

## Data Exploration for Hematoma Image Analysis

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**Introduction.** Hematomas and bruises are relatively common conditions. For example, in one case about 20 % of children younger than 3 years have been found to have bruises [1]. The same study has noted that bruises have to be detected visually by the doctors, and that such method might have resulted in missed bruises in case of pigmented skin [1]. That indicates the usefulness of automated analysis of hematomas. Since they are so common, and get little medical attention, analysis of such images might be suitable for smartphones (for example, for following the progress of healing).

However, such analysis of hematomas of such type doesn't seem to be performed. More effort is dedicated to finding out the age of the bruise for forensic purposes [4-6, 8, 9]. For example, one study has found that b\* component of L\*a\*b\* can be used to estimate the age of a bruise [4], while another study found use for all three components of the same colour space [6]. One more study has been dedicated to demonstrating high variability in photographs of bruises resulting from the same cause [5]. An effort has also been made to use more complex imaging methods [8, 9]. For example, it has been shown that hyperspectral imaging can be used to estimate the age of the bruise, and, coincidentally, to estimate its area [8]. Infrared and ultraviolet imaging has also been tested, yet the experts found the more conventional photography more useful, especially with cross polarised filters [7].

Thus this paper explores suitability of different colour combinations for detection of hematomas using conventional photography, using methods similar to the ones successfully used for eye fundus image analysis [2, 3].

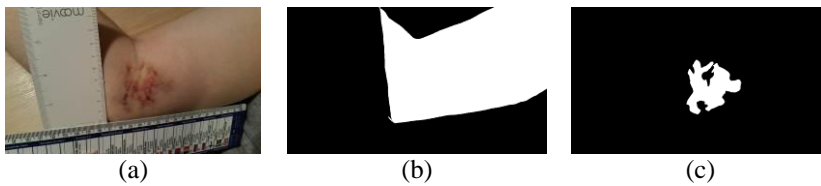
**Materials and Methods.** Two hematomas of a single subject, resulting from a venipuncture, have been observed for 12 days (starting on the 5th day after the venipuncture). In most cases pictures (sometimes multiple pictures) were taken twice a day (using smartphone, image size 5312 × 2988 px), although there were exceptions. In some cases rulers have been photographed as well, to illustrate the scale. In total, 75 images have been collected.

A sample of those images (9 in total) has been chosen for further analysis. The images have been chosen for different hematomas (4 of one and 5 of

another) and different days (3 for the 1st day, 2 for the 2nd, 2 for the 5th, 2 for the 8th, 1 for the 12th).

Those images have been manually segmented. The region of interest, consisting of the visible skin, and the hematoma itself has been marked.

Fig. 1 shows an example of the image, with region of interest (ROI) mask and marked hematoma mask.



**Fig. 1.** An example of an image used in the study (a), the ROI mask (b) and the marked hematoma mask (c)

As the sample is unlikely to be representative, it was used for data exploration only. Thus no effort to find optimised colour combinations, like in [3], has been made.

For data exploration, the RGB components and their differences have been checked, along with components of  $L^*a^*b^*$  (given their popularity in literature). Area under ROC curve (that, in turn, shows dependence between sensitivity and specificity) was used to estimate the suitability of them for recognition of hematoma's area. Such areas have been calculated for each image separately. Then statistical estimates (minimum, maximum, average and standard deviation) were calculated. It can be expected that the most suitable combination will consistently give the highest area under the ROC curve.

**Results.** Calculated statistical estimates of area under ROC curve for various combinations of RGB components are presented in table 1.

**Table 1.** Statistical estimates of area under ROC curve for various combinations of RGB components and  $L^*a^*b^*$  components

Combination	Min	Max	Average	Std
R	0.3034	0.8369	0.4807	0.1912
G	0.1776	0.4922	0.2889	0.1267
B	0.1268	0.5039	0.2418	0.1273
R-G	0.8862	0.9774	0.9475	0.0313
R-B	0.8124	0.9962	0.9343	0.0613
G-B	0.2639	0.9931	0.6384	0.2648
L	0.2146	0.5517	0.3312	0.1371
a	0.8849	0.9840	0.9360	0.0302
b	0.6858	0.9970	0.8486	0.1371

It can be seen that, RGB channels taken separately are not very suitable for detection of hematomas, as for each of them the area under ROC curve is close to 0.5 for at least some images (the same value can be achieved by

completely random classification). That is somewhat surprising, since the green channel was found to be useful for detection of blood vessels in eye fundus images [2]. We can also see that the G and B components of RGB tend to be less intense in hematomas, as the areas under ROC curve are less than 0.5 for them.

All of the differences between RGB components seem to be highly suitable for detection of hematomas, with the maximal area under ROC curve being higher than 0.975. Yet at this stage it looks like the R-G difference is the most promising, with the highest minimal and average area under ROC curve and lowest standard deviation. Notably, in eye fundus images such difference was found to indicate the pixels that are certain to belong to blood vessels [2].

Out of L\*a\*b\* components, a\* has achieved a result similar to R-G difference. That is not surprising, given that this component is supposed to represent the colour's position in red-green (or magenta-green) axis. Since the original images are going to use RGB colour space, use of R-G difference should probably be preferred, as requiring less calculation.

**Conclusions.** The suitability of different RGB channels and their differences for detection of hematomas has been explored. It looks like the R-G difference is the most promising for this task. However, the tests should be repeated with more images of other subjects and different causes of hematomas. It is especially likely that the results would depend on the pigmentation.

Still, the results could be used to create a simple system for hematoma recognition and analysis of progress of their healing. The results indicate the possibility to use thresholding for such recognition (perhaps even semi-automated thresholding of R-G could achieve reasonably good results), although actual healing progress analysis would also require image registration.

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