673	0.8168	0.1050	-0.2455	-0.2895	0.9252
a5	0.7889	0.4967	0.3620	-0.5687	0.8132	0.1236	-0.2329	-0.3034	0.9240
b1	0.7741	0.5027	0.3848	-0.5107	0.1369	0.8488	0.3740	-0.8536	0.3627
b2	0.7763	0.5015	0.3819	-0.5222	0.1723	0.8353	0.3531	-0.8478	0.3956
b3	0.7714	0.5054	0.3867	-0.5387	0.1950	0.8196	0.3388	-0.8406	0.4227
b4	0.7717	0.5049	0.3866	-0.5311	0.1774	0.8285	0.3498	-0.8447	0.4051
b5	0.7702	0.5071	0.3868	-0.5382	0.1915	0.8208	0.3421	-0.8404	0.4204
c1	0.7842	0.4977	0.3706	-0.5473	0.2736	0.7909	0.2922	-0.8231	0.4870
c2	0.7796	0.5016	0.3751	-0.5482	0.2567	0.7960	0.3030	-0.8262	0.4750
c3	0.7802	0.5009	0.3747	-0.5445	0.2491	0.8009	0.3078	-0.8289	0.4671
c4	0.7815	0.5005	0.3724	-0.5557	0.2871	0.7802	0.2836	-0.8167	0.5025
c5	0.7817	0.5012	0.3711	-0.5642	0.3148	0.7633	0.2657	-0.8060	0.5289

**Table 8.** Eigenvectors Values of the original images of (Patient 2, Lesion A)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.7357	0.4960	0.4611	-0.6460	0.3094	0.6978	-0.2035	0.8113	-0.5480
a2	0.7226	0.4835	0.4940	-0.6898	0.4574	0.5613	-0.0454	0.7463	-0.6640
a3	0.7002	0.4862	0.5227	-0.7123	0.4275	0.5566	-0.0472	0.7621	-0.6457
a4	0.6893	0.4940	0.5299	-0.6160	0.0147	0.7876	-0.3812	0.8694	-0.3144
a5	0.7205	0.5208	0.4578	-0.6413	0.2493	0.7257	-0.2638	0.8164	-0.5137
b1	0.7558	0.4836	0.4415	-0.5923	0.2174	0.7758	-0.2792	0.8479	-0.4507
b2	0.7917	0.4609	0.4009	-0.5524	0.2601	0.7920	-0.2607	0.8485	-0.4605
b3	0.7804	0.4649	0.4182	-0.5571	0.2133	0.8026	-0.2839	0.8593	-0.4254
b4	0.7805	0.4655	0.4173	-0.5652	0.2400	0.7893	-0.2672	0.8519	-0.4504
b5	0.7434	0.4822	0.4636	-0.6380	0.3029	0.7080	-0.2010	0.8220	-0.5328
c1	0.6783	0.5409	0.4974	-0.5692	-0.0414	0.8212	-0.4647	0.8401	-0.2798
c2	0.6758	0.5230	0.5194	-0.5789	-0.0596	0.8132	-0.4563	0.8503	-0.2625
c3	0.6790	0.5200	0.5182	-0.6357	0.0633	0.7693	-0.3672	0.8518	-0.3735
c4	0.6831	0.5192	0.5136	-0.6447	0.0981	0.7581	-0.3433	0.8490	-0.4018
c5	0.6524	0.5192	0.5521	-0.6771	0.0721	0.7323	-0.3404	0.8516	-0.3986
d1	0.7510	0.4804	0.4530	-0.5957	0.1968	0.7788	-0.2850	0.8547	-0.4339
d2	0.7844	0.4682	0.4068	-0.5583	0.2473	0.7919	-0.2702	0.8483	-0.4554
d3	0.7884	0.4686	0.3986	-0.5533	0.2570	0.7923	-0.2689	0.8452	-0.4619
d4	0.7838	0.4697	0.4062	-0.5687	0.2802	0.7733	-0.2494	0.8372	-0.4868
d5	0.7716	0.4712	0.4273	-0.6049	0.3358	0.7220	-0.1967	0.8156	-0.5441

**Table 9.** Eigenvectors Values of the original images of (Patient 2, Lesion B)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.8076	0.4736	0.3514	-0.5486	0.3846	0.7423	0.2164	-0.7923	0.5705
a2	0.8015	0.4789	0.3582	-0.5583	0.3847	0.7351	0.2142	-0.7891	0.5757
a3	0.8050	0.4757	0.3547	-0.5528	0.3842	0.7395	0.2155	-0.7913	0.5722
a4	0.8002	0.4788	0.3612	-0.5607	0.3836	0.7338	0.2128	-0.7897	0.5754
a5	0.7937	0.4831	0.3696	-0.5678	0.3706	0.7350	0.2181	-0.7932	0.5685
b1	0.8928	0.3729	0.2527	-0.4424	0.6201	0.6479	0.0849	-0.6903	0.7185
b2	0.8767	0.3961	0.2729	-0.4698	0.5835	0.6625	0.1032	-0.7090	0.6976
b3	0.8305	0.4508	0.3273	-0.5312	0.4637	0.7091	0.1679	-0.7627	0.6245
b4	0.8316	0.4499	0.3256	-0.5360	0.4964	0.6829	0.1455	-0.7424	0.6540
b5	0.8460	0.4342	0.3095	-0.5178	0.5305	0.6711	0.1272	-0.7280	0.6737
c1	0.8167	0.4751	0.3275	-0.5312	0.3973	0.7483	0.2254	-0.7851	0.5769
c2	0.8158	0.4761	0.3282	-0.5360	0.4094	0.7383	0.2172	-0.7782	0.5892
c3	0.8148	0.4737	0.3342	-0.5406	0.4123	0.7334	0.2096	-0.7782	0.5920
c4	0.8122	0.4770	0.3359	-0.5444	0.4127	0.7303	0.2097	-0.7760	0.5949
c5	0.8179	0.4718	0.3293	-0.5165	0.3499	0.7815	0.2535	-0.8093	0.5299
d1	0.8334	0.4572	0.3107	-0.4745	0.3033	0.8264	0.2836	-0.8361	0.4697
d2	0.8299	0.4589	0.3173	-0.4883	0.3223	0.8110	0.2699	-0.8279	0.4916
d3	0.8282	0.4598	0.3204	-0.4884	0.3119	0.8150	0.2747	-0.8315	0.4829
d4	0.8241	0.4606	0.3299	-0.5002	0.3183	0.8053	0.2659	-0.8286	0.4926
d5	0.8263	0.4599	0.3250	-0.4768	0.2642	0.8384	0.2997	-0.8478	0.4376

**Table 10.** Eigenvectors values of the original images of (Patient 2, Lesion C)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.7914	0.4704	0.3904	-0.6060	0.5195	0.6025	0.0806	-0.7133	0.6962
a2	0.8022	0.4589	0.3820	-0.5863	0.4841	0.6496	0.1131	-0.7451	0.6573
a3	0.8000	0.4597	0.3857	-0.5917	0.4971	0.6347	0.1000	-0.7359	0.6697
a4	0.7922	0.4686	0.3910	-0.6023	0.4972	0.6244	0.0982	-0.7302	0.6762
a5	0.8019	0.4596	0.3819	-0.5903	0.5101	0.6256	0.0927	-0.7270	0.6803
b1	0.7794	0.4841	0.3977	-0.6155	0.4730	0.6305	0.1171	-0.7362	0.6666
b2	0.8021	0.4558	0.3859	-0.5962	0.5723	0.5631	0.0358	-0.6817	0.7308
b3	0.8006	0.4591	0.3850	-0.5979	0.5696	0.5639	0.0396	-0.6817	0.7306
b4	0.8011	0.4582	0.3851	-0.5972	0.5703	0.5639	0.0388	-0.6818	0.7305
b5	0.8144	0.4459	0.3715	-0.5798	0.5985	0.5528	0.0241	-0.6656	0.7459
c1	0.7603	0.5052	0.4083	-0.6453	0.5156	0.5637	0.0742	-0.6921	0.7180
c2	0.7580	0.5083	0.4087	-0.6498	0.5342	0.5408	0.0565	-0.6755	0.7352
c3	0.7564	0.5125	0.4064	-0.6474	0.4981	0.5769	0.0932	-0.6995	0.7086
c4	0.7618	0.5162	0.3914	-0.6254	0.4284	0.6522	0.1690	-0.7416	0.6492
c5	0.7573	0.5138	0.4032	-0.6419	0.4718	0.6045	0.1204	-0.7166	0.6870
d1	0.7614	0.5056	0.4057	-0.6016	0.3179	0.7328	0.2416	-0.8020	0.5463
d2	0.7622	0.4993	0.4121	-0.6095	0.3390	0.7166	0.2181	-0.7974	0.5627
d3	0.7563	0.5098	0.4101	-0.6039	0.3029	0.7372	0.2517	-0.8052	0.5370
d4	0.7506	0.5173	0.4111	-0.6181	0.3299	0.7135	0.2334	-0.7897	0.5674
d5	0.7533	0.5105	0.4146	-0.6319	0.3872	0.6714	0.1822	-0.7678	0.6142

**Table 11.** Eigenvectors Values of the original images of (Patient 3, Lesion A)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.6940	0.5265	0.4911	-0.7185	0.4628	0.5192	0.0461	-0.7132	0.6995
a2	0.6707	0.5414	0.5070	-0.7402	0.4449	0.5042	0.0474	-0.7135	0.6991
a3	0.7409	0.4924	0.4567	-0.6701	0.4968	0.5514	0.0447	-0.7146	0.6981
a4	0.6766	0.5371	0.5037	-0.7341	0.4383	0.5186	0.0577	-0.7207	0.6909
a5	0.6724	0.5378	0.5085	-0.7383	0.4390	0.5120	0.0522	-0.7197	0.6923
b1	0.6686	0.5498	0.5007	-0.7431	0.4680	0.4783	0.0287	-0.6919	0.7214
b2	0.6618	0.5542	0.5048	-0.7491	0.4627	0.4742	0.0292	-0.6920	0.7213
b3	0.6518	0.5608	0.5106	-0.7580	0.4593	0.4631	0.0252	-0.6889	0.7245
b4	0.6220	0.5830	0.5227	-0.7824	0.4354	0.4453	0.0321	-0.6859	0.7270
b5	0.6196	0.5839	0.5245	-0.7844	0.4375	0.4396	0.0273	-0.6838	0.7291
c1	0.7944	0.4652	0.3907	-0.6040	0.5368	0.5891	0.0643	-0.7039	0.7074
c2	0.7911	0.4687	0.3931	-0.6092	0.5449	0.5762	0.0559	-0.6952	0.7166
c3	0.7896	0.4693	0.3952	-0.6114	0.5475	0.5714	0.0518	-0.6928	0.7192
c4	0.7802	0.4744	0.4078	-0.6228	0.5279	0.5774	0.0587	-0.7045	0.7073
c5	0.7929	0.4644	0.3946	-0.6067	0.5410	0.5824	0.0570	-0.7011	0.7107
d1	0.7985	0.4512	0.3986	-0.5992	0.5316	0.5986	0.0582	-0.7168	0.6949
d2	0.7962	0.4565	0.3970	-0.6011	0.5227	0.6045	0.0684	-0.7200	0.6906
d3	0.7955	0.4583	0.3964	-0.6021	0.5242	0.6022	0.0682	-0.7177	0.6930
d4	0.7957	0.4587	0.3955	-0.6019	0.5267	0.6003	0.0670	-0.7157	0.6952
d5	0.7928	0.4634	0.3959	-0.6056	0.5262	0.5969	0.0683	-0.7130	0.6978

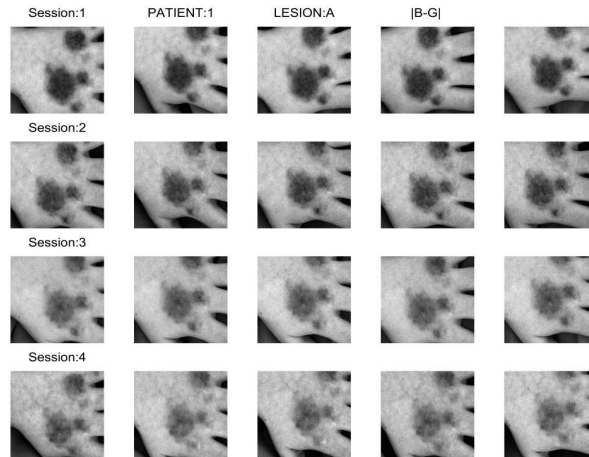
**Table 12.** Eigenvectors Values of the original images of (Patient 3, Lesion B)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.7766	0.4496	0.4412	-0.6298	0.5683	0.5295	-0.0127	-0.6891	0.7245
a2	0.7863	0.4414	0.4323	-0.6178	0.5680	0.5438	-0.0055	-0.6946	0.7193
a3	0.7884	0.4395	0.4304	-0.6151	0.5695	0.5453	-0.0054	-0.6946	0.7193
a4	0.8175	0.4012	0.4132	-0.5744	0.6188	0.5358	-0.0408	-0.6754	0.7364
a5	0.8167	0.4029	0.4132	-0.5760	0.6143	0.5394	-0.0365	-0.6785	0.7337
b1	0.7753	0.4399	0.4532	-0.6268	0.6240	0.4666	-0.0775	-0.6458	0.7596
b2	0.7775	0.4386	0.4506	-0.6244	0.6238	0.4701	-0.0748	-0.6469	0.7589
b3	0.7534	0.4648	0.4652	-0.6543	0.6002	0.4601	-0.0653	-0.6510	0.7563
b4	0.7923	0.4254	0.4374	-0.6059	0.6330	0.4819	-0.0719	-0.6468	0.7593
b5	0.7959	0.4219	0.4342	-0.6012	0.6356	0.4844	-0.0716	-0.6466	0.7594
c1	0.8104	0.4167	0.4119	-0.5851	0.5370	0.6077	0.0320	-0.7335	0.6790
c2	0.8126	0.4139	0.4104	-0.5822	0.5440	0.6042	0.0268	-0.7299	0.6830
c3	0.8914	0.2994	0.3404	-0.4434	0.7321	0.5171	-0.0944	-0.6118	0.7853
c4	0.8933	0.3009	0.3338	-0.4397	0.7392	0.5102	-0.0932	-0.6025	0.7926
c5	0.9297	0.2380	0.2811	-0.3577	0.7651	0.5353	-0.0877	-0.5983	0.7965
d1	0.8128	0.4098	0.4140	-0.5786	0.6507	0.4917	-0.0679	-0.6392	0.7660
d2	0.8134	0.4105	0.4122	-0.5772	0.6573	0.4846	-0.0720	-0.6321	0.7715
d3	0.8438	0.3701	0.3886	-0.5298	0.6899	0.4933	-0.0855	-0.6221	0.7782
d4	0.9875	0.1063	0.1164	-0.1575	0.6951	0.7015	-0.0063	-0.7111	0.7031
d5	0.8461	0.3693	0.3843	-0.5271	0.6870	0.5003	-0.0793	-0.6258	0.7759

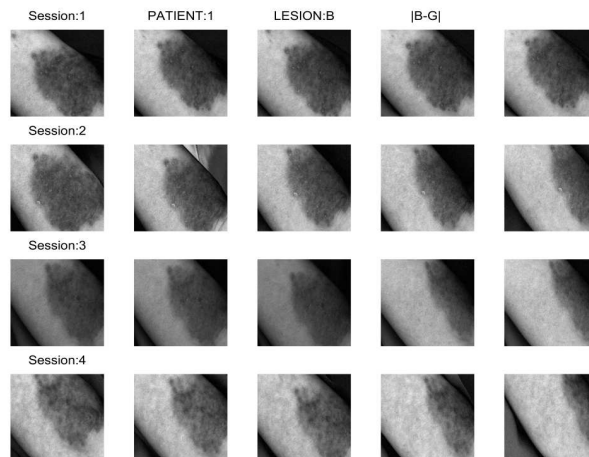
**Table 13.** Eigenvectors Values of the original images of (Patient 3, Lesion C)

Image	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	0.7756	0.4380	0.4546	-0.6307	0.5665	0.5303	0.0252	0.6980	-0.7156
a2	0.7624	0.4475	0.4675	-0.6455	0.5776	0.4997	0.0464	0.6827	-0.7292
a3	0.7834	0.4302	0.4485	-0.6190	0.6050	0.5009	0.0558	0.6700	-0.7403
a4	0.7655	0.4446	0.4652	-0.6405	0.5957	0.4847	0.0616	0.6690	-0.7407
a5	0.7691	0.4399	0.4637	-0.6357	0.6022	0.4830	0.0668	0.6663	-0.7427
b1	0.7525	0.4748	0.4564	-0.6580	0.5699	0.4922	0.0264	0.6707	-0.7412
b2	0.7385	0.4868	0.4665	-0.6742	0.5375	0.5064	0.0042	0.6885	-0.7252
b3	0.7608	0.4624	0.4554	-0.6455	0.6121	0.4569	0.0675	0.6415	-0.7641
b4	0.7097	0.5041	0.4921	-0.7017	0.5678	0.4303	0.0625	0.6507	-0.7567
b5	0.7117	0.5038	0.4896	-0.7001	0.5664	0.4348	0.0582	0.6522	-0.7558
c1	0.7836	0.4473	0.4311	-0.6083	0.6935	0.3861	0.1263	0.5648	-0.8155
c2	0.7816	0.4488	0.4332	-0.6089	0.6999	0.3734	0.1356	0.5556	-0.8203
c3	0.8154	0.4151	0.4034	-0.5669	0.7134	0.4119	0.1168	0.5646	-0.8170
c4	0.7977	0.4367	0.4160	-0.5875	0.7186	0.3722	0.1364	0.5412	-0.8297
c5	0.7939	0.4410	0.4186	-0.5924	0.7162	0.3690	0.1370	0.5409	-0.8298
d1	0.7993	0.4397	0.4096	-0.5825	0.7343	0.3485	0.1475	0.5172	-0.8431
d2	0.8095	0.4262	0.4038	-0.5696	0.7367	0.3644	0.1422	0.5250	-0.8391
d3	0.8280	0.4149	0.3772	-0.5540	0.7087	0.4367	0.0861	0.5706	-0.8167
d4	0.8212	0.4236	0.3823	-0.5623	0.7146	0.4160	0.0970	0.5566	-0.8251
d5	0.8036	0.4352	0.4060	-0.5791	0.7290	0.3649	0.1372	0.5284	-0.8379

### B.1 The estimations of the third component using the |Blue-Green| band



**Fig. 12.** Set of |B-G| Images of (Patient 1, Lesion A).



**Fig. 13.** Set of |B-G| Images of (Patient 1, Lesion B).

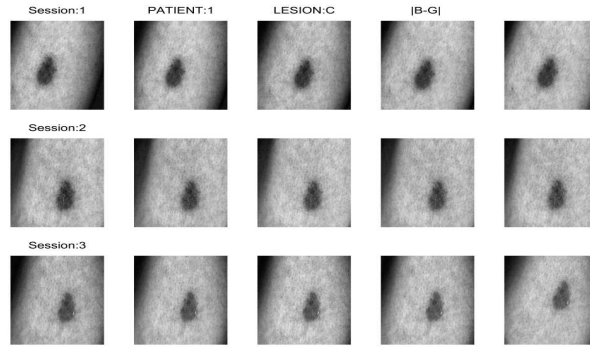


Fig. 14. Set of |B-G| Images of (Patient 1, Lesion C).

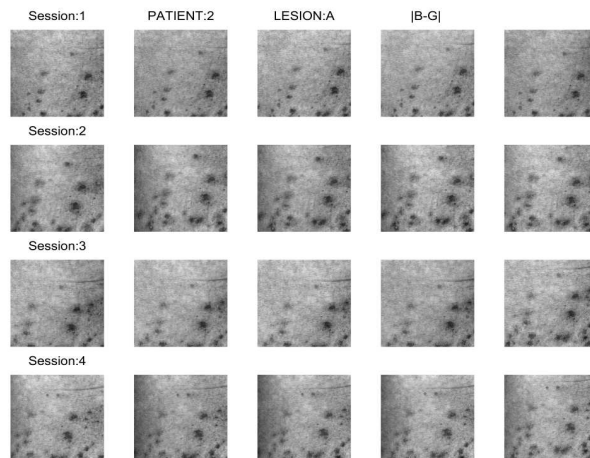
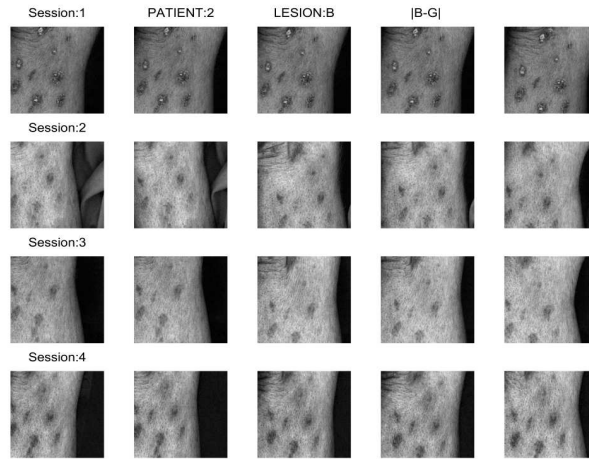
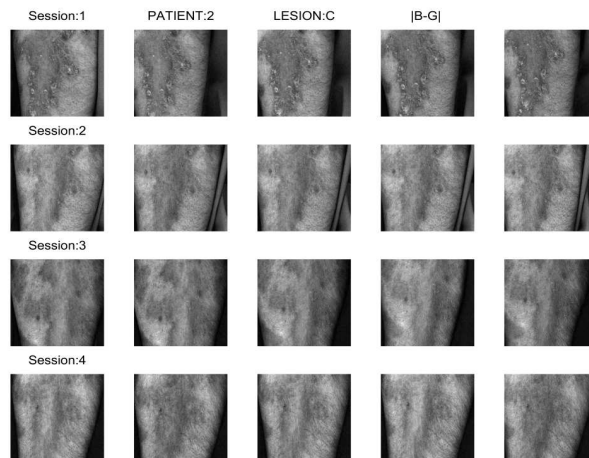


Fig. 15. Set of |B-G| Images of (Patient 2, Lesion A).

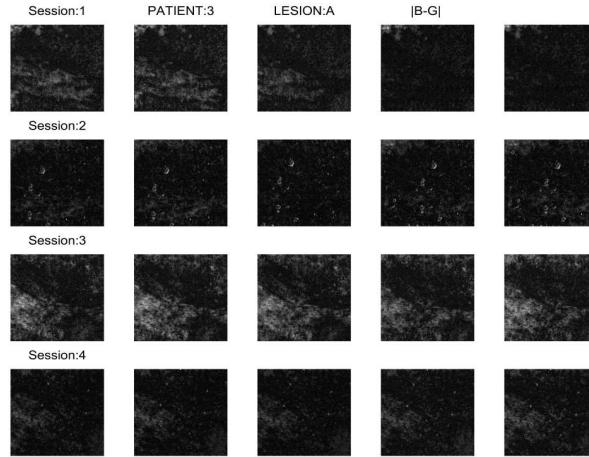


**Fig. 16.** Set of |B-G| Images of (Patient 2, Lesion B).

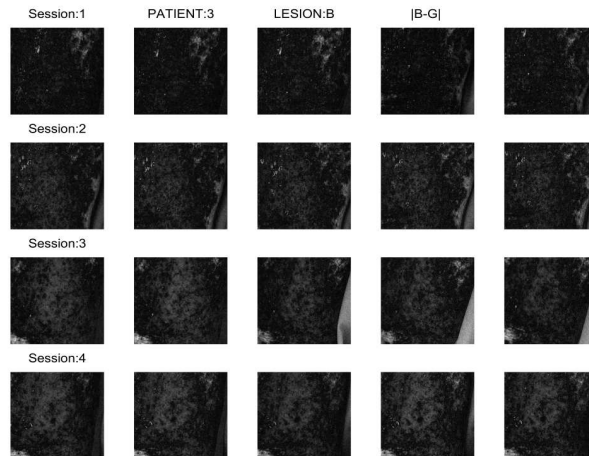


**Fig. 17.** Set of |B-G| Images of (Patient 2, Lesion C).

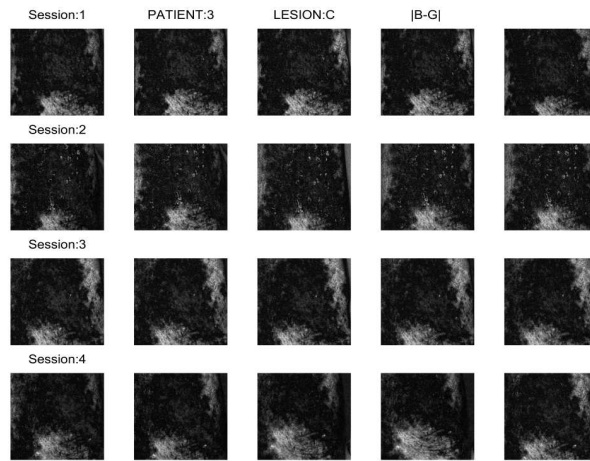




**Fig. 18.** Set of |B-G| Images of (Patient 3, Lesion A).



**Fig. 19.** Set of |B-G| Images of (Patient 3, Lesion B).



**Fig. 20.** Set of |B-G| Images of (Patient 3, Lesion C).

## C Eigenvalues

**Table 14.** Eigenvalues of the original images of Patient 1

Image	Lesion A			Lesion B			Lesion C		
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	1444.88	54.42	12.75	3596.48	25.48	8.42	2285.39	7.31	4.86
a2	2526.04	70.61	12.69	3106.99	20.41	9.27	2005.87	7.32	4.44
a3	1749.43	57.12	9.73	3388.21	28.69	8.09	1874.55	7.30	5.01
a4	1992.79	47.79	9.95	2880.91	34.18	11.33	1372.19	8.47	5.64
a5	2372.88	52.13	9.93	3138.65	22.62	10.86	1346.64	8.75	5.44
b1	1691.89	36.36	9.69	2401.09	34.23	9.49	1675.95	12.83	3.96
b2	2458.85	39.03	9.38	3148.66	36.86	10.86	1764.73	12.44	3.83
b3	1739.71	33.00	9.82	2776.68	23.46	9.34	1559.24	12.29	3.93
b4	1499.85	30.12	10.46	3188.71	21.02	7.69	1588.07	12.27	3.80
b5	1729.61	25.50	9.33	2682.42	32.03	8.49	1510.40	12.10	3.94
c1	2208.10	44.47	7.72	2703.60	31.40	10.15	1824.84	7.52	3.39
c2	2282.69	39.09	7.80	2835.99	21.76	9.30	1597.96	7.41	3.24
c3	2484.93	42.24	7.41	3227.58	17.70	8.18	1597.69	7.47	3.18
c4	1772.81	34.85	7.41	3146.52	20.15	5.72	1637.90	7.53	3.20
c5	2352.96	41.59	7.68	3075.80	21.01	5.83	1499.40	7.05	3.41
d1	2333.76	35.34	6.41	1888.44	28.28	5.62			
d2	1851.65	28.93	6.75	2363.85	30.98	5.26			
d3	2856.83	40.40	6.70	2834.36	24.25	4.53			
d4	2138.39	26.13	6.67	2726.42	24.39	3.88			
d5	2849.13	29.47	6.37	2766.16	117.89	3.25			

## References

1. R. Larsen. Maf and other transformations applied to remote sensing. Master's thesis, Institute for Mathematical statistics and Operations Research (IMSOR), Technical University of Denmark, DTU, 1991. pp. xii+130+205.

**Table 15.** Eigenvalues of the original images of Patient 2

Image	Lesion A			Lesion B			Lesion C		
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	172.33	7.81	3.93	2231.70	46.91	3.21	2513.00	106.44	8.49
a2	152.58	6.55	4.19	1819.39	43.95	3.32	3383.01	81.88	4.73
a3	148.49	5.64	4.88	2042.38	45.60	3.19	3324.11	76.87	5.82
a4	147.52	5.66	4.86	1783.37	44.10	3.20	3327.13	75.38	6.18
a5	156.78	7.12	4.00	1686.52	44.73	3.35	3316.42	82.44	5.58
b1	321.17	9.76	4.75	2346.98	55.01	3.64	2898.91	37.79	4.93
b2	553.82	10.70	4.36	2040.16	44.42	3.72	2778.70	67.35	5.62
b3	389.53	9.83	4.38	1763.97	26.64	5.30	2857.95	69.98	5.08
b4	395.31	10.89	4.21	1728.86	30.87	4.94	2823.23	68.87	4.99
b5	226.90	9.76	4.84	2079.96	35.50	5.87	3238.57	87.96	5.20
c1	154.41	9.17	4.51	3790.00	20.12	3.21	3262.82	27.35	4.61
c2	157.91	8.50	4.54	3445.74	20.91	3.55	3536.77	24.82	4.70
c3	154.56	8.36	4.58	2434.32	24.07	4.28	4381.46	24.73	4.41
c4	160.29	8.33	4.60	2347.57	24.22	4.01	4176.64	27.17	4.29
c5	175.15	7.76	4.85	3457.68	24.17	3.66	5274.74	26.34	4.09
d1	339.97	11.56	4.19	3054.50	16.41	3.58	3244.15	24.45	4.09
d2	624.10	11.73	3.66	3466.72	16.08	3.37	2823.77	22.74	5.52
d3	655.37	12.13	3.71	2346.85	17.96	3.84	3222.69	25.79	3.86
d4	582.09	12.45	3.72	2407.31	20.74	3.99	3216.34	30.16	3.78
d5	459.18	12.29	3.98	2602.88	25.12	4.13	3388.39	28.01	5.53

**Table 16.** Eigenvalues of the original images of Patient 3

Image	Lesion A			Lesion B			Lesion C		
	1 <sup>st</sup> C.	1 <sup>st</sup> C.	1 <sup>st</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	2 <sup>nd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.	3 <sup>rd</sup> C.
a1	432.79	38.48	2.39	1118.61	32.33	2.23	945.99	39.22	6.37
a2	383.62	36.70	2.38	1283.75	32.68	2.32	810.32	34.82	6.43
a3	598.55	41.30	1.99	1261.05	33.08	2.35	749.23	44.51	6.75
a4	350.66	38.99	1.88	1444.51	56.44	2.35	698.18	39.69	6.81
a5	352.76	38.41	1.84	1451.91	50.91	2.46	815.85	39.76	5.70
b1	545.49	31.44	2.52	1353.42	67.05	3.61	2080.46	57.52	6.34
b2	523.02	31.61	2.59	1347.74	65.91	3.63	1713.35	52.22	7.51
b3	525.11	32.61	2.12	986.75	54.96	3.57	1587.72	83.14	6.21
b4	443.85	31.12	2.32	1267.77	62.97	3.31	1196.66	47.50	7.07
b5	438.80	31.44	2.36	1344.24	64.67	3.39	1234.96	46.53	7.22
c1	388.04	19.31	2.15	1054.96	11.68	3.62	588.61	20.91	7.73
c2	339.61	21.80	2.24	916.67	12.92	3.47	527.21	21.09	7.69
c3	316.48	23.07	2.17	874.05	77.91	2.63	796.43	29.10	7.17
c4	246.08	23.08	1.97	835.44	95.21	2.76	694.37	24.10	7.31
c5	311.00	22.75	1.91	923.03	93.51	3.19	585.96	24.98	7.14
d1	616.06	15.92	1.98	1387.41	19.47	3.66	825.42	16.95	6.34
d2	527.81	16.37	1.90	1384.15	20.19	3.61	1230.42	17.53	5.56
d3	491.69	16.99	1.92	1095.60	29.06	3.70	1940.85	27.61	6.49
d4	472.31	17.18	1.93	1130.25	29.10	3.69	1968.43	24.25	6.59
d5	440.91	17.75	2.01	1038.86	28.94	3.67	770.58	20.26	5.84